Financing Medicine's Last Mile in Uganda:
Exploring Linkages between Patient Access to Medicine and Supply Chain Access to Finance

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Abstract

Pharmaceutical companies operating in Africa are well positioned to contribute to the United Nations' ongoing efforts to improve access to medicine in Africa. This thesis explores how access to finance for businesses in the Ugandan private pharmaceutical supply chain affects access to medicine for end patients. Specifically, we consider three components of access to medicine—payment affordability, on-shelf availability, and geographic accessibility—and how each might be affected by supply chain financing. For payment affordability, we leverage field data via interviews with two distributors, two wholesalers and ten retail pharmacies in Uganda. We use the data to model free cash flows; the estimates gathered from interviewees are modeled with PERT distributions to capture variability in cash flows. For on-shelf availability, we explore methods of categorizing operational uncertainties associated with demand and working capital to inform how financing can improve on-shelf availability. For geographic accessibility, we analyze density in each district of retail pharmacies and financial lending institutions using data visualization. Our analyses reveal several key findings. First, retailers suffer substantial working capital constraints leading to constant product stockouts. Increasing access to working capital for retailers, combined with supply chain management training, may help mitigate stockouts and increase accessibility of medicines for patients. Second, literature on operational uncertainty and disruptions provides a framework for how to allocate financing to help improve on-shelf availability. Finally, a substantial portion of Uganda is still largely underserved in terms of pharmaceutical retail outlets and financial lending services. Our analyses fill a gap in the literature concerning how to approach improving patient access to medicine by financing pharmaceutical supply chain improvements. Our analyses serve as a basis for pharmaceutical companies looking to contribute to improving access to medicine in Africa.

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Biographical Notes

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[1] PharmCo is the company sponsoring our thesis; their name has been changed to maintain anonymity.

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List of Acronyms and Abbreviations

Acronym / Abbreviation	Meaning
ATM	Automated Teller Machine
BankCo	Alias for Bank
BU	Boston University
CCC	Cash Conversion Cycle
COGS	Cost of Goods Sold
D1	Distributor 1
D2	Distributor 2
DIO	Days Inventory Outstanding
DPO	Days Payables Outstanding
DSO	Days Sales Outstanding
EBIT	Earnings Before Interest and Tax
FX	Foreign Exchange (Currency)
GDP	Gross Domestic Product
GIS	Geographic Information Systems
ActingConsultant	Alias for an Acting Consultant
MIT	Massachusetts Institute of Technology
NOPAT	Net Operating Profit After Tax
OLS	Ordinary Least Squares
PDCA	Plan Do Check Act
PERT	Project Evaluation and Review Technique
PharmCo	Alias for Thesis Sponsor
POS	Point of Sale
RA1	Retail Pharmacy, Class A, 1
RA2	Retail Pharmacy, Class A, 2
RB1	Retail Pharmacy, Class B, 1
RB2	Retail Pharmacy, Class B, 2
RB3	Retail Pharmacy, Class B, 3
RC1	Retail Pharmacy, Class C, 1
RC2	Retail Pharmacy, Class C, 2
RC3	Retail Pharmacy, Class C, 3
RC4	Retail Pharmacy, Class C, 4
RD1	Retail Pharmacy, Class D, 1
SACCO	Savings and Credit Cooperative
SMS	Short Message Service
UGX	Ugandan Shillings
USD	United States Dollars
VSLA	Village Savings and Loans Association
W1	Wholesaler 1
W2	Wholesaler 2

Introduction

The United Nations estimates that more than 2 billion people below the international poverty line lack adequate access to medicine, presenting a challenge to the notion of health as a human right (Leach, Paluzzi, & Munderi, Paula, 2005). Access to medicine has been a central objective of the United Nations' development strategy in Africa and plays a critical role in sustaining the health of the local populations (Leach et al., 2005). Inability to access both finance and health is a result of poverty, causing the poverty cycle to become more deeply entrenched (Narayan & Patesch, 2002).

Gross Domestic Product (GDP) in Uganda grew by 6.6% in 2014 and is estimated to grow by 7% in 2015, yet access to medicine is still a major challenge (African Development Bank Group, 2014). There is emerging research showing improved GDP alone is not an indicator of social progress (Porter, Stern, & Green, 2015).

Between 2009 and 2014, the number of registered pharmacies grew from 477 to 795 (UNIDO, 2010; Uganda NDA, 2014), still high prices for quality pharmaceuticals, supply shortages at pharmacies, general unaffordability of private health insurance for most customers, and a lack of infrastructure in rural areas push most pharmacies to urban areas leaving many rural areas unreached (Leach et al., 2005; Gathaiya, 2010). Frequent stockouts of medicines, forecasting/ordering problems, poor inventory management, inadequate transport networks, and a lack of supply chain management expertise are common challenges (UNIDO, 2010; Jahre, 2010; Logendra, Rosen, & Rickwood, 2012).

Solving these challenges is difficult because of the widespread lack of accurate data. For example, information on medicine consumption—a key aspect of measuring demand—is patchy and fragmented (Logendra et al., 2012). These factors contribute to poor health outcomes and a lack of access to medicine (Leach et al., 2005; Gathaiya, 2010).

Compounding these challenges, the health sector suffers from a lack of access to affordable financing (Logendra et al., 2012). A Deloitte survey of formal lending institutions in Uganda revealed a lack of willingness to finance health institutions for the following reasons (Gathaiya, 2010):

- Lack of business and financial expertise which led to poor management of funds
- Poor financial record-keeping
- Poor knowledge of regulations and laws requiring registration
- Lack of staff and equipment
- Lack of a strong referral base to sustain business
- Lack of collateral that can easily be reclaimed and liquidated

The Ugandan government has also acknowledged that capital constraints within the pharmaceutical supply chain may be a contributing factor to shortages in pharmaceutical supplies (Seiber & Robinson, 2007).

Due to the high cost and complexity of collecting quantitative data, few research papers have been published on these capital constraints and their relationship to material flows, especially in the context of access to medicine, suggesting that these challenges are not well understood. We begin to fill this gap in data and analysis by analyzing how access to finance within the pharmaceutical supply chain affects patient access to medicine (see Figure 1).

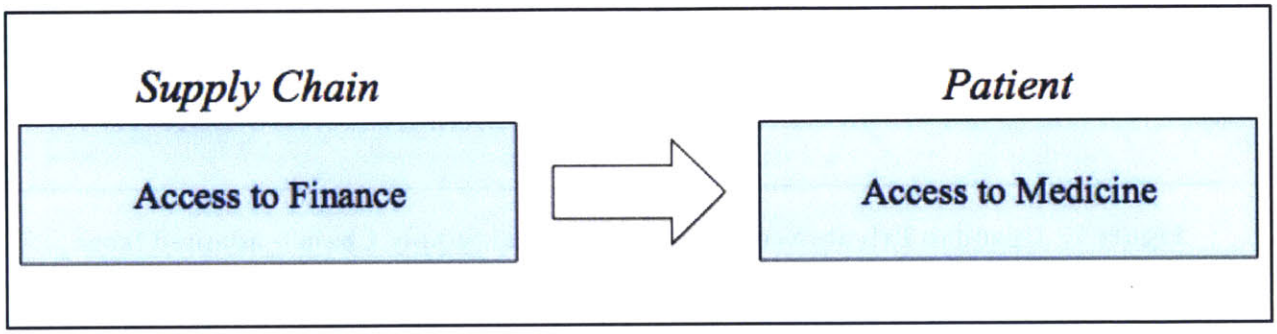


Figure 1. Macro Research Question

Leveraging the three characteristics of access as defined by Penchansky and Thomas' seminal work (1981), we explore the following sub-questions:

- Payment Affordability: Where in the last mile of the pharmaceutical supply chain—namely the segment including the distributor, wholesaler, and retailer—does increased access to finance most improve patient access to medicine? Or, where in the supply chain does there appear to be the worst capital constraints that ultimately impact the payment affordability of the medicine, and thus access for the end patient?
- On-shelf Availability: For each business in the supply chain, how should financing be used to minimize operational disruptions that affect on-shelf availability? How can each business be advised to leverage financing to minimize operational disruptions, thereby increasing on-shelf availability and access for the patient?
- Geographic Accessibility: At a strategic level, what districts in Uganda have the least accessibility to medicine, or the least density of pharmacies? Which districts benefit most in geographic accessibility to medicine for patients in financing new pharmacies?

We conducted primary case research on private sector pharmaceutical supply chains in Uganda and analyzed publicly available data to develop theories of where in the supply chain financing might have the greatest impact on access to medicine, how different types of financing capital might improve access to medicine at different levels within the pharmaceutical supply chain, and what districts in Uganda lack registered pharmacies to provide the accessibility to medicine.

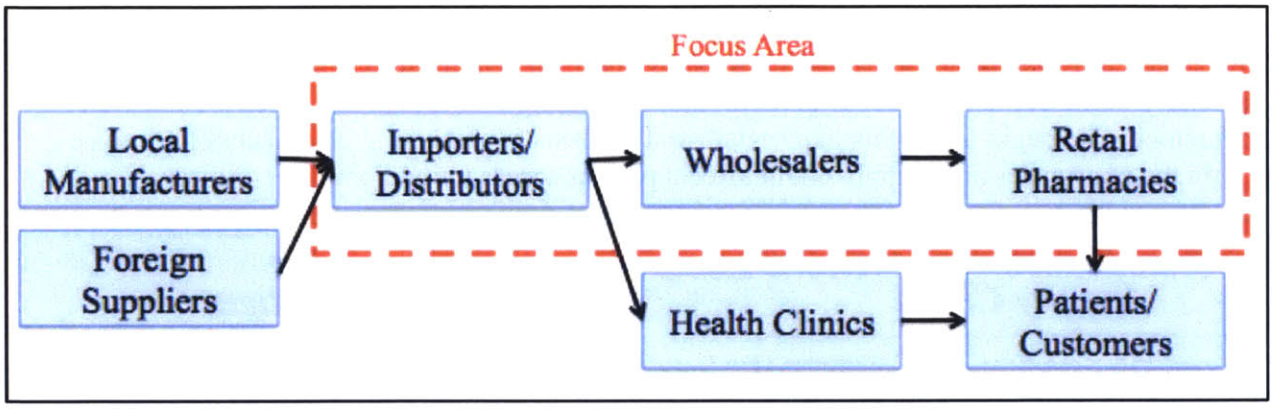


Figure 2. Ugandan Private Sector Pharmaceutical Supply Chain – adapted from (Gathaiya, 2010)

Our questions focus on the last mile of private sector pharmaceutical supply chains in Uganda with an emphasis on the distributors, wholesalers, and retailers (see Figure 2). In Uganda, the pharmaceutical market follows a single-importer model where importers also fill the role of distributors. We seek to obtain a better understanding of how to grow last-mile pharmaceutical supply chains in frontier markets, fill gaps in academic literature, and generate practical, relevant policy and business insights regarding access to medicine and access to finance in Uganda.

Literature Review

The following sections will highlight high-level research on the ideas of access to medicine and access to finance and dive deeper into specific research focusing on the challenges in the Uganda pharmaceutical and finance industries, along with research on the impact of microfinance on health service outlets in Uganda. Additionally, we look at literature that summarizes discourse on how to categorize and address operational disruptions, how trade credit impacts operational performance, and the use of case research for quantitative theory development in data-constrained contexts.

Access to Medicine

Access to health services is broadly defined by five characteristics: availability, affordability, accessibility, acceptability, and accommodation (Penchansky & Thomas, 1981). Since provision of medicine is a subset of health services, access to medicine falls under this definition for access to health services. For our purposes, we will propose slightly elaborated versions of these ideas to clarify our usage and approach to access in the context of medicine. We will reference these ideas as on-shelf availability, payment affordability, geographic accessibility, cultural acceptability, and customer accommodation. This section will further define these characteristics as they pertain to access to medicine to reveal how each pertains to supply chain operations.

Affordability measures whether the pricing of the pharmaceutical products is within the reach of the target market segment and whether financial and credit arrangements meet customers' needs (Penchansky & Thomas, 1981). Related to affordability are two ideas, the pricing of medicine and the payment terms for obtaining medicine. Previous research at MIT considered price sensitivity at different levels within the African pharmaceutical supply chain (Graham & Ghersa, 2014). We will consider how the payment affordability made possible by trade credit terms impact the average cash flow at each level in the supply chain and whether operations that have better trade credit terms or cash positions are more profitable, thus being able to stay in business and provide medicine to patients. Related to payment affordability is the notion of access to finance, which is further defined in the next section.

Availability measures the volume and types of medicines that are physically on the pharmaceutical retailer's shelf. Availability considers the adequacy of supply and facilities (Penchansky & Thomas, 1981), and can be assessed with operational performance metrics such as stock out rates.

Accessibility refers to the geographic proximity of customers to retail outlets and factors the travel time, distance and cost of patron customers (Penchansky & Thomas, 1981). This characteristic is best explored using geographic information system (GIS) software. Its effectiveness and usefulness, however, is only as good as the availability and granularity of geo-coded data.

Acceptability and accommodation are the two final components of access. Acceptability denotes the degree to which there is a lack of cultural barriers for the customer to use the pharmaceutical product (Penchansky & Thomas, 1981). Accommodation refers to the manner in which the business meets the client needs and schedule, such as having business hours conducive for customer visits, telephone services, or walk-in facilities with customer service, and is measured by clients' perceptions of their appropriateness (Penchansky & Thomas, 1981).

ANALYZING "ACCESS"		
Dimension	***Indicators***	***Within Scope?***
Affordability	**Cash Flow, Profitability**	**Yes**
Availability	**Operational Disruptions, Demand Uncertainty, Working Capital Unpredictability**	**Yes**
Accessibility	**Density of Retail Locations**	**Yes**
Acceptability	**Customer Perception of Products**	**No**
Accommodation	**Customer Perception of Services**	**No**

Figure 3. Focus on Three of Five Dimensions of Access

Our research will consider the first three dimensions of access and their pertinence to supply chain operations: payment affordability, on-shelf availability and geographic accessibility (see Figure 3). We chose to leave the two remaining characteristics, cultural acceptability and customer accommodation, outside the scope of our analysis because they seemed less pertinent to the linkage with financing.

Regarding on-shelf availability, we believe demand uncertainty and working capital unpredictability are important indicators to analyze. However, we were unable to gather data on these indicators from our field research; thus, for on-shelf availability we have opted to focus our analyses on operational disruptions.

Access to Finance and Financial Inclusion

Research shows that developing countries lack small and medium enterprises because access to finance is severely lacking (Beck, 2007). Access to finance is "the availability … of affordable and appropriate financial services" (Center for Financial Inclusion, 2014).

Access to finance finds its roots in Mohammed Yunus' work in Bangladesh, where he noticed that many women had entrepreneurial skills, but were too poor to qualify for a formal loan from a bank. So he began lending small amounts of his own money to them in 1976, pioneering the idea of social collateral and group lending. Group lending is where groups co-signing a loan with friends and family they trust—the trust is the social collateral. During the 1980s and 1990s, Yunus built an organization around this idea called the Grameen Bank to lend small amounts of money on a large scale to help poor entrepreneurs start and grow businesses. The Grameen Bank eventually scaled these loans throughout Bangladesh and into other countries, and Yunus' work gained global attention. Yunus' success through the Grameen Bank inspired the launch of an entire sector aimed at creating better access to finance for those living in poverty at the bottom of the economic pyramid. His work ultimately won him the Nobel Peace Prize (Yunus, M. & Jolis, A., 2003).

By the early-2000s, microfinance had gained popularity within the international development practitioners and private sector investors looking to make money. Without proper regulation and controls to prevent over-lending, opportunists flooded the market to profit off of the poor by exploiting financial illiteracy among borrowers, causing an increase in over-indebtedness among borrowers. In the mid-2000s, high interest rates and over-indebtedness led to falling repayment rates causing many lenders to increase collection pressure. In the Indian state of Andra Pradesh, the rapid accumulation of debt among microfinance borrowers led more than 200 borrowers to commit suicide in October 2010 (AP, 2012). This incident, along with subsequent investigations into a number of for-profit microfinance institutions, revealed exorbitantly high interest rates and unethical collection practices and sullied the reputation of microfinance as a perfect solution for helping the poor (Schicks & Rosenberg, 2011).

The trend of exploitation of the poor highlights the need for guidance and accountability when designing financial services for the poor. Accion International's Center for Financial Inclusion has taken the lead on defining industry standards to govern and promote the ethical practice of financial inclusion. Building on their definition of access to finance, part of these

efforts includes client protection principles to ensure products, services, and collection practices are in line with the 'affordability' and 'appropriateness' principles. To further guide development of these kinds of products, Accion outlined Client Protection Principles, which are summarized in Table 1 (Center for Financial Inclusion, 2014).

Table 1. Accion International's Client Protection Principles (Source: Center for Financial Inclusion, 2014)

Inclusive Finance - Client Protection Principles
1. Avoidance of over-indebtedness
2. Transparent and responsible pricing
3. Appropriate collections practices
4. Ethical staff behavior
5. Mechanisms for redress of grievances
6. Privacy of client data

These principles are useful for evaluating existing financing available to businesses in pharmaceutical supply chains in Africa, as well as a framework for developing new, alternative 'inclusive' financing schemes. Another key concept in designing goods and services for customers at the bottom of the pyramid is finding a payment structure with means and timing compatible with the customers' cash flows, which may require a keen understanding of customers' typical cash flows (K. Wilson, 2014).

A large volume of research on financial inclusion has accumulated over the last three decades. Much of the discourse centers on microfinance, and a sampling of themes include microfinance's impact on household income, female empowerment, educational attainment, domestic violence, regulation, commercialization, ethics, and incorporating health education into microfinance programs (Hagan et al., 2012; Halouani & Boujelbene, 2013; Hudon & Sandberg, 2013; Kim et al., 2007; Kondo, Orbeta Jr., Dingcong, & Infantado, 2008; Maldonado & González-Vega, 2008; Panda & Atibudhi, 2010; Purkayastha, Tripathy, & Das, 2014). (Leatherman, Metcalfe, Geissler, & Dunford, 2012). The following section describes the financial services landscape in Uganda and where microfinance and financial inclusion lie within that landscape.

Financial Services Landscape in Uganda

Uganda's financial market has a variety of financial services aimed at different customers, including savings and credit cooperatives (SACCOs), credit institutions, commercial banks, and microfinance institutions (Mixmarket.org, 2014). These services are broadly categorized into three sectors: formal services, semi-formal services, and informal services (The Steadman Group Limited, 2007). Formal services are typically represented by large banks and include a nation's central bank and any banks regulated by the central bank. Semi-formal services, such as deposit-taking microfinance institutions, are not regulated by a central bank yet are sanctioned by law. Informal financial services comprise small, locally run services that operate without regulation or legal sanction. The sector divisions are more readily apparent in

developing countries, where use of semi-formal and informal services are more central to the economy than in developed countries.

Informal services have different names in different countries, but their format and structure share commonalities across the board. An example of an informal financial service in Uganda is called a Savings and Credit Cooperative (SACCO), which is comprised of a group of approximately 30 individuals who share responsibility for money pooled from among trusted friends and family within their own village. They issue savings and issue loans to SACCO members just like a regular bank (The Steadman Group Limited, 2007).

Despite these options, access to finance continues to be a significant challenge for many Ugandans. Most Ugandans are saving or investing, but only 1 in 6 use bank products to do so. One third of Ugandans use informal savings methods, which can take the form of savings groups or simply stashing money in a secret place (FinMark Trust, 2009). According to the 2007 FinScope II survey, only 20% of Ugandans use banking services and the majority of Ugandans rely on informal financial services (FinMark Trust, 2009). One third of Ugandans are considered 'unbanked', meaning they do not use any banking services (FinMark Trust, 2009; Investopedia, 2015).

Access to Finance – Initiatives in Uganda

In the last decade, a number of experimental programs have emerged seeking to increase access to finance for the estimated 2.3-million rural Ugandans who comprise the market for lower-cost banking services (Chemonics, 2007). Many studies and projects have experimented with technology-based solutions to improve access to finance in Uganda, and the efforts have encompassed mini-ATMs, point of sale (POS) banking, and low-cost card-based solutions (Chemonics, 2007). However, these projects focused too much on the product development without "developing and implementing a comprehensive strategy for deployment, card distribution, merchant and consumer education, and marketing," and the initiatives failed to be effective (Chemonics, 2007).

Access to finance through mobile phone services is another technology-based solution being explored. While mobile phone penetration is still relatively low in Uganda, the market is postured to grow rapidly in the coming years (Chemonics, 2007). Simba Telecom is a Ugandan-owned mobile phone and pre-paid airtime retailer with 43 company-owned stores and 1,600+ outlets in Uganda. Simba Telecom has implemented a mobile payment system that has seen rapid uptake among Ugandan users (Chemonics, 2007). Critics of Simba Telecom emphasize that technology-driven financial services are not an end in and of themselves, but a means to support meeting customers' other needs.

In Tanzania, Vodaphone's subsidiary Vodacom has been working on a mobile SMS ordering system in partnership with Novartis, the Tanzania Ministry of Health, and other stakeholders. This initiative is an effort to apply mobile payment technology to pharmaceutical supply chains (Rosen & Rickwood, 2014). Applying technology-driven services to the challenges found in the pharmaceutical supply chain may provide a way to more easily alleviate capital constraints among the various levels in the pharmaceutical supply chain.

Financial Inclusion and Pharmaceutical Supply Chains

Published research exists that investigates financially inclusive services in the healthcare services sector. Leatherman et al. summarizes a number of research papers that broadly focus on microfinance's ability to influence an individual's behavior towards healthy outcomes such as seeking medical treatment (2012). Since our thesis focuses on how financing might influence the operational behavior of businesses within the pharmaceutical supply chain, these research papers fall outside the scope of our thesis.

Two published articles investigate the impact of microfinance on customers' perceptions of quality health services, both within the Ugandan context. The first article focuses on measuring the impact of business skills training and revolving micro-loans to a group of midwives on clients' perceptions of quality service with results showing the loans may have a positive impact (Agha, Balal, & Ogojo-Okello, 2004). The second article is a similar impact study on client perceptions of quality, but for private-sector health care providers in Uganda (Seiber & Robinson, 2007). This study shows positive evidence for clients' increased propensity to choose loan-recipient clinics on the basis of better drug availability, fair charges, cleanliness, and confidentiality and produced statistically significant evidence of increased customer flows to loan-recipient clinics as a result of higher drug availability (Seiber & Robinson, 2007). Seiber and Robinson took a customer-centric approach but did not analyze the loan-recipient clinics' cash flows, an aspect particularly of interest in our research.

The William Davidson Institute at University of Michigan produced an in-depth analysis of working capital among rural drug outlets in Tanzania and Uganda for the Sustainable Drug Seller initiative, a program of Management Science for Health (Yadav, Smith, & Alphs, 2012). The study comprised detailed interviews of pharmacies along with full inventory samples for a subset of the interviewees and analyzed the working capital, inventory quantities, stocking patterns, perceived access to capital, additional product what-if scenarios, and compared various solutions for working capital financing (Yadav et al., 2012). Though the study was limited with a small sample size, the survey results suggest that working capital constraints do have an impact on access to medicine and are an impediment to running a sustainable business (Yadav et al., 2012). Survey respondents asserted that their most critical challenges were maintaining their shops (renovations) and stocking "enough" inventory (Yadav et al., 2012, p. 8). The primary recommendation is that pharmacies receive a combination of working capital financing and fixed capital financing mechanisms with integrated training as a prerequisite (Yadav et al., 2012). The fixed capital financing would finance renovations and one-time investments to boost competitiveness and the working capital financing would be used for improving stock level and adding in-demand but stocked-out items to improve cash flow (Yadav et al., 2012).

These papers and reports serve as a helpful reference points in our research. The William Davidson Institute report aligns most closely with our analysis, but our methodology varies in the data collection strategy, the depth of our cash flow analysis, scope of our analysis spanning three levels of the supply chain.

Categorizing Operational Uncertainty

Inability to cope with operational uncertainty in any business can adversely impact customer service levels, product and service quality, and delivery to market. Within a pharmaceutical supply chain, operational uncertainties can cause operational disruptions that affect the end patient's access to medicine. Unlike supply chains for generic consumer packaged goods, a disruption in the supply chain of pharmaceutical products can be fatal for the customer who needs medicine to live. This context drives the importance of analyzing the frequency and impact of operations disruptions within pharmaceutical supply chains.

The Basel Committee defines operational disruptions as "the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events" (BCBS, 2001, p. 2). Mizgier et al. highlights seven types of operational disruptions that can be aggregated into two categories summarized in Figure 4: (1) high-impact, low-frequency events, and (2) low-impact, high frequency events (2015).

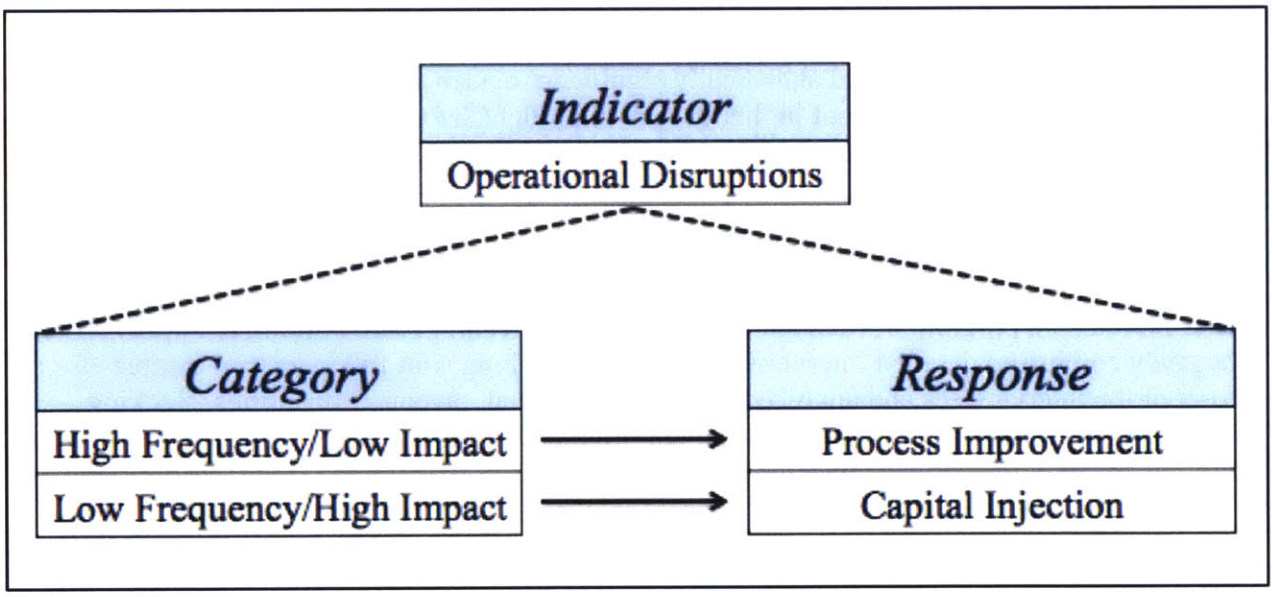


Figure 4. Improving Availability with Tailored Responses to Operational Disruptions

Mizgier et al. posits that the discourse uses capital injections to preemptively mitigate the effects of high-impact, low-frequency disruptions (2015). Given the unpredictable nature of such events, organizations are more likely to invest in mitigation rather than prevention. In pharmaceutical supply chains, this can best be seen as capital investment to hedge against delayed shipments, low production yield, and economic risk (e.g., increasing safety stock).

The discourse also shows that process improvement is used to mitigate the effects of low-impact, high-frequency disruptions (Mizgier et al., 2015). Contrary to low-frequency disruptions, these events are relatively predictable and therefore more manageable. Investments are likely to be made in preventative maintenance or instructional seminars in order to educate the organization on continuous improvement. A common example of preventative maintenance in pharmaceutical supply chains is long-term investments in Lean Six Sigma programs (Furterer,

2014). Although these programs might be challenging to implement for sole proprietors, they are strongly recommended for mid-scale firms. Furterer contends that "Healthcare is struggling with shrinking revenues and trying to control costs, what better environment could there be to apply Lean Six Sigma" (Furterer, 2014, p. vii).

Due to the changing nature of operational disruptions across industries and regions, Mizgier at al. suggests that the correct response for a given disruption may vary (2015). In developed regions, strong economic development, specifically in transportation infrastructure, allows for relatively efficient supply chains. Less developed regions (e.g. Africa) present unique challenges in defining and responding to operational disruptions. Arvis et al. suggests that weak transit/transportation infrastructure (e.g. highways, ports) in less developed regions has the tendency to create highly irregular operational disruptions (2007, p. 1). These irregularities, so far, have made it difficult to formulate a framework for operational disruptions in regions like Africa. Arvis et al. argues that a "push towards implementation [of transportation infrastructure]...primarily at the national level" is a critical next step for the reduction of operational disruptions in less developed regions (2007).

Mizgier et al.'s categorization of operational risks and the two typical responses of capital charges and process improvement are relevant to the Ugandan pharmaceutical market. The complementary solution of capital charges and process improvement provide an insightful framework for addressing operational disruptions that affect access to medicine, which is relevant to our study of pharmaceutical supply chains in Uganda. Nonetheless, the types of capital charges are of interest. We seek to understand from the business owner and customers' perspectives how the various forms of capital charges might compare.

Trade Credit

A large amount of literature has explored various aspects of trade credit through various lenses, and operations researchers have increasingly added to the volume of research (Seifert, Seifert, & Protopappa-Sieke, 2013). Trade credit as a means of financing is relevant to our exploration of types of capital charges. Because trade credit is integrated into business contracts and not an external financial service, it was not part of our review of the Ugandan financial services industry. Nonetheless, trade credit serves as both a complement and substitute for bank credit, and this is relevant to our study of financing options in Uganda (Chant & Walker, 1988; Danielson & Scott, 2004; Ono, 2001; Seifert et al., 2013).

Capital access is one of the motives in the discourse for studying trade credit (Seifert et al., 2013). Trade credit is a form of marketing incentive that leverages the time value of money to induce buyers to purchase more (Schwartz, 1974). Firms with more access to credit could offer more credit to buyers, but empirical research suggests otherwise and researchers have speculated on the possible drivers (Fabbri & Klapper, 2008; Horen, 2007; N. Wilson & Summers, 2002). Emery and Jain suggest that suppliers have the advantage of detailed information about their customers, which gives them an incentive to be an intermediary between the customer and the bank (1984; 2001). Ironically, despite this superior information, Wilner and Huyghebaert contend that suppliers' extension of trade credit may be a more expensive practice than institutional lending, because suppliers have an incentive to sustain a market for

their goods and "grant more concessions to buyers in financial distress than lenders in competitive credit markets" (2000; 2006; Seifert et al., 2013, p. 250). Relatedly, a number of studies have explored/modeled order quantity decisions and credit term decisions under various conditions (Seifert et al., 2013). One such paper studies the relationship between supplier and retailer credit periods and suggests that changes in the former have little impact on the latter (Jaggi, Goyal, & Goel, 2008). Another paper models the effect of two-level trade credit on demand for a product. The results suggest that longer trade credit may not initially stimulate demand, but had a "significant" albeit delayed positive effect on demand. The paper's model analyzes the challenge of simultaneous trade credit period and cycle time decisions for business owners (Jaggi, Goyal, Kapur, & Goel, 2013).

Statistical Modeling of Expert Opinions

Expert opinions can be estimated and modeled using simplified parametric distributions that leverage three key statistical parameters: minimum, mode, and maximum. These distributions are useful for two reasons: first, those three parameters are easier for interviewees to estimate during oral interviews, and secondly, parametric distributions are both finite and continuous, thus making them relatively intuitive and easy to analyze (Vose, 1996). These types of distributions are useful in estimating probabilities of variables in contexts where data is scarce due to difficulty or cost of collection, and little is known about the actual values comprising the real distribution (Brighton Webs Ltd, 2013). The simplest parametric distribution for modeling expert opinion is the triangular distribution, which has been used extensively in risk analysis because of its intuitive structure (Vose, 1996). This distribution has no theoretical basis but draws its statistical properties from the geometry defined by the three parameters: minimum, mode, and maximum (Vose, 1996). Examples of triangular distributions with different parameters are shown in Figure 5.

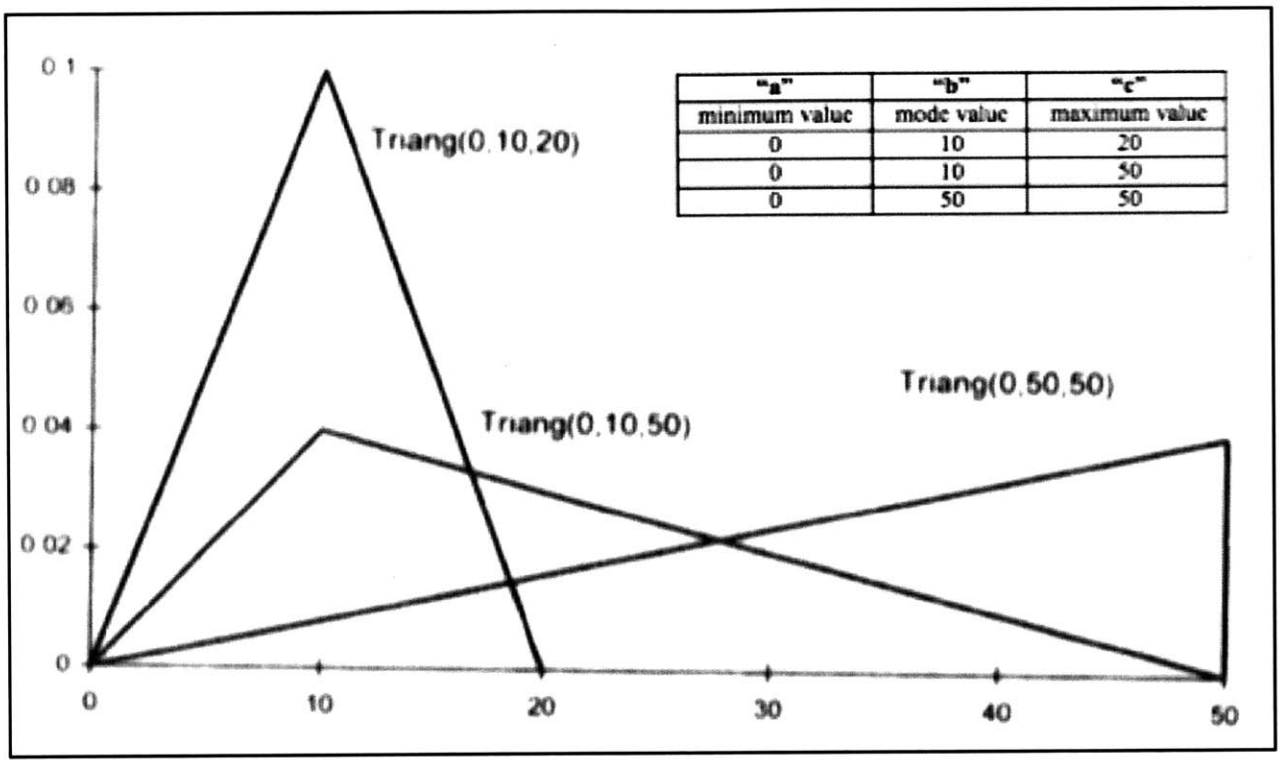


Figure 5. Examples of Triangular Distributions, Source: (Vose, 1996, p. 168)

The triangular distribution has a distribution and probability density functions as shown in Equation 1. Mean and standard deviation formulas are summarized in Equation 2 (Vose, 1996).

Distribution Function

$$\begin{cases} \frac{(x-a)^2}{(b-a)(c-a)}, & if\ a \le x \le c \\ 1 - \frac{(b-x)^2}{(b-a)(b-c),}, & if\ c \le x \le b \end{cases}$$

Probability Density Function

$$\begin{cases} \frac{2(x-a)}{(b-a)(c-a)}, & if\ a \le x \le c \\ \frac{2(b-x)}{(b-a)(b-c),}, & if\ c \le x \le b \end{cases}$$

Equation 1. Distribution and Probability Density Functions of Triangular Distributions, Source: (Forbes, Evans, Merran, Hastings, & Peacock, 2011, p. 189)

$$Mean = \frac{(a + b + c)}{3}$$

$$Standard\ Deviation = \frac{(a^2 + b^2 + c^2 + ab - ac - bc)}{18}$$

Equation 2. Mean and Standard Deviation Formulas of Triangular Distributions, Source: (Forbes et al., 2011, p. 189)

One critique of the triangular distribution is it overemphasizes the tails of the distribution and underemphasizes the shoulders of the distribution (Vose, 1996). In other words, it weights equally the three parameters of the distribution in contrast to normal distributions that put greater weight on the average.

Another parametric distribution that addresses this critique is a variation of the beta distribution called the Project Evaluation and Review Technique (PERT) distribution or the BetaPERT distribution. Developed by the U.S. Navy's Special Projects Office in 1957 to aid planning for the Polaris nuclear submarine project, the PERT distribution allows the user to adjust the weight given to the mode parameter based on the perceived confidence in the expert's estimated parameters, thus controlling the kurtosis of the distribution (Malcolm, Roseboom, Clark, & Fazar, 1959; Hill, 2010; Vose, 1996).

$$BetaPERT(a, b, c) = Beta(\alpha_1, \alpha_2) * (c - a) + a$$

$$\alpha_1 = \frac{(\mu - a) * (2b - a - c)}{(b - \mu) * (c - a)}$$

$$\alpha_2 = \frac{\alpha_1 * (c - \mu)}{(\mu - a)}$$

$Mean\ (\mu) = \frac{a+\gamma*b+c}{\gamma+2}$, where γ is the weight given to the mode parameter.

Equation 3. Formulas for Scaling, Shifting, and Shaping a Beta Distribution into a PERT Distribution, Source: (Vose, 1996, pp. 170–171)

The PERT distribution is a transformation of the beta distribution, achieved by scaling the beta distribution by the range between the minimum and maximum parameters, and then shifting it by the amount of the minimum parameter (see Equation 3 and Figure 6). The mode is then given a weighting factor γ (typically set to 4) that shapes the kurtosis of the distribution (see Equation 3 and Figure 7) (Vose, 1996).

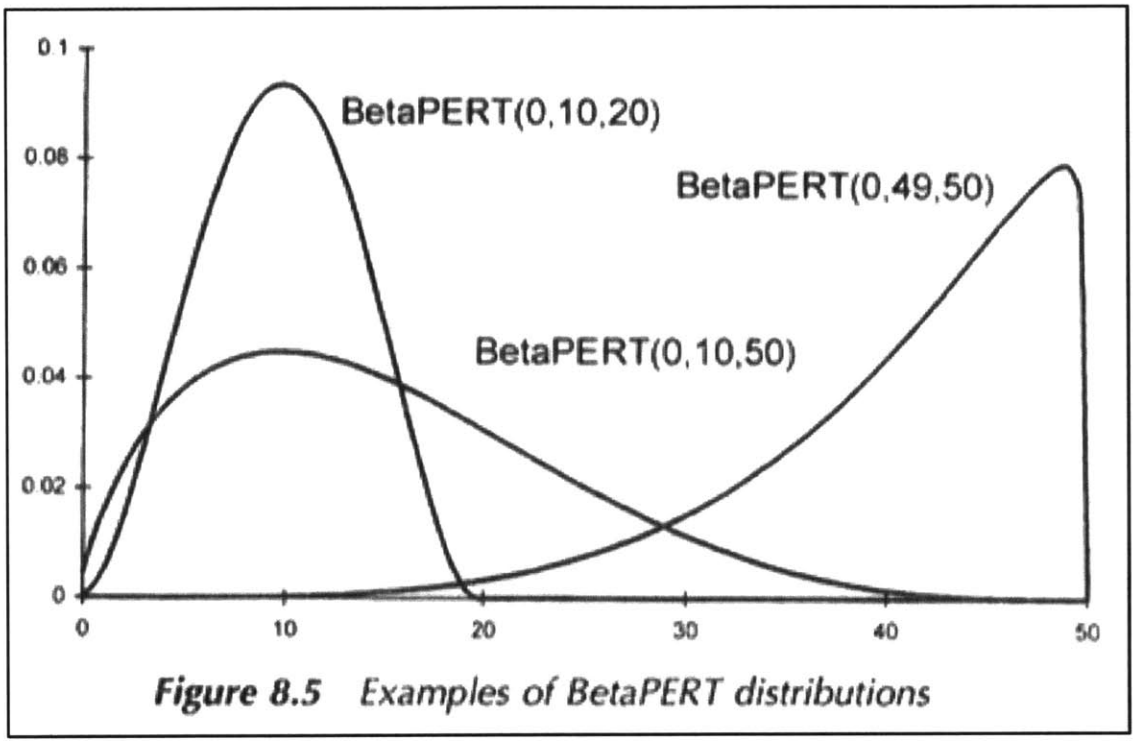


Figure 6. Scaling, Shifting and Shaping PERT Distributions, Source: (Vose, 1996, p. 171)

Changing the weight of the gamma parameter allows the user to adjust the fit of the distribution, based on the perceived accuracy of the expert opinions. An example of the effect of different gamma parameters on the shape of the PERT distribution is demonstrated in Figure 7.

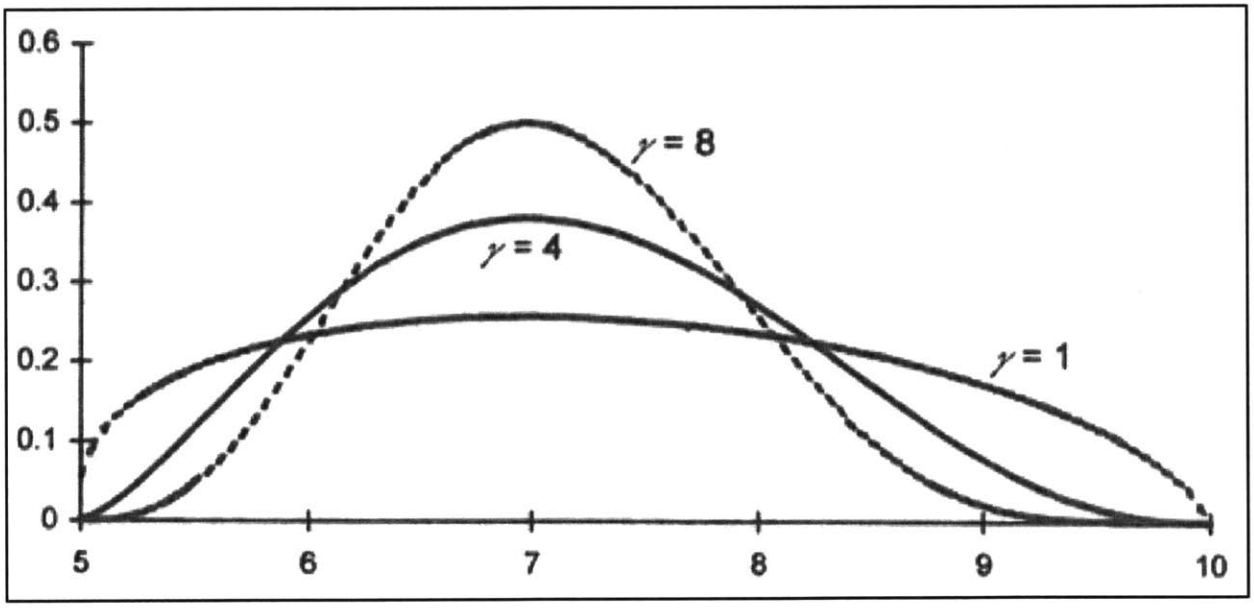


Figure 7. Changes in a PERT Distribution with Varying Gamma Values

Given the PERT distribution's relevance to doing analysis in data-constrained environments, we think this methodology is relevant and useful for capturing uncertainty in the variables of our financial model.

Geographic Information Systems (GIS) for Mapping Accessibility

Geographic Information Systems (GIS) are useful visualization tools for data that is tied to specific coordinates, landmarks, etc. on maps. They are most commonly used to express economic data (e.g. demographics, population, income distribution) in geospatial axes (Smith, Goodchild, & Longley, 2007).

Within the pharmaceuticals industry, GIS can be used to study population density, consumer behavior and market penetration of essential medicines (Smith, Goodchild, & Longley, 2007). It can also be used to study patient access to (1) capital via essential financial services, and (2) medicine via local pharmaceutical retailers (e.g. retail banking, microfinancing).

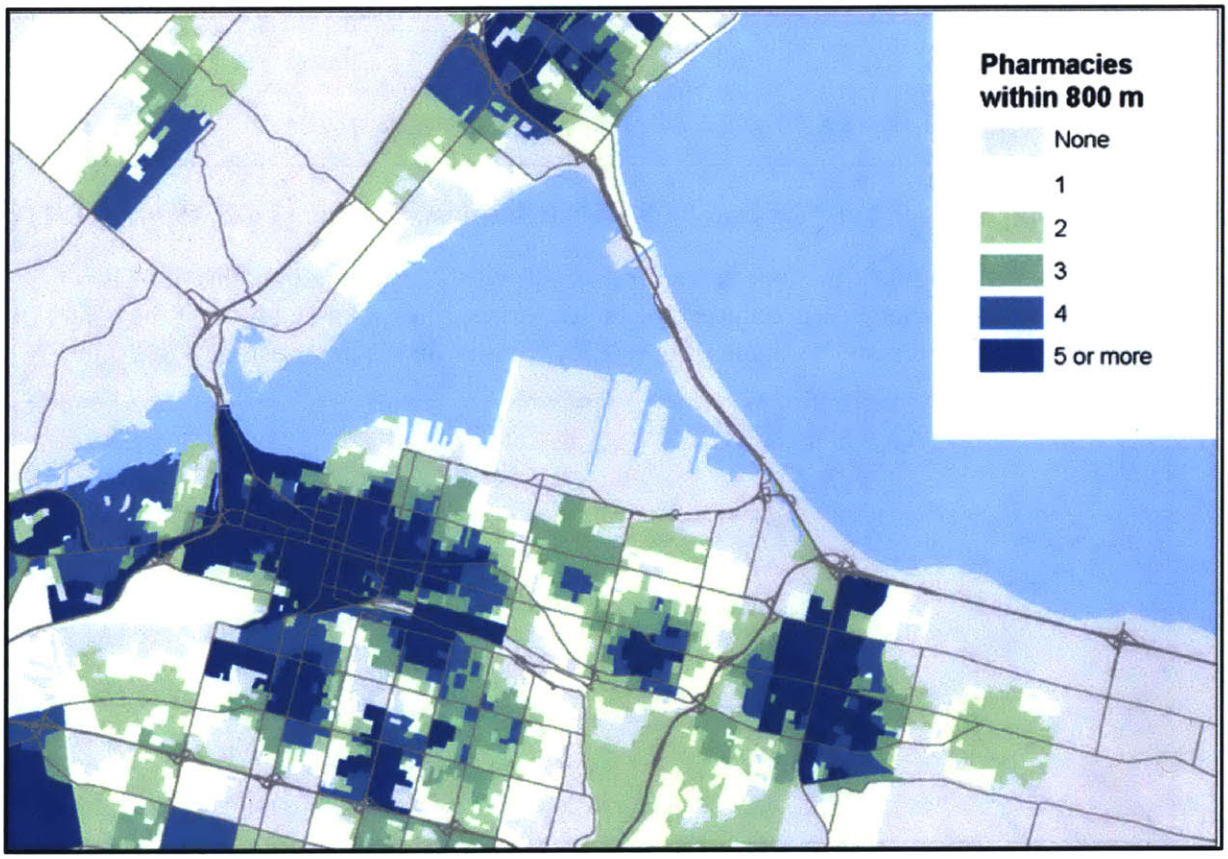


Figure 8. Number of pharmacies within 800m road travel distance of census dissemination blocks in Hamilton, Ontario, Source: (Law, Dijkstra, Douillard, & Morgan, 2011)

With granular geo-coded population and pharmacy location data, pharmacy density can be mapped and depicted using GIS. The example in Figure 8 shows the number of pharmacies within 800 meters of the population in Hamilton, Ontario. Granular data is difficult to obtain in

Uganda, but GIS and other data visualization tools are useful for studying gaps in geographic accessibility of medicine. We were unable to find examples of GIS analysis for the Ugandan pharmaceutical sector, so we intend to begin filling that gap with our analysis.

Quantitative Case Research

Case study research has been well established as a viable methodology in operations research. Having chosen a context where existing data is limited, and given the artificial constraints of our ability to gather a representative sample via primary research methods, conducting statistical analysis in the traditional, large-sample sense is not feasible. For this reason, an inductive approach using case study methodology seems both practical and useful.

The use of case studies in operations research has often been classified as qualitative, but Ketokivi and Choi (2014) challenge this notion. They highlight that the discourse has inherently defined quantitative research as…

> …either large-sample research that relies on statistical inference (i.e., empirical quantitative) or mathematical and stochastic modeling (i.e., analytical quantitative). In contrast, qualitative research has typically been considered through what it is not. Whatever is not quantitative is qualitative; what is not numerical data is textual (e.g., interviews); what is not deductive is inductive; et cetera (2014, p. 233).

They argue that case studies can, in fact, be of a quantitative nature without using those explicit types of analysis, as long as the case research meets what they call the duality criterion. The duality criterion requires that case research is both (1) situationally grounded and (2) seeking a sense of generality (Ketokivi & Choi, 2014). They further argue that the goal of case studies is not whether the case can be generalized to other contexts, but "the extent to which a sense of generality can be found in terms of theory" (Ketokivi & Choi, 2014, p. 234).

Case research aims to create knowledge via three different modes: theory generation, theory testing, and theory elaboration. Eisenhardt described the first variant as inductive case study where an explanatory theory derives from analytical exploration (Eisenhardt, 1989). Our paper will leverage the first mode of case research to generate an initial theory.

Meeting the duality criterion's requirement for being situationally grounded is straightforward with case research as theory generation, but establishing a sense of generality can be more difficult. Theory generated inductively from a case study relies heavily on the specific context, but drawing from an established general theory helps improve the sense of generality of the new theory and inform other emerging theories induced through the case research (Ketokivi & Choi, 2014).

This paper will follow case research methodology to inductively draw theory from the empirical data gathered in our field research. We will build on existing general theories outlined in our review of existing literature pertaining to access to medicine, access to finance, categorizing operational disruptions, and trade credit. In this way, the case study of Uganda

should provide insights into how to increase patient access to medicine by financing pharmaceutical supply chains in similar contexts.

Gaps and Opportunities

This literature review has highlighted gaps in current research that our paper may help fill. Existing research has focused on how financially inclusive services impact health-related behavior with a few articles studying how financially inclusive services affect perceptions of quality related to health service delivery. However, we could not find any research that analyzes the quantitative impact of access to finance on supply chain performance. The literature on measuring client perceptions of service quality is a starting point for understanding rural supply chain performance within the health sector, but its qualitative nature does not provide clear direction for where, how, and to what degree, investment in the pharmaceutical supply chain may improve access to medicine.

Mizgier et al.'s summary of how to best categorize risks of operational disruption and preempt or address them is helpful at a strategic level to determine how best to finance supply chain growth in the pharmaceutical supply chain. This is learning is complemented by the client protection principles put forth by Accion International. Furthermore, the operational learnings of technology-based approaches to improving access to finance provide a useful basis for developing a solution for the Ugandan pharmaceutical context.

Our thesis seeks practical, actionable insights based on quantitative modeling to answer our questions concerning quantitative analysis of capital constraints, optimal locations of capital injections within the pharmaceutical supply chain, and the impact on improved access to medicine.

Framework & Scope

Our thesis aims to understand how access to credit may impact access to medicine for patients in Africa. Drawing on Thomas and Penchansky's conceptual framework for access to medicine, we will attempt to show how financial constraints may affect the shelf availability and price affordability of medicine and how different types and quantities of capital injections at the each tier in a pharmaceutical supply chain might improve availability and affordability.

We chose to limit the scope of our research to the country of Uganda. Uganda's political stability, ease of travel, relatively stable market conditions, soaring macro-economic growth, high proportion of people seeking healthcare from the private sector, and unmet needs for access to medicine, allows for a good case study for our surveys and research.

Uganda will serve as a useful case study to build on some existing literature and begin filling the gaps in existing literature. Uganda will serve as a basis for theory generation regarding where in private-sector pharmaceutical supply chains financing can be used to improve *payment affordability* of medicines to achieve better patient access to medicine, how businesses should use that financing to mitigate operational disruptions that impact *on-shelf availability*, and

what districts in Uganda would benefit from investing in new pharmacies to improve *geographic accessibility*.

Methodology

The following sections describe methodology for our research. We use a quantitative case study approach based primarily on field research to frame the context, and then use financial modeling, statistical regression, and geo-spatial modeling, to inform our exploration of the three research questions.

Field Research

The objective of our primary field research was to study the financial and operational constraints of private-sector distributors, wholesalers and retail pharmacies in the Ugandan pharmaceutical supply chain.

The research trip comprised five workdays in Uganda. The first day and a half consisted of meetings with our sponsoring company, PharmCo. We also met with two other organizations working in Uganda, BankCo and ActingConsultant.[2] The latter three and a half days comprised a field survey conducted by the MIT team using semi-structured interviews of managers or owners of two pharmaceutical distributors (importers), two wholesalers, and 10 retailers. Two distributors, two wholesalers, and four retail pharmacies were located in Kampala (2 – Class A, 1 – Class B). Two retail pharmacies were located in Nansana, a suburb of Kampala (1 – Class B, 1 – Class C). Four retail pharmacies were located in Masaka (1 – Class B, 2 – Class C, 1 – Class D), a town located approximately 120 kilometers southwest of Kampala. Appendix A contains a table summarizing the businesses we interviewed and their type, location, and class. Figures 9 and 10 show the locations of our interviews.

We designed survey questions to gather empirical data on the business plans of pharmaceutical distributors, wholesalers, and retailers (see Appendix B for survey template). We asked to interview a 'decision-maker' at each business, which typically yielded a manager or assistant manager with limited knowledge or willingness to share detailed financial metrics. But occasionally, we were able to interview an owner or a manager with detailed knowledge of their business's financial metrics. For our data collection, we considered each interviewee an expert and the data he or she shared as expert opinion.

[2] The names of these organizations have been changed to maintain anonymity.

Figure 9. Map of Uganda with Interview Locations (Source: Google Maps, 2015)

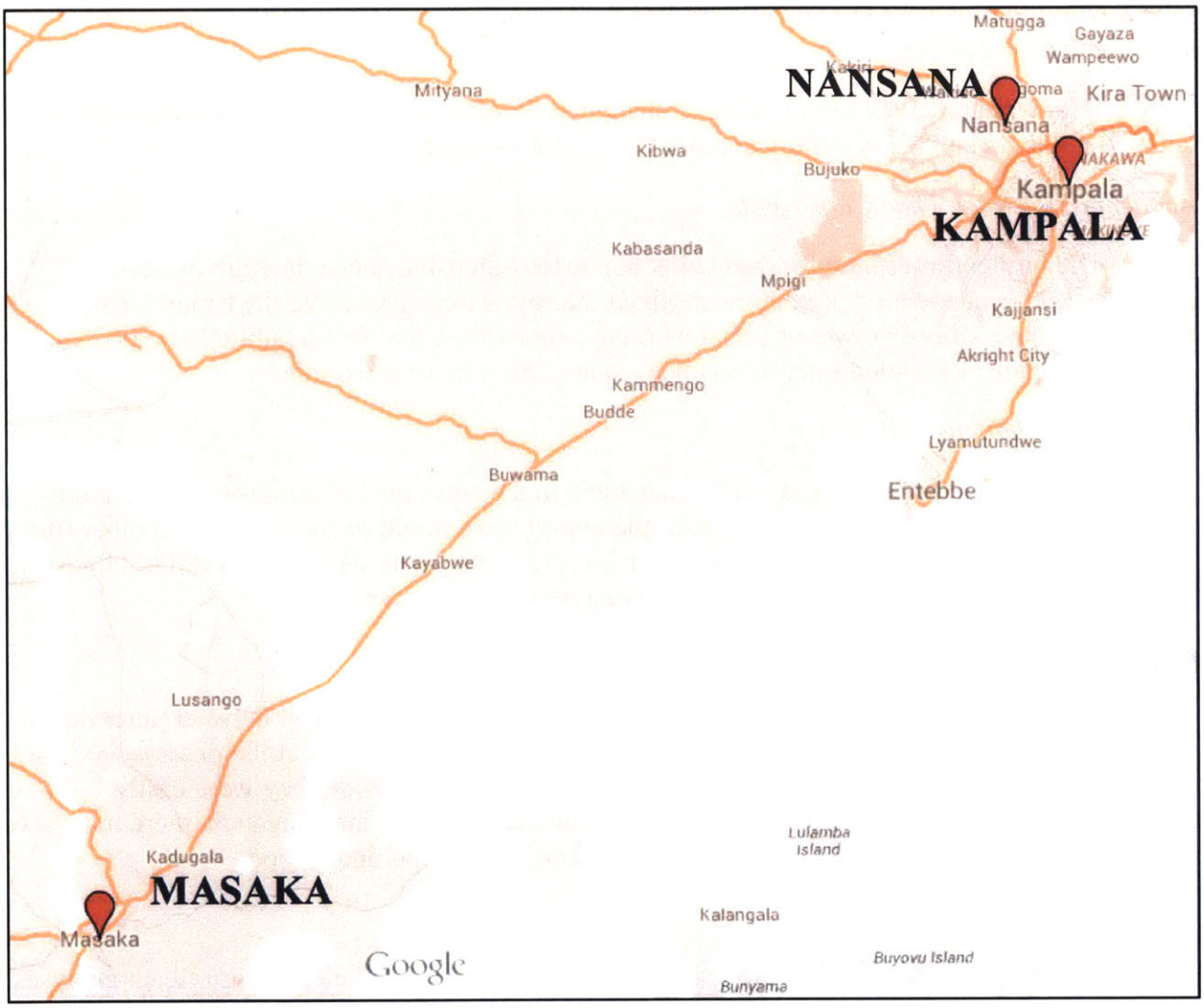


Figure 10. Detail of Southern Uganda with Interview Locations (Source: Google Maps, 2015)

The survey questions also sought to characterize the seasonality of demand for medicines and the profit margins and working capital of each node in the supply chain in order to better understand how and to what extent, variability in those areas affects access to medicine for the end Ugandan customer. Upon returning from Uganda, we consolidated the data into a single table (see Appendix C), and used the data to inform the assumptions around our financial model, the details of which follow in the next section.

Field Context

Interviewees Selection Bias

PharmCo selected the interviewees based on the strength of their relationship to PharmCo, the owner's or manager's availability during our trip's timeframe, and the

interviewees' willingness to meet and answer survey questions. This process introduced selection bias in our data.

Many pharmacists were willing to share details, although some were guarded with detailed numbers and a few simply avoided or refused to share their numbers.

Academic Calendar Time Constraints

The limited timeframe for data collection made extensive data collection extremely difficult. MIT's academic schedule constrained the seven-day duration of the trip in Uganda. Of those seven days, only five were official workdays (one of the five was a public holiday). The sponsor company scheduled interviews on all four of the available workdays.

Interviewee Challenges

Even though our interviews were scheduled in advance, the business owners were not always available for interview. Sometimes, the interviewee would be the owner, and other times it would be the manager, assistant manager, or inventory manager. Many either did not know the answers to our quantitative questions or would not share the answers.

Logistical and Cultural Challenges

We experienced logistical constraints that included delays in transit between interviews and busyness that distracted the interviewee related to serving customers at the pharmacies. At times, we also found it difficult to convey the intent of our questions so they were easily understood. Besides the occasional barrier of translating questions into Luganda, there may have been an education barrier that prevented our questions from being understood.

Sample Size Limitations

A relatively small data set precluded us from conducting statistically significant analyses. We had to make assumptions in our model to fill in gaps in the data. In order to characterize uncertainty in a limited data set, we used PERT distributions that are discussed in the following section.

Payment Affordability: Financial Model Design

To understand the affordability of medicine for different businesses in the pharmaceutical supply chain, we modeled profitability against cash conversion cycle (CCC), which used as a singular proxy for the business cash flow health. Since cost of goods sold (COGS) is a central component of the income statement and affects to some degree the ability of a business to be profitable, and since CCC indicates the nature of cash flows, the statistical relationship between these two elements may approximate the payment affordability element of access to medicine. Below we describe how we calculated profitability for each business.

We based our model on transcribed interview data gathered during the field trip to Uganda. By aggregating the data into a single grid, we were able to identify recurring trends in data configuration (e.g. units of measure, data accuracy, variables with insufficiency in data).

This helped us (1) identify assumptions we would have to make in the model, (2) smooth data points by standardizing units of measure, and (3) fill data gaps by estimating missing data with averages across existing samples.

We did not have complete data for class A and class D pharmacies, so we decided to focus on class B and class C for our model. In the model, we refrained from combining class B and class C pharmacy data to explore whether behavior and capital constraints varied significantly across the two pharmacy classes. Codes represent each business's position within the supply chain, the class (for retailers), and an arbitrary number to delineate within those categories. For example, D1 is the first distributor on our list, W2 is the second wholesaler, and RC2 is the second C-class retailer.

We identified the financial metrics (aside from the actual financial figures) that we intended to analyze to help us understand the financial constraints of each business, particularly CCC and profit margins. From the aggregated and cleaned data, we constructed simplified cash flow models for each business at each of the three nodes in the supply chain: one model for the distributor, one for the wholesaler, and two for the retailer (class B and class C). Each cash flow model captures revenue, cost of goods sold (COGS), and operating expenses, and calculates gross, margin, operating profit (before tax), and net operating profit after taxes (NOPAT). We applied the 30% corporate income tax of Uganda and assumed that businesses that did not make a positive net operating profit would not pay income tax. All numerical figures reflect aggregated annual amounts, and we converted all currency figures to US Dollars.

Simplified Income Statements

A complete list of the financial variables we intended to analyze allowed us to create simplified income statements for each of our interviewees. With data on revenues, COGS, operating expenses and income taxes, we were able to calculate (1) gross margins, (2) operating margins, and (3) net operating profit after taxes (NOPAT) for each of our interviewees.

Since our interviews did not produce any variation patterns for COGS, we assumed that the variation in COGS would match the variation pattern in revenues. We adjusted the average revenue and COGS figures to reflect the variation data we gathered in our interviews by using multipliers for high/low demand variability per the following equations:

$$\text{Increased Sales Multiplier} = 1 + \left(\frac{\text{Most Customers Served} - \text{Mode Customers Served}}{\text{Mode Customers Served}}\right)$$

$$\text{Decreased Sales Multiplier} = 1 - \left(\frac{\text{Mode Customers Served} - \text{Least Customers Served}}{\text{Mode Customers Served}}\right)$$

Equation 4. Sales Multipliers Used to Calculate High- and Low-Demand Months

Finally, since our interviewees provided financial figures in Ugandan Shillings (UGX), we decided to convert all currencies into United States Dollars (USD) for ease of comprehension. To make the conversion, we used the foreign exchange rate from 02 March 2015 (1 USD = 2,895 UGX). In total, our model comprised 14 simplified income statements in parallel, one for each business we interviewed.

Cash Conversion Cycle (CCC)

We wanted to calculate the cash conversion cycle (CCC) for each business using the following equation relating days payable outstanding (DSO), days sales outstanding (DSO), and days inventory outstanding (DIO):

$$CCC = DIO + DSO - DPO$$

Equation 5. Cash Conversion Cycle (CCC) Formula

Since precise DIO, DSO and DPO are difficult to assess because their calculation requires detailed, granular financial data, we selected an alternative approach to their estimation. We estimated DPO as supplier payment terms, DSO as average days until a customer paid for an order, and DIO as the average number of days a business could operate without further inflow of new inventory. We were unable to collect DIO data from all interviewees and thus excluded some businesses from our calculations of CCC and subsequent analysis. Additionally, we had to estimate the minimum and maximum for the DIO. Since we know from our literature review that trade credit agreements with customers and suppliers have little impact on each other, we can reasonably assume DPO and DSO as independent random variables (Jaggi et al., 2008). We also assumed DIO to be independent of DSO and DPO considering inventory levels to be a strategic decision of the business owner.

Our approach modeled the three DIO, DSO, and DPO variables as PERT distributions in Excel using an open-source add-in macro called OpenPERT ("OpenPERT," 2011). We then used a Monte Carlo simulation to pull random samples from each of those three distributions and combine them according to the CCC formula above. We performed this calculation 10,000 times using random samples from each distribution, and we used the 10,000 calculated CCC values to generate a new CCC distribution. We did this for each business for which we had a complete DIO, DSO, DPO data set, and the new CCC distributions are depicted in histogram format in Appendix C.

Our newly created CCC distributions looked fairly normal with some slight skew, so we calculated the mean and standard deviation from the sample of 10,000 calculations. The mean and standard deviation formulas are given in Equation 6.

$$\mu = \frac{a + 4 * b + c}{6}$$

$$\sigma = \frac{\sqrt{(a-x)^2 + 4 * (c-x)^2 + (b-x)^2}}{6}$$

Equation 6. Mean and Standard Deviation for PERT Distribution, Source: (Vose, 1996)

This process gives a reasonable method of determining mean and standard deviation of the business's CCC using estimates of the parameters for the probability distribution of the CCC components: DSO, DIO, and DPO. Finally, we plotted the mean and the standard deviation against the profitability of each business to draw inductive theories.

On-shelf Availability: Categorizing and Addressing Operational Disruptions

Given the limited research done in the space of operational disruptions in Africa, this section proposes a Six-Sigma framework to define and address operational disruptions that effect on-shelf availability, namely stockouts. We use the proposed simplification framework that aggregates operational disruptions into two most categories: (1) low-frequency/high-impact disruptions, and (2) high-frequency/low-impact disruptions.

High-Frequency/Low-Impact Disruptions

Commonly referred to as "common cause variation," the high frequency (and low impact) of events allows for a steady collection of representative data. Empirical studies using process control tools (e.g. Statistical Process Control) allow for the creation of a baseline distribution for the highly frequent, yet randomly occurring, events. Common cause variation does not require capital investment, but rather investment of time in process control studies (Furterer, 2014). Due to the low-impact nature of the disruptions, return on invested time/effort is generally low. Yet over an extended period of time, any/all savings in process control, material flow and resource allocation creates tangible savings (Furterer, 2014).

Within pharmaceutical supply chains, typical symptoms of common cause variation include relative lack of knowledge of best practices (often leading to low customer service levels), low capacity utilization, frequent production disruptions, poor preventative maintenance, inappropriate operating procedures, lack of management control, poor working conditions and high employee turnover (Furterer, 2014).

A recommended strategy for high-frequency/low-impact disruptions is prioritization of process control programs (e.g. Six Sigma, Plan-Do-Check-Act), with guidance and supervision from continuous improvement professionals (Furterer, 2014).

Low-Frequency/High-Impact Disruptions

These disruptions are generally referred to as "special cause variation." Given the low frequency of events, the root cause of most occurrences is easily identifiable. Contrary to

common cause variation, it is difficult to create a representative distribution of events (Furterer, 2014). On a macro level, the general lack of data creates complexity in the management of special cause variation. Thus, a common management approach for low-frequency/high-impact disruptions is mitigation of losses (Furterer, 2014).

In pharmaceutical supply chains, symptoms of special cause variation are often underinvestment in inventory (leading to low customer service levels), poor quality control (leading to recalls) and overutilization of company assets (Furterer, 2014). A common thread in these process defects is underinvestment by the organization. Unlike common cause variation, it is generally easier to find a solution for special cause variation; the difficulty is finding the cash flow for capital investment (Furterer, 2014).

To manage low-frequency/high-impact disruptions, it is critical to understand the system dynamics of the special cause variation (Sterman, 2000). Identifying the true root cause of weakness in a system may yield alternative solutions, deeper insights and increased awareness for potential high-impact disruptions in the future. Capital investment in the African context may be essential to counter operational disruptions created by special cause variation.

Geographic Accessibility: Pharmacy and Financial Services Density

Calculating ratios of people-to-pharmaceutical outlets, people-to-financial services, and financial services-to-pharmacies for different geographic areas may help indicate regions with lower geographic accessibility to medicine and financing. GIS software is ideal for this analysis, but requires geocoded data. Where data is not granular or geo-coded, similar analysis can also be done using standard data visualization software to identify patterns and gaps without the mapping the data geospatially. These methods can inform policy and strategy for public and private sectors.

Our analysis leverages data visualization software to analyze publicly available district-level pharmacy and population data for Uganda as a proxy for geographic accessibility to medicine and access to financial service locations as compared to the local demand for those financial services.

Analysis

In the following sections, we will discuss key findings from our field research and interviews in Uganda, the generation of our financial model and the related sensitivity analysis of free cash flows, our suggested framework for categorizing operational disruptions with a six sigma approach, and the GIS model we created to identify retail pharmacy density throughout Uganda.

Key Findings from the Field Research

The following section outlines the key observations and trends from our field research and interviews in Uganda. The observations span additional financial inclusion initiatives,

financial constraints, the causes of stockouts, trends related to financing growth, entrepreneurial spirit, and two case studies of RC1 and RB1.

Additional Financial Inclusion Initiatives

Our meetings in Uganda elucidated the informal banking sector and revealed some initiatives to link the informal and formal sectors. We learned of a partnership between BankCo and ActingConsultant aimed at connecting informal banking groups called VSLAs with the formal banking sector. VSLAs (village loan and savings associations) or SACCOs (savings and credit cooperatives) are groups of approximately 30 individuals from the same village who entrust each other to co-sign a group loan. In the initiative, a VSLA group borrows from BankCo and offers loans internally to members, allowing the group to access capital at a cheaper rate than any individual could through the market. This allows VSLAs to access more capital, build up members' savings, and credit individual credit histories for their members.

VSLAs were previously 'unbanked' groups without a means for safely storing their saved money, and they had no credit history. The solution BankCo and ActingConsultant developed enables VSLAs to safely store their money; after a period of six months they can then access the capital, based on the credit history they had created. The interest rate for the group was lower than that given to a standard customer, the bank account was provided without charges, and the money in the savings account belonging to all the group members accrued interest. The VSLA solution seems to fit the financing challenges faced by the end patient, which could prove useful for addressing payment affordability for patients, although it is outside the scope of this paper.

Financial Constraints

In the initial examination of data, financial constraints (e.g. profitability, cash flow) were not apparent at the distributor, wholesaler, or top-tier retail levels, but were increasingly apparent in lower class retail pharmacies, notably classes C and D. In addition to the class level of the pharmacy, retailers that were owned by a larger parent company seemed to have fewer financial constraints, perhaps due to their ability to leverage economies of scope and scale. Our interviews indicated that independent outlets operating on their own were unable to spread variances in risk, inventory, and profits across a larger network of outlets; however, we were unable to gather sufficient data to substantiate this insight. We believe this could be an excellent follow-up opportunity for future research. In general, financial constraints were not vocalized as a top challenge among distributors, wholesalers, and top tier (class A and B) pharmacies; they were more of a concern in smaller, single outlet pharmacies in the Class C and D range.

Causes of Stockouts

Stockouts of medicine were infrequent at distributors and class A pharmacies, and most commonly attributed to manufacturer supply shortages. Stockouts at wholesalers and lower class pharmacies (e.g. class C and D) were more commonly attributed to unpredictable demand (identifiable as special cause variation). One wholesaler commented about a PharmCo product that was long stocked out, and PharmCo's country director shared how production changes had resulted in a large supply gap.

According to one wholesaler, the unpredictable demand seems in part due to large cash purchases made by traders from South Sudan, Democratic Republic of the Congo, or Rwanda (identifiable as common cause variation). These stockouts reportedly happen as often as once a month. Since "cash is king", business owners are willing to serve these customers, even if it adversely affects their ability to meet the demand of their local, loyal customers. This challenge suggests that parallel trade and inappropriate reference pricing across countries is happening, perhaps as a result of manufacturers' differential pricing (Logendra et al., 2012).

Changes in production are common occurrences in many organizations. Businesses in developed markets are likely to invest in additional inventory or demand planning to hedge against this risk; but this level of investment may not be possible for businesses in developing markets such as Uganda. As mentioned in the Methodology section of this paper, unpredictable demand (special cause variation) requires capital injection, which can be a more difficult proposition for businesses.

Trends Related to Financing Growth

From our field surveys, we noticed that none of the fourteen businesses banked with BankCo or used an informal banking service like a VSLA. Almost all of them had bank accounts with at least two or more other local commercial banks. One class D pharmacy, RD1, took a microloan from a large, reputable microfinance organization, but the interviewee would not share any further details on the interest rate, size of the loan, or the other terms. Relatedly, we also observed a general lack of supply chain knowledge across all interviews, particularly regarding forecasting, replenishment, and inventory management. More importantly, there was also a lack of awareness that these skills were missing.

Commercial loans were commonly cited as unappealing due to high interest rates (22-30%) and collateral requirements. One distributor and one wholesaler resorted to low interest "loans" from a holding company. Retailers, on the other hand, preferred to leverage supplier payment terms as a type of interest-free loan and grow their businesses organically.

Entrepreneurial Spirit

One class C pharmacy, RC1, had been in business for six months and was actively looking to build more branches in areas with less dense pharmacy coverage. The owner had an entrepreneurial spark, was actively shopping for commercial loans, and had a vision to manage a large number of pharmacies in underserved areas. PharmCo's country director for Uganda classified this pharmacy as "Class C, but transitioning to Class B".

Case Study: RC1

RC1 demonstrated a strong entrepreneurial penchant in wanting to open more pharmaceutical outlets. They cited brand presence, increased sales/market penetration and higher gross margins (possibly through volume purchasing) as motivations for wanting to open new retail outlets. Unlike many other pharmacy owners, the directors of RC1 had educational backgrounds in business and medicine. This presented a very interesting case study of a observing how a business-trained professional in Uganda was managing a recent startup.

We had the opportunity to discuss commercial loans with RC1, prompting candid feedback from the owner about loan structures and interest rates. The owner commented,

> Loans are a choice of last resort. The interest rates are very high and not business friendly. The only loans we will be looking at are the ones denominated in USD since their borrowing rates are LIBOR based and can be absorbed by the business. Grants and supplier credit is a preference for small businesses like ours.

In later discussions, the owner reaffirmed that without the LIBOR based interest rates, RC1 would not at all consider leveraging commercial loans.

When asked about other capital funding opportunities, RC1 expressly indicated that they would prefer microfinance loans above all other means of debt-financing (including commercial loans). Supplier payment terms and government funding, respectively, were cited as second and third preferences, followed by commercials loans in USD. When asked to explain the rationale behind these preferences, the owner responded, "These are especially tailored for the microbusiness environment."

Next, we inquired deeper into the specific banking services and financial instruments that RC1 would leverage if it were to leverage a microfinance or commercial loan. The owner showed a strong understanding of financial services in identifying letters of credit; import financing options and bills-discounting facilities as the most appealing microbusiness support products.

RC1 identified working capital as a key obstacle to business growth. The owner stated that a capital injection of $50,000 would cover the fixed costs and stocking needs of opening two more retail outlets in Kampala. As a caveat, the owner mentioned, "The figure will progressively vary depending on the growth needs and sales coverage in terms of working capital bridging." We were particularly interested in learning how constrained cash flows affected sales for RC1. The owner mentioned that a majority of RC1's working capital is tied up in inventory, with slow moving inventory as the majority. The owner mentioned, "This is one of the reasons we are looking at more branches so that we are able to transfer certain products to branches where they have the potential to move faster." RC1 believed that stockouts were the primary cause of operational disruptions, causing 50-60% of lost sales per annum. The owner believed the biggest externality of stockouts was mismanagement of client relationships. If RC1 did not have a desired medicine in stock, customers would have to travel long distances to purchase the medication from other retail outlets outside of Kampala. Other than stockouts, obsolete inventory (i.e. expired medicines) was identified as the only other major operational disruption.

Perhaps of greatest importance, RC1 was very receptive to educational seminars in continuous improvement, supply chain finance, demand forecasting and inventory management. The owner expressed interest in a focus group of pharmacies from other towns to learn/share best practices.

The owner of RC1 shared the growth strategy for the business over the next 3-5 years: "We intend to (1) maintain one wholesale outlet with a set of 5 retail outlets in strategic areas around Kampala for ease of management in the next 2 years, and (2) expand the number of the

retail outlets to satellite towns in Uganda like Mbarara, Fortportal Gulu and into the East in the 3rd to 5th Year."

Case Study: RB1

RB1 is an interesting case study because they have (in the past) received loans from the World Bank and the Ugandan Ministry of Health. When asked about the motivation for these loans, the owner responded, "we extend a service to majority of Ugandans at our facilities, reducing the burden to Ministry of Health (MOH) through its Public Facilities. In so doing, we are eligible to loans guaranteed by Government through MOH. The terms of repayment are good, longer grace periods, and good interest rates on the loan compared to other financial institutions." Similar to our interview with RC1, RB1 has also expressed prohibitive interest rates as a challenge to leveraging commercial loans in Uganda.

Given the larger scale of RB1 (as compared to other smaller pharmacies interviewed), we were interested in knowing the different sources of debt financing they were considering. As expected, the owner nullified commercials loans as a source of capital due to high interest rates. Interestingly, microfinance loans and SACCOs were also nullified because they were "smaller loans compared to what we [RB1] may need." The owner also mentioned that SACCOs were difficult to obtain because they typically had political/bureaucratic implications. RB1 cited supplier payment terms and government funding as the most preferred sources of capital due to low risk and favorable repayment terms, respectively.

Similar to responses from RC1, RB1 was also open to attending education seminars for demand forecasting, inventory management and supply chain planning. The owner mentioned that he would be willing to spend 20,000 Ugandan shillings (or about USD 7) per participant to educate his team on industry best practices.

Stockouts were identified as the biggest operational disruption. The owner stated that working capital restrictions, along with stringent policies for repayment, precluded RB1 from being able to optimize free cash flows. However, these disruptions were said to occur very infrequently, or approximately once every two months.

We were interested in learning how RB1 was able to successfully scale their business. The owner mentioned that, among other variables, having capital to open multiple retail outlets was the biggest enabler of success. Having multiple retail outlets allowed RB1 to engage in volume procurement for the entire retail network, which enabled increased gross margins. Given RC1's ambition to scale the business by opening more retail outlets, we believe it is critical for PharmCo to connect RC1 and RB1 to share experiences, ideas and best practices. RB1 has mentioned that they would be happy to participate in a focus group with other retail pharmacies to share its success story.

RB1 expressly mentioned that they would prefer procuring medicines directly from manufacturers. Currently, PharmCo is selling products to distributors, who sell to wholesalers, who sell to retailers, who sell to patients. It is likely that price markups from node-to-node in the supply chain cause the retail price to become prohibitive for patients. If RB1 were to obtain an importer license and procure directly from PharmCo, it is possible that RB1 would be able to

charge a greater markup, while still offering more affordable prices to patients. In this regard, RB1 would be balancing the creation of economic value and social value.

In terms of challenges, RB1 believes that persistent currency depreciation of the Ugandan shilling and increased transportation costs due to tax volatility on oil are significant challenges for the business in the near future.

Financial Modeling and Sensitivity Analysis

Applying a heat map across the cash flow models for each business, divisions between the three levels of the supply chain become apparent (see Figure 11). The heat map yields two observations: (1) while distributors have the largest volume of sales, it appears that wholesalers may actually be more profitable, and (2) most of the retailers are not profitable, and the one that is profitable is barely so.

Business Details	Code	D1	D2	W1	W2	RB1	RB2	RB3	RC1	RC2	RC3	RC4
	SC Node	Distributor	Distributor	Wholesaler	Wholesaler	Retailer	Retailer	Retailer	Retailer	Retailer	Retailer	Retailer
	Class	-	-	-	-	B	B	B	C	C	C	C
Cash Flow Models	Revenue (Annual)											
	COGS											
	Gross Margin											
	Operating Expense											
	Operating Income											
	Income Tax (30%)											
	NOPAT (Annual)											
	NOPAT (%/Revenue)											

Figure 11. Heat Map of Aggregated Cash Flow Data

We were unable to plot all CCC distributions, because not all businesses had complete data. For some businesses, we had to estimate certain parameters as a result of limited data (see bolded and italicized numbers in Figure 12). The estimate figures were primarily for DIO minimum and maximum, and were chosen to be $\pm$ 5 days around the mode for wholesalers and distributors, and $\pm$ 2 days around the mode for retailers. This assumption seemed reasonable to us because wholesalers and distributors are larger businesses that carry more inventory volume, and they may have larger swings in DIO when ordering larger quantities. We used the parameters listed in Figure 12 for each component (DSO, DIO, DPO) to generate the data in Figure 13 for CCC.

	CCC Component -->	DSO			DIO			DPO		
	Statistical Parameter -->	Min	Mode	Max	Min	Mode	Max	Min	Mode	Max
DISTRIBUTORS	*D1*	30	60	90	***85***	90	***95***	0	30	90
	D2	30	45	90	***85***	90	***95***	60	60	90
WHOLESALERS	*W1*	0	30	***60***	***25***	30	***35***	30	60	60
	W2	30	60	90	***85***	90	***95***	0	60	120
RETAILERS	*RB3*	0	0	***1***	***5***	7	***9***	0	15	30
	RC1	7	14	30	***5***	7	***9***	0	45	60
	RC2	1	15	30	***12***	14	***16***	0	7	15
	RC4	0	14	***28***	***5***	7	***9***	30	60	60
BOLD = estimated values										

Figure 12. CCC Component PERT Distribution Summaries (DSO, DIO, DPO)

	CCC Component -->	CCC			CCC		PROFITABILITY (%, NOPAT/REVENUE)
	Statistical Parameter -->	Min	Mode	Max	Mean	Stdev	
DISTRIBUTORS	*D1*	46	115	173	115.15	20.07	4.50%
	D2	41	75	113	75.01	11.71	8.09%
WHOLESALERS	*W1*	-29	5	60	5.06	12.20	25.67%
	W2	12	90	174	89.87	25.47	23.51%
RETAILERS	*RB3*	-23	-8	8	-7.85	5.70	-8.86%
	RC1	-44	-18	24	-17.64	11.46	-7.43%
	RC2	3	22	41	21.95	6.24	-39.19%
	RC4	-52	-34	-6	-34.01	6.84	2.91%

Figure 13. CCC Distributions Using Monte Carlo Simulation

Our estimations in CCC component parameters clearly reflect a low variance assumption. We also considered how the CCC mean and standard deviation might change if the parameter estimates reflected a larger variation. Figure 14 shows how mean and standard deviations might change as a result of increased variance in the components.

		DIO (Small Var)			DIO (Large Var)			CCC (Small Var)		CCC (Large Var)		Comparison	
	Business	Min	Mode	Max	Min	Mode	Max	Mean	Stdev	Mean	Stdev	CCC Mean - % Change	CCC Stdev - % Change
DISTRIBUTORS	*D1*	***85***	90	***95***	***60***	90	***120***	115.15	20.07	115.28	20.01	0.11%	-0.30%
	D2	***85***	90	***95***	***60***	90	***120***	75.01	11.71	75.13	16.04	0.16%	36.98%
WHOLESALERS	*W1*	***25***	30	***35***	***0***	30	***60***	5.06	12.20	4.87	16.76	-3.75%	37.38%
	W2	***85***	90	***95***	***60***	90	***120***	89.87	25.47	89.85	27.89	-0.02%	9.50%
	RB3	***5***	7	***9***	***0***	7	***14***	-7.85	5.70	-7.80	6.34	-0.64%	11.23%
	RC1	***5***	7	***9***	***0***	7	***14***	-17.64	11.46	-17.51	11.80	-0.74%	2.97%
	RC2	***12***	14	***16***	***7***	14	***21***	21.95	6.24	22.06	6.73	0.50%	7.85%
	RC4	***5***	7	***9***	***0***	7	***14***	-34.01	6.84	-33.93	7.30	-0.24%	6.73%

Figure 14. Sensitivity to Minimum and Maximum Estimates of DIO

We were unable to gather empirical data on the minimum and maximum days of inventory held by our interviewees in Uganda, leading us to estimate values for these parameters. Figure 14 depicts a sensitivity analysis of our min/max estimates for DIO. A key takeaway is that changing DIO has trivial impact on mean CCC (less than 1% change for most businesses). The high impact on CCC standard deviation is expected, given the wider spread of variances in the data (e.g. $\pm$5 days of DIO versus $\pm$30 days of DIO).

Figure 15 plots profitability against mean CCC for each of the businesses interviewed in Uganda and suggests that despite having the strongest cash flow position (lowest average CCC), 75% of the interviewed retailers were still unprofitable. Retailers' hoarding of cash may be preventing them from investing in the proper inventory levels to generate sales and remain profitable. This observation resonates with Yadav et al.'s observations in Tanzania and Uganda (2012), and is a normal behavior for businesses faced with operational uncertainty.

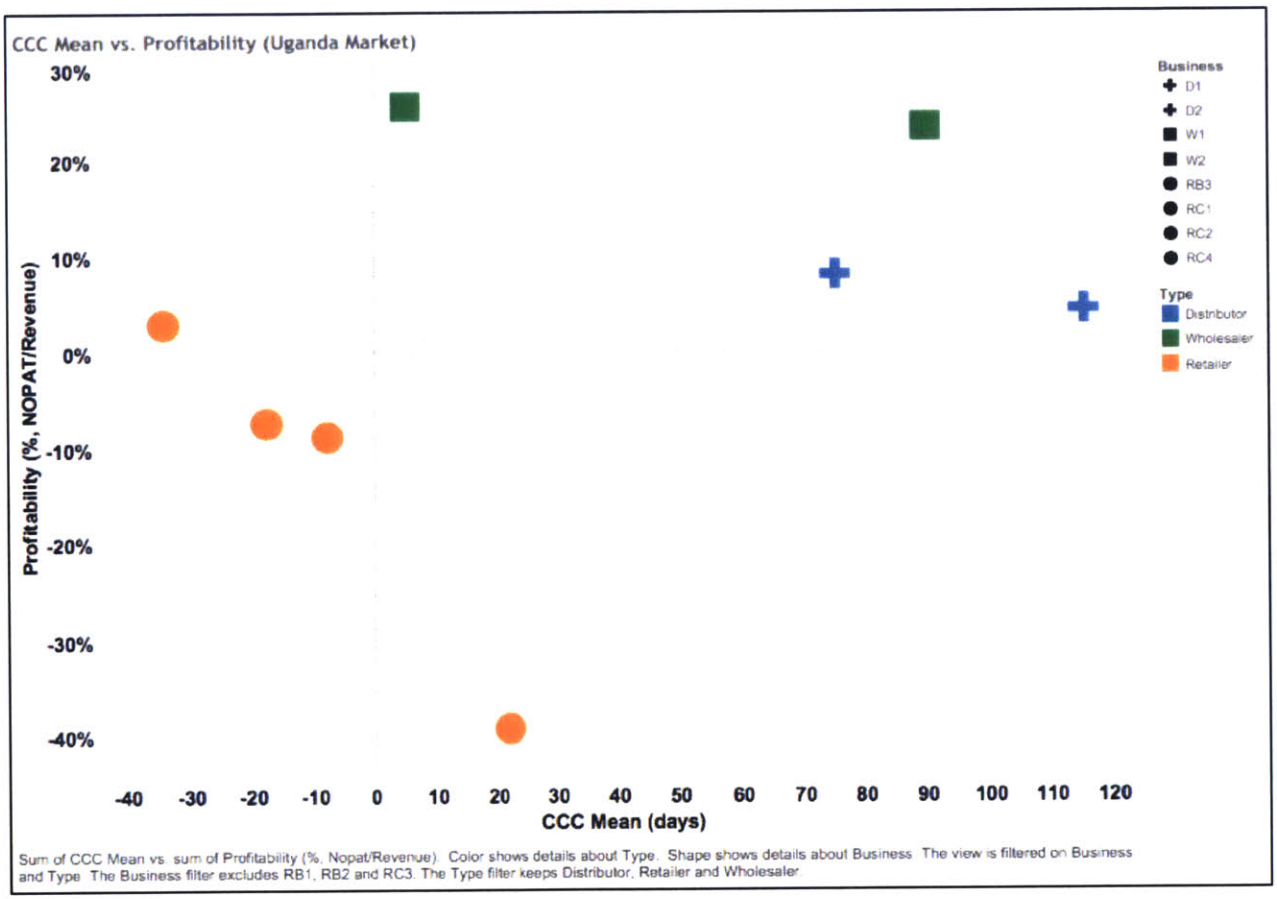


Figure 15. CCC Mean vs. Profitability (Uganda Market)

At the other end of the spectrum, distributors appear to have the weakest cash flow position (highest mean CCC) yet are still profitable. Given the relative insufficiency of data, conclusions from this analysis are difficult to draw. But perhaps their higher inventory and longer customer payment terms allows them to generate more sales.

Analyzing wholesaler data made for a very interesting case study. While both wholesalers enjoy healthy profitability of +20%, one wholesaler has a very strong cash position (negative CCC) and the other has a relatively weak liquidity position (high CCC). Due to the general lack of data, we are unable to draw any conclusions regarding this phenomenon. However, one of the wholesalers with negative CCC could be benefitting from network effects.

Figure 16 also plots profitability against mean CCC, but for businesses in the US pharmaceuticals market. All profitability and CCC data was gathered from publicly available financial reports as opposed to interviews. It is worth noting that this analysis includes manufacturer data, whereas the analysis of the Ugandan market did not include manufacturer data. In the US market, the cash positions of retailers and distributors are opposite to the cash positions of retailers and distributors in the Ugandan market. Retailers have a higher average CCC with moderate profit margins, while distributors have the lowest average CCC with razor-thin profit margins averaging 1%. In the US, retailers may be more likely to invest free cash flows in additional inventory, thereby increasing profitability. Distributors, on the other hand, may conserve capital by holding fewer inventories, which may be a key contributor to their lower profitability. Despite having the longest average CCC, manufacturers enjoy the highest profit margins.

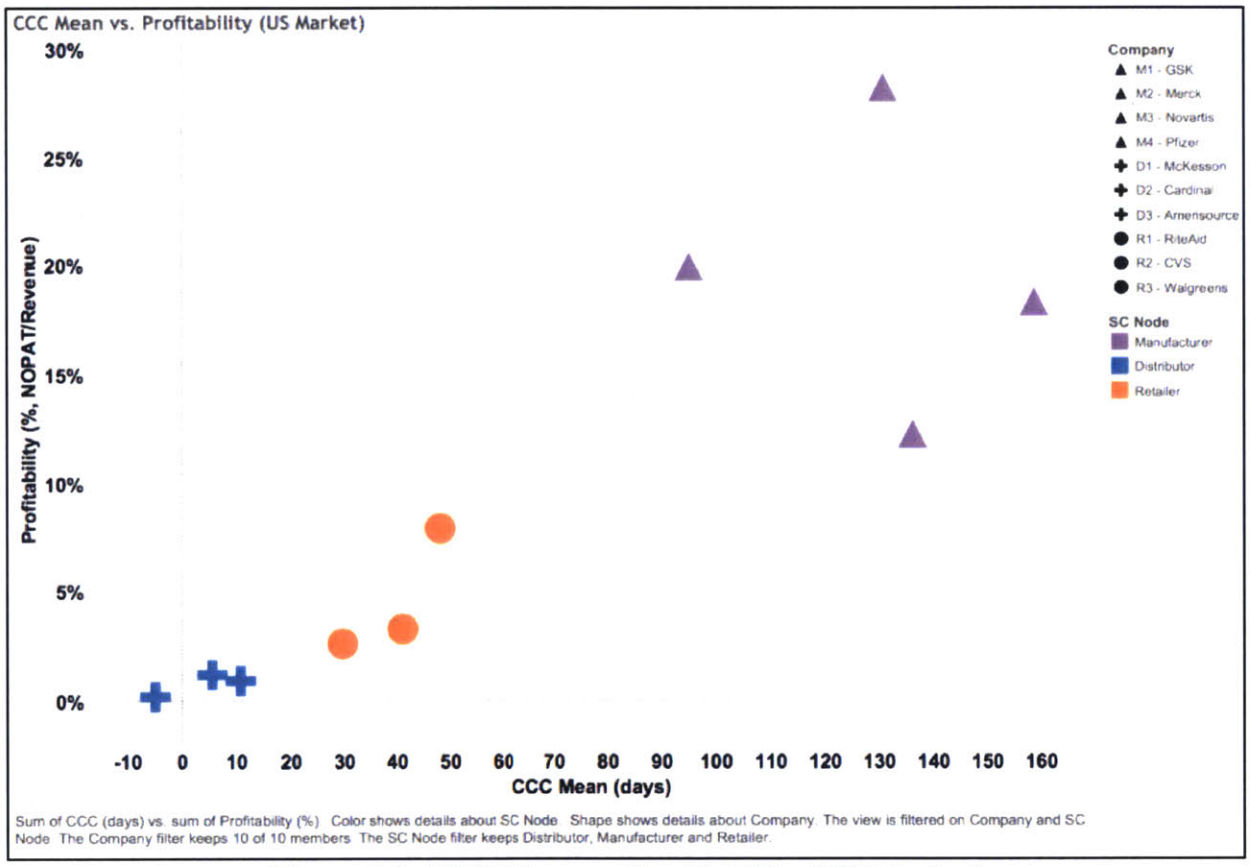


Figure 16. CCC Mean vs. Profitability (US Market)

In comparing retailers from Figures 15 and 16, it is important to note a key difference in market dynamics between the United States and Uganda. The pharmaceutical retail market in

Uganda is largely fragmented, compared to a more consolidated market in the US. Market economics suggest that a fragmented market could result in over-competition. It is possible that the fragmented nature of the Ugandan pharmaceutical retail market is causing retailers to exhibit lower profitability than pharmaceutical retailers in the US.

Figure 17 plots profitability against standard deviation of CCC for each of the businesses interviewed in Uganda. Since we do not have standard deviation data for the US market, our analysis for this section is non-comparative. There are clear clusters of profitability by supply chain node, with wholesalers averaging 20-30% profit margins, distributors averaging 5-10% profit margins, and retailers exhibiting mostly negative profitability.

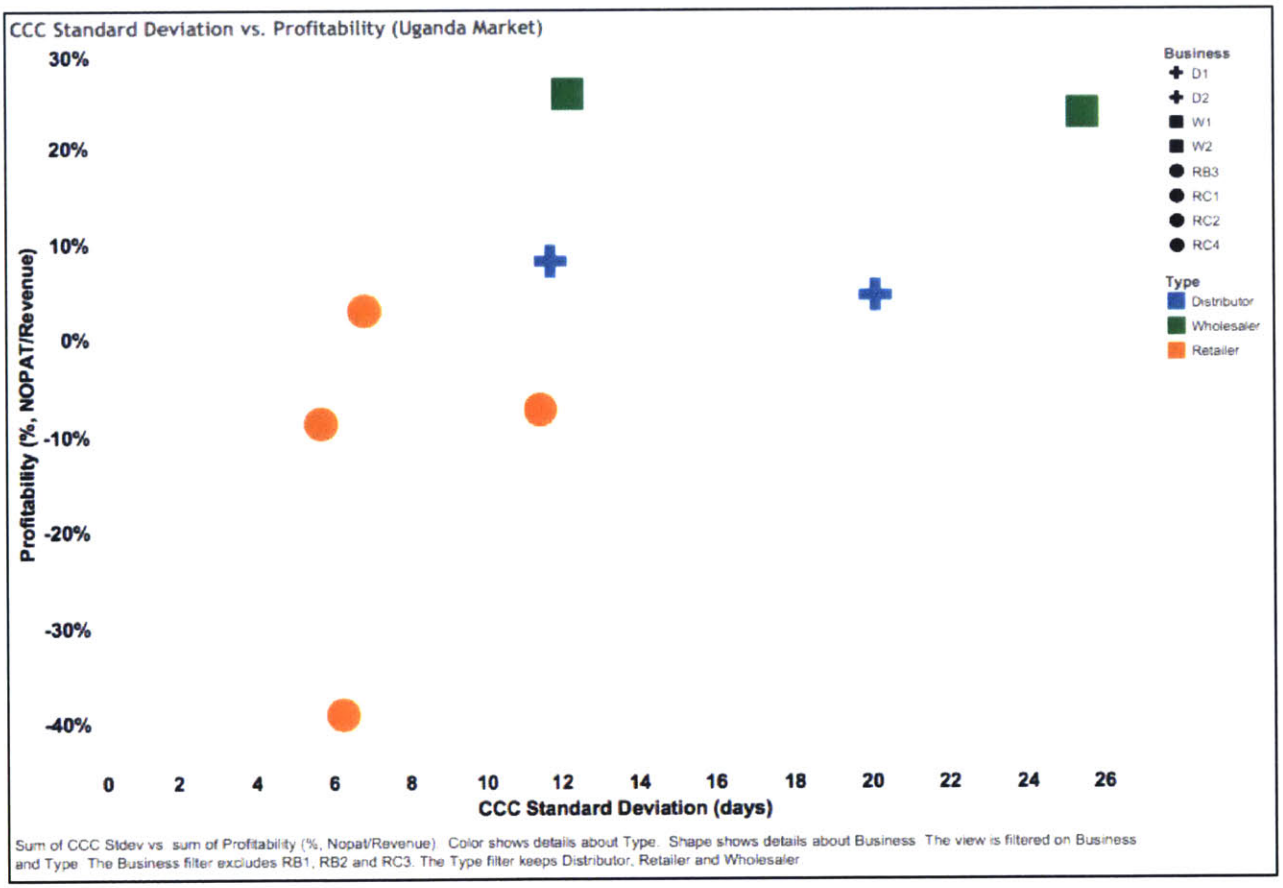


Figure 17. CCC Standard Deviation vs. Profitability (Uganda Market)

A key observation here is that wholesalers exhibit the greatest variation in CCC, while maintaining the highest average profitability. Distributors follow with slightly less variation in CCC and lower average profitability. Retailers exhibit a very small variation in CCC with negative profitability on average. Overall, the data suggest interesting trends and insights about the need for and the use of cash at different levels in the pharmaceutical supply chain.

On-Shelf Availability: A Proposed Framework for Operations Disruptions

Although our interviews suggest that operational disruptions were more pronounced in the lower echelons of the pharmaceutical supply chain, a commonly reported disruption throughout the entire supply chain was product stockout. Distributors commented that, although infrequent, a majority of disruptions were caused by lack of supply from manufacturers. Wholesalers and retailers commented that product stockout was predominantly caused by unexpected market demand.

Without further research into the business models of the interviewees, it is hard to assess whether the stockouts are a result of high-frequency/low-impact events (common cause variation) or low-frequency/high-impact events (special cause variation). Given that stockouts can be a symptom of either type of event it is critical to conduct further research to understand the true cause of stockouts. The data suggest that, at a minimum, analyzing the specific stockout frequencies and root causes for each business provides a basis for guiding decisions regarding investment allocation to improve operation performance.

Modeling and Mapping Access to Medicine and Access to Finance

We used ArcGIS and Tableau software to map and visualize geographic accessibility to medicine and financial services in Uganda. For access to medicine, we used both software packages. We found publicly available population data from the 2014 census through Uganda's National Bureau of Statistics on Open Data Uganda, and combined it with a list of registered pharmacies from the Uganda National Drug Authority (Data.Ug, 2015; Uganda NDA, 2014). The NDA pharmacy data contained address, city, and district, but none of it was geocoded. Therefore, we joined the raw pharmacy list with the publicly available, geocoded district-level population data set for Uganda. We aligned the pharmacies with district coordinates and the associated polygons of each district. This enabled us to plot people per pharmacy with color gradients on a map in ArcGIS (see Figure 18). The map indicates a severe shortage in registered pharmacies in the southwest, central, and northeast regions. The dearth of registered pharmacies in those areas may indicate a lack in geographic accessibility to quality medicine.

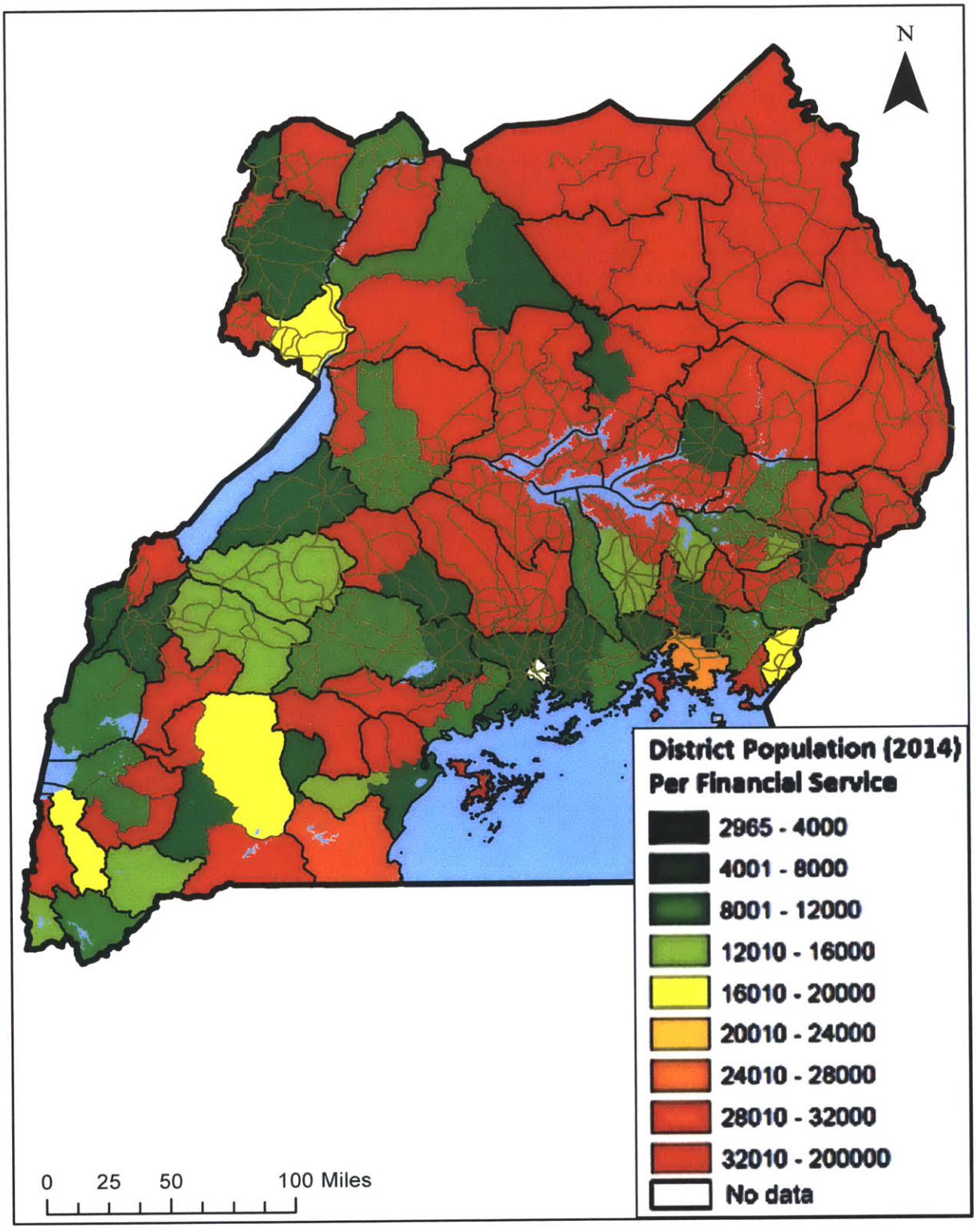


Figure 18. People Per Pharmacy by District in Uganda

We also used Tableau to plot pharmacy density. Figure 19 shows a scatter plot of population versus people-per-pharmacy in each district, with each of the four regions (central, east, north, and west) having a unique color and shape. Districts in the upper portion of the graph have more people per pharmacy, or fewer registered pharmacies per capita. These districts have less access to registered pharmacies, and potentially have less geographic access to medicine. Appendix E contains additional data plots disaggregated by region to complement Figure 19.

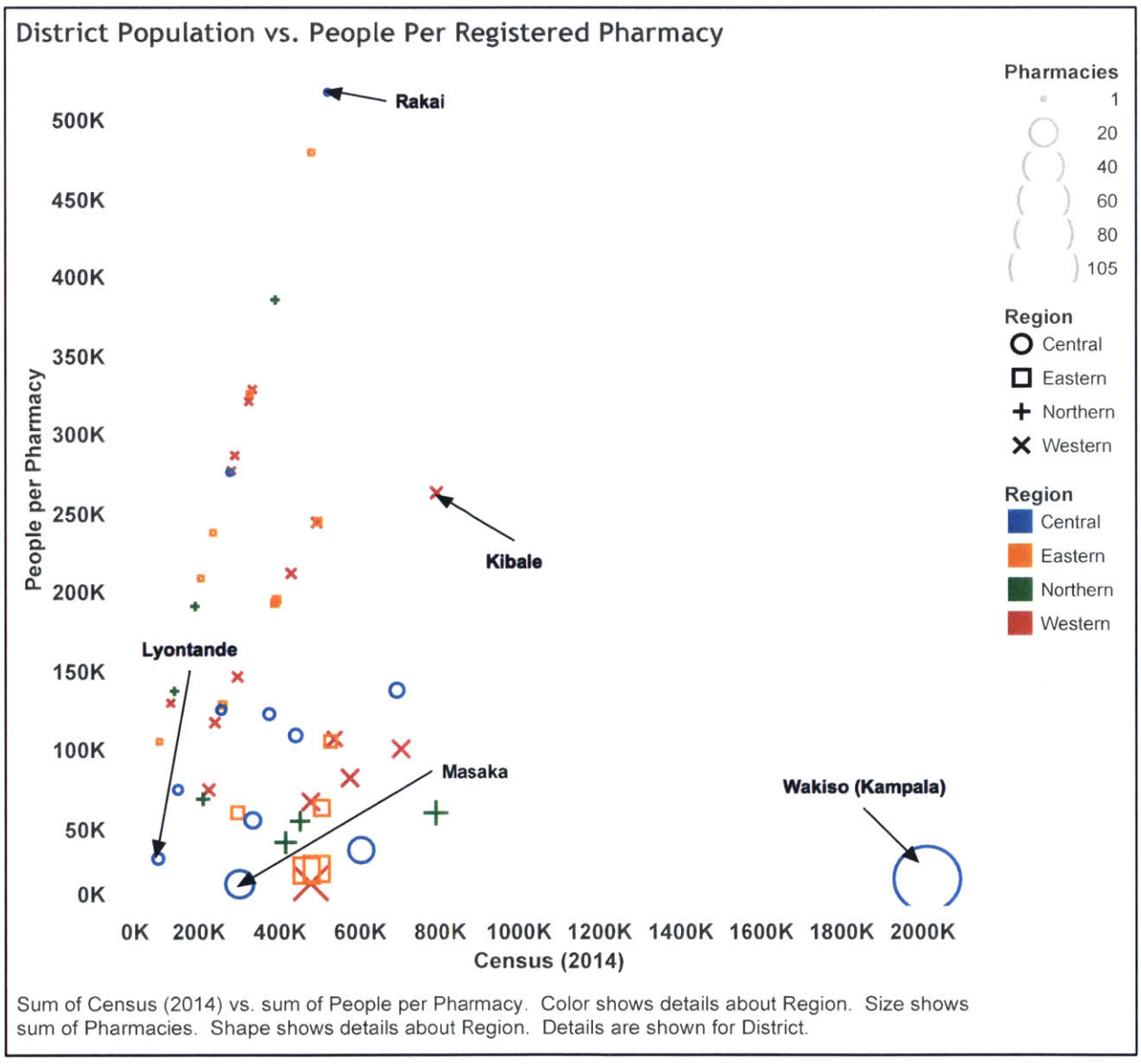


Figure 19. Population versus People Per Pharmacy Across Districts in Uganda

For geographic access to financial services, we downloaded financial services data from Finclusion.org, a website with aggregated data from the 2011 Registry for SACCOs and the 2011

AMFIU directory. Appendix F contains more information on data sources. Figure 20 depicts geographic access to financial services throughout Uganda. Green colors indicate better access to financial services, while yellow, orange and red indicate less access to financial services. A key takeaway is the clear need for deeper penetration of financial services in the northeast districts of Uganda.

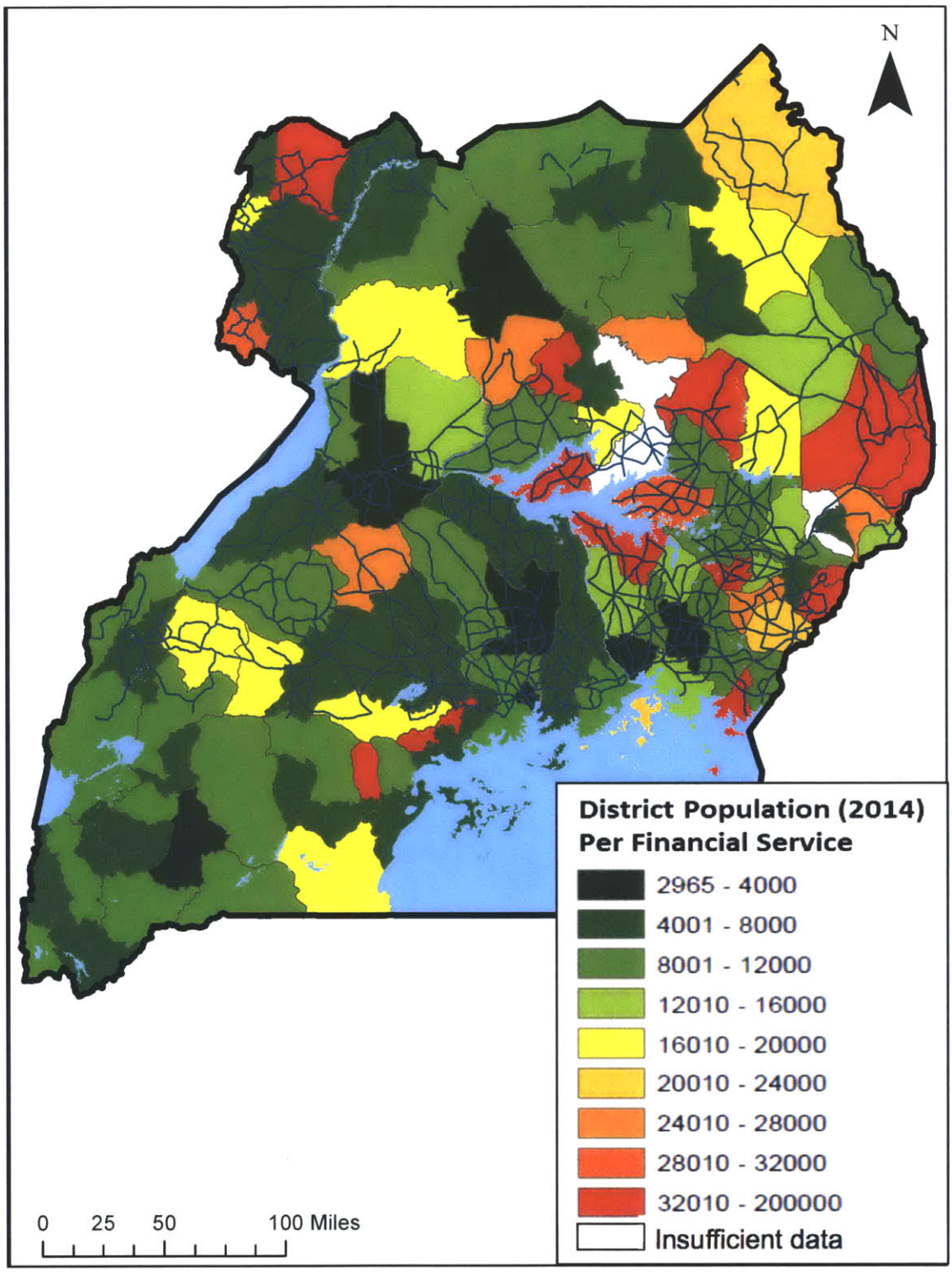


Figure 20. Ratio of Total Population to Financial Services By District in Uganda

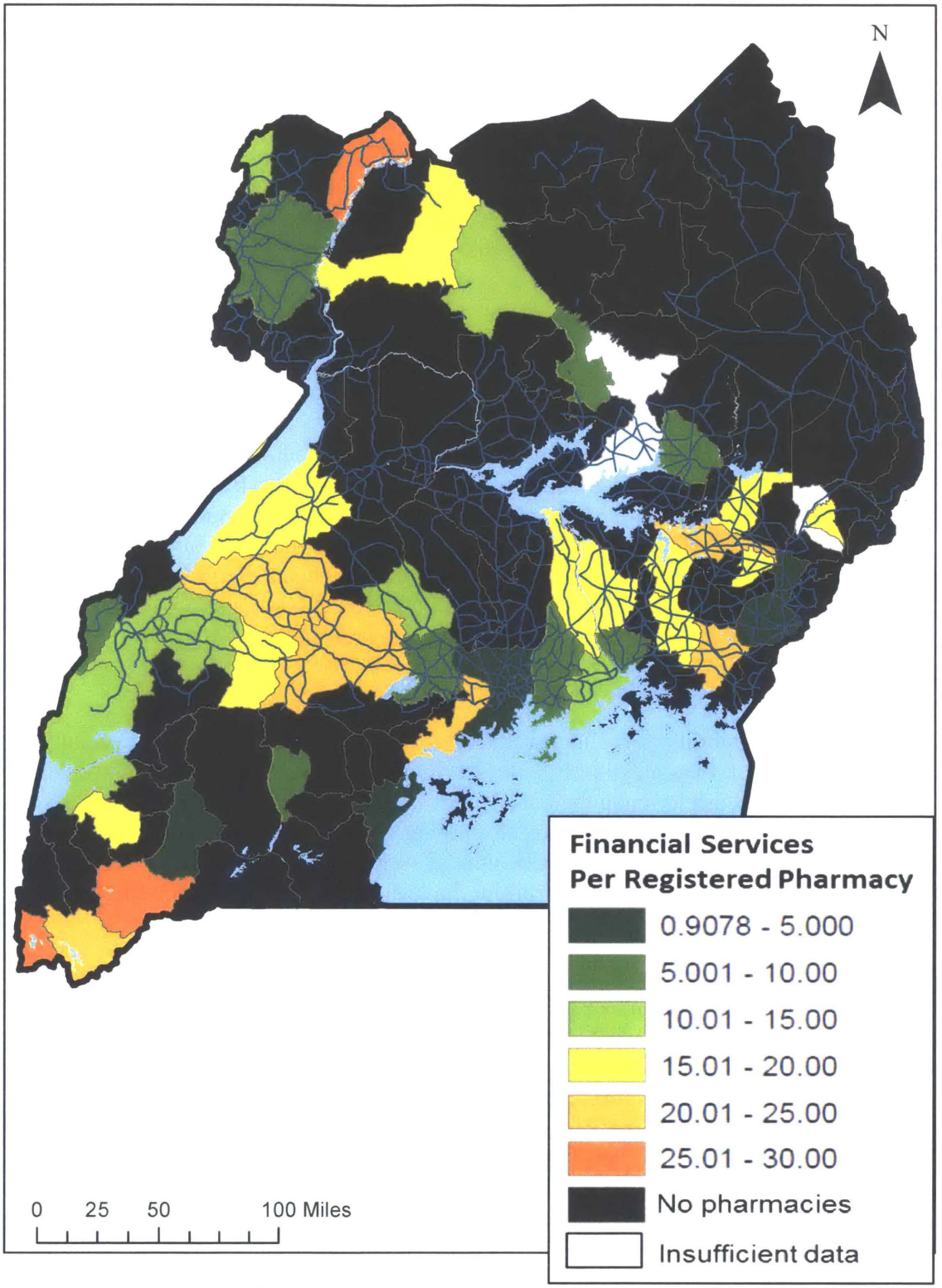


Figure 21. Financial Services Providers Per Registered Pharmacy By District in Uganda

Figure 21 depicts the relationship between financial services providers (SACCOs, commercial banks, microfinance institutions and other financial institutions) and the number of registered pharmacies in each district of Uganda. We did not include mobile money agents and ATMs because they are not sources of loans. It is clear from Figure 21 that several districts exhibit a strong presence of financial services providers, with very few registered pharmacies colored in yellow and orange. These districts could be ideal locations to finance additional start-up retail pharmacies, given the prevalence of financial services providers relative to registered pharmacies. Districts without any registered pharmacies colored in black may also be good for start-up retail pharmacies, especially in northeast Uganda where Figure 20 indicates the presence of financial services.

Discussion

Our analyses looked at three components of access to medicine. First, we analyzed the relationship between average CCC and profitability for primary data from businesses at different levels in the Ugandan pharmaceutical supply chain. Second, we explored a framework for how to best allocate financing to address the operational disruptions like stockouts. Finally, we used GIS to plot density of registered pharmacies and density of financial services in each district of Uganda. The following section discusses crosscutting trends, proposes hypotheses and theories to aid future research goals, and offers context into certain challenges we faced in our analyses.

Payment Affordability: Field Data & Financial Analysis

The CCC-Profitability data suggest that retailers have the best cash position but are least profitable. The problem then may not lie with having cash on hand, but rather in knowing how or where to invest that cash to make their business more profitable (or even just to break even). Yadav et al. proposed that inventory management training be integrated with financing mechanisms, and as we observed a lack of technical supply chain skills among our interviewees, we agree that business and supply chain training have significant potential for catalyzing improvement in operations.

Based on our research and understanding of how to categorize operational disruptions, and the integral role that inventory places in the cash position, the crux may lie in matching an appropriate type of financing mechanism for the type of disruption. If stockouts are categorized as high-frequency, low-impact, then supply chain training may help businesses extend better payment terms to customers, carry more inventory, forecast variability in demand, and grow sales and profitability. In this case, financing may be needed at the wholesaler level so retailers can benefit from wholesalers' 'onward lending' via trade credit. The wholesalers' financing would need to be contingent on extending better trade credit to their retailer customers. On the other hand, if stockouts are low-frequency, high-impact, as was the case with W2, suffering large stockouts from cross-border traders, perhaps a loan for the retailer is needed to quickly overcome the larger disruption.

Based in Amsterdam, PharmAccess is a foundation that oversees two non-profit organizations Medical Credit Fund (www.medicalcreditfund.org) and SafeCare (www.safe-

care.org). Together, the PharmAccess Group has been developing a model to provide training and financing in tandem to health clinics, and they have been working in several countries in Sub-Saharan Africa. To date they are only beginning to adapt the model to pharmacies, but evaluations of their current pilot work may complement this research well.

The lack of accurate supply chain data at lower echelons in the pharmaceutical sector in Africa is a barrier to doing rigorous statistical analysis and to the optimality of supply chain decisions in Uganda. The development of mobile, SMS-based systems for supply chain management and simple ordering functions could produce a wealth of data to guide further efforts to improve access to medicine. It may also make payments for goods and streamline the implementation of trade credit throughout the supply chain to the end patients. This kind of system may help retailers and wholesalers anticipate cross-border traders such that the cross-border traders could place advanced orders prior to showing up and clearing out the inventory.

Since mobile solutions may not be an immediate solution to the dearth of data, there may be opportunities to leverage existing data found in the prescription software used by many class A and B pharmacies. This data could be (1) used to model and predict the demand, which could perhaps even be integrated in the inventory management training recommendation, and (2) build credit scores for retail pharmacies. This would likely require extensive training to help pharmacy owners learn and implement forecasting techniques.

First, the analysis suggests that the high prioritization by retailers in Uganda of having a good cash position might be inhibiting their profitability. They may need to carry more inventory (higher DIO) and extend more credit to their customers to increase sales (DSO). The analysis also suggests that distributors have a less favorable cash position (larger CCC), but remain profitable. Finally, wholesalers in Uganda might be most adept at optimizing cash flow to achieve higher profitability, and distributors.

Regarding the methodology, we found the triangular and PERT distributions to be useful for estimating probability of trade credit terms and inventory levels. The Monte Carlo simulation allowed us to easily combine multiple PERT distributions to produce a more accurate cash conversion cycle distribution. Using a single distribution to approximate cash flow for each business was useful for studying correlations with the descriptive statistics of those distributions.

We learned that a thorough understanding of the PERT distribution and its limitations is imperative before designing and executing the field research. We found that a targeted and simpler survey questionnaire might produce cleaner data for the distribution parameters and prevent missing parameters that spoil the sample and necessitate after-the-fact estimations.

On-Shelf Availability: Categorizing Operational Disruptions

Ensuring on-shelf availability is a critical component of ensuring access to medicine more broadly. Understanding the nature of operational disruptions within pharmaceutical supply chains in Uganda is critical to taking the correct preventative measures and responding effectively. Our research revealed a lack of research in this niche subject will continue to add complexity for businesses looking to expand into the Ugandan pharmaceuticals market. We have

proposed a Six Sigma approach to categorize operational disruptions in the pharmaceuticals industry in Uganda.

We hypothesize that the use of this framework may offer two benefits. First, a Six Sigma framework will allow for a better design of future survey questions. Understanding the true nature of operational disruptions may allow future researchers to ask more targeted questions that (1) yield data that can easily fit a PERT or Triangle distribution, and (2) offer deeper insights into the core challenges faced by businesses within different nodes of the supply chain. Second, a Six Sigma framework will inform pharmaceutical companies how to most effectively invest their capital. For instance, utilization of this framework might reveal that investing in educational seminars, or retail networks for consolidated purchasing, might influence patient access to medicine more than providing additional capital to businesses in the supply chain. Categorizing operational disruptions using a Six Sigma framework may elucidate the core challenges of patient access to medicine in Uganda.

Geographic Accessibility: Leveraging Data Visualization Software

Understanding geographic accessibility can increase by using data visualization and GIS software. The software results provide a visual basis for geographic regions in need of registered pharmacies and financial services. This information informs funding allocation and geographic expansion strategies in both sectors.

The insights gained, however, are only as good as the granularity of the underlying data. To lay the foundation for more in-depth analysis in the future, PharmCo should begin collecting and centralizing geo-coded pharmacy data for its own use, and sharing that data in support of the broader pursuit of access to medicine.

Opportunities for Future Research

Our research scratches the surface on a number of challenges, and there are many opportunities to go deeper in research, data collection, and analysis.

Collecting a larger data set on key financial measures will allow for more rigorous statistical analysis of cash flow sensitivity, since smaller data samples make statistical analysis with commonly used distributions difficult. Nonetheless, the use of PERT distributions was helpful in our analysis and we recommend using it for estimating parameters where respondents do not naturally think in terms of mean, variance and long-tail probabilities.

Analyzing payment affordability would also benefit from an in-depth case study of the various supply chain nodes. Further interviews with key retailers may illuminate how certain retailers are profitable despite the average profitability across all retailer interviews being negative.

On-shelf availability could be better understood by a more rigorous analysis of the types and frequencies of operational risks and disruptions experienced at each level in the pharmaceutical supply chain. Using the framework we proposed for the categorization of various

operational disruptions in follow-up interviews could reveal a pattern in the types of operational disruptions that most businesses face.

Future research could look at causal regression analysis of profitability and CCC, taking into account potential factors such as work experience of the business owner, business education of the business owner, membership within a network of pharmacies, or other external factors. Adding regression variables or dummy variables to capture years of business education, business experience, participation in a network of pharmacies, etc., could help explain the dynamics between profitability and cash conversion cycle.

Further research into network effects of retail outlets could provide deeper insights. It would be interesting to explore the impact of network effects on financial constraints (e.g. profitability, free cash flow) for wholesalers and retailers in the private sector pharmaceutical supply chain. A case study approach in this area could reveal if network dynamics correlate to relaxed constraints in free cash flow and profitability.

Accessibility could be studied at a more granular level if the physical locations of each registered pharmacy were tagged with a geo-coded location. It is also worthwhile to use GIS software to look at the intersection of pharmacy density and the densities of various forms of formal.

Finally, a natural extension of this analysis would be to understand the relationship between patient access to medicine and *patient* access to financing. Since the majority of customers paid cash, the question remains how the customers themselves could benefit regarding better payment affordability that matches their personal cash flows.

Appendices

Appendix A – Table of Interviewed Businesses

Interview Reference No.	Name	Type	Class
1	D1	Distributor	n/a
2	D2	Distributor	n/a
3	W1	Wholesaler	n/a
4	W2	Wholesaler	n/a
5	RA1	Retailer	A
6	RA2	Retailer	A
7	RB1	Retailer	B
8	RB2	Retailer	B
9	RB3	Retailer	B
10	RC1	Retailer	B
11	RC2	Retailer	C
12	RC3	Retailer	C
13	RC4	Retailer	C
14	RD1	Retailer	D

Appendix B – Field Survey Template

Name:
Town:
Coordinates:
Date of Visit:
Visited By:
Contact Person:
Contact Number:
Licensed (Y/N):
Bank Account (Y/N):
Retail Bank:

Revenue	
Most revenue per month?	
Least revenue per month?	
Most likely per month?	
COGS	
Most paid for drugs per month?	
Least paid for drugs per month?	
Most likely per month?	
Customer/Demand	
Most customers per month?	
Least customers per month	
Most likely per month?	
Seasonality? Which months?	
Customer Payment	
Most sold on credit per week (%)?	
Least sold on credit per week (%)?	
Most common per week (%)?	
Seasonality? Which months?	
Supplier Payment	
Best payment terms to suppliers?	
Worst payment terms to suppliers?	
Most common payment terms to suppliers?	
How many total suppliers?	
Inventory	
How often do you reorder?	
What causes you to reorder?	
How much do you order?	
Do you use an inventory management system?	
Other	
Are you willing to receive loans?	
Do you plan to grow your business aggressively?	
Do you have financial records?	

Appendix C – CCC Distribution Graphs

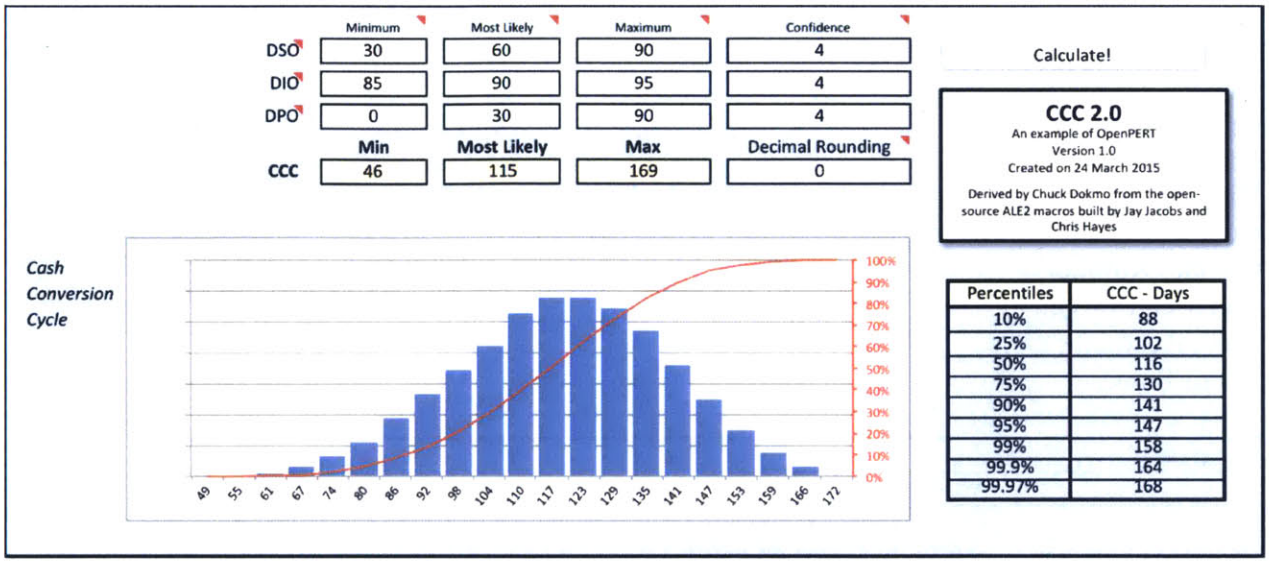


Figure 22. CCC Distribution of D1

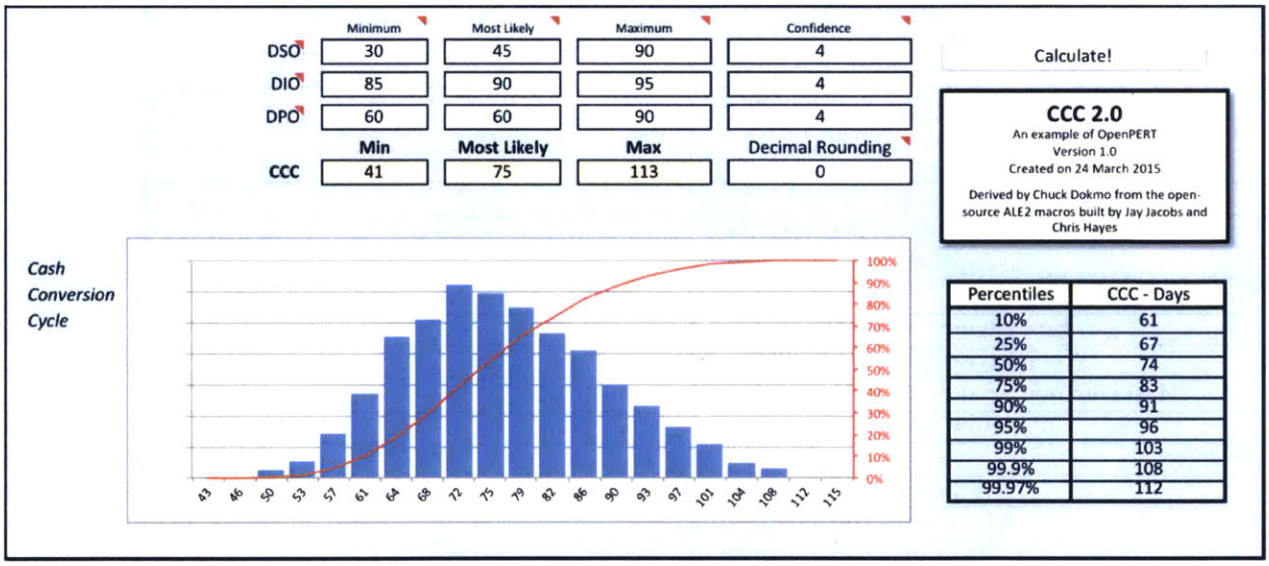


Figure 23. CCC Distribution of D2

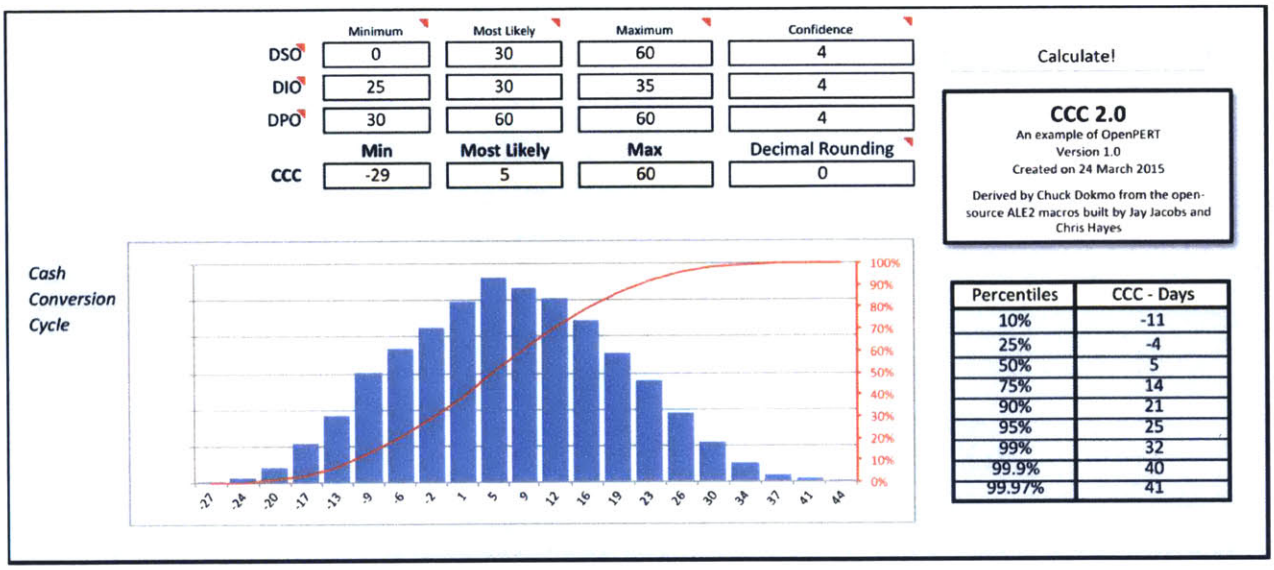


Figure 24. CCC Distribution of W1

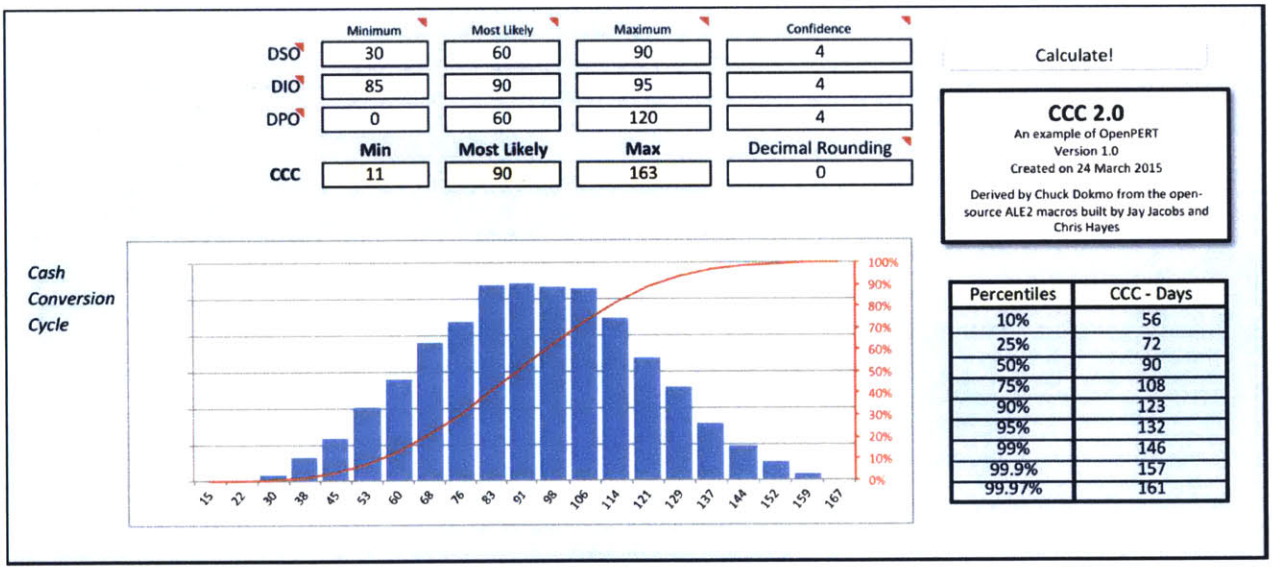


Figure 25. CCC Distribution of W2

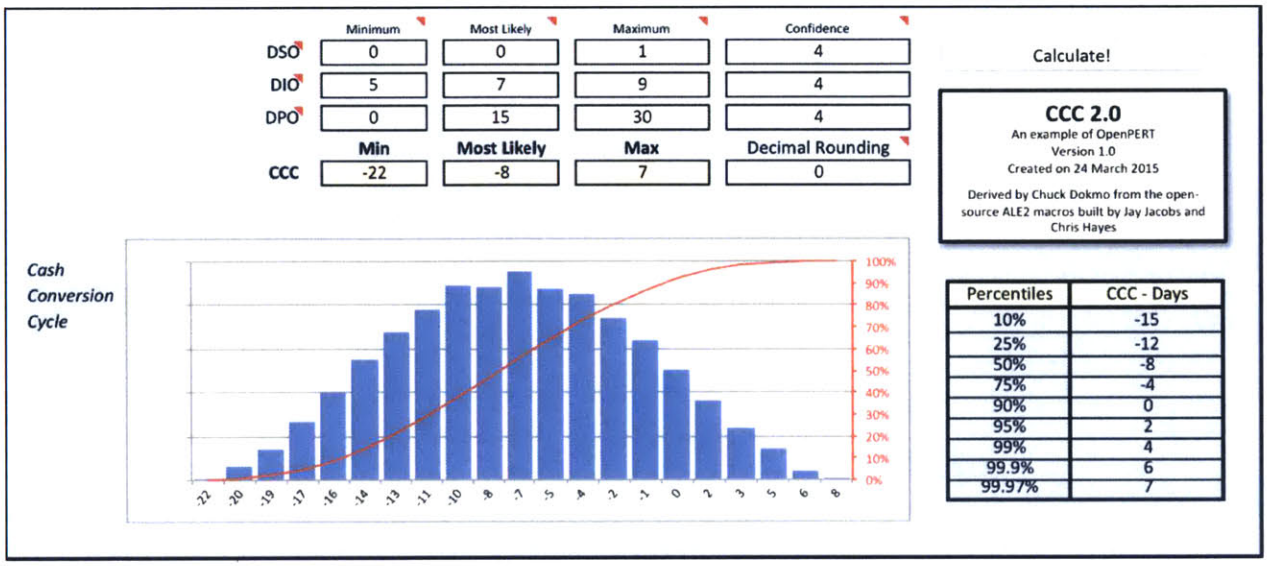


Figure 26. CCC Distribution of RB3

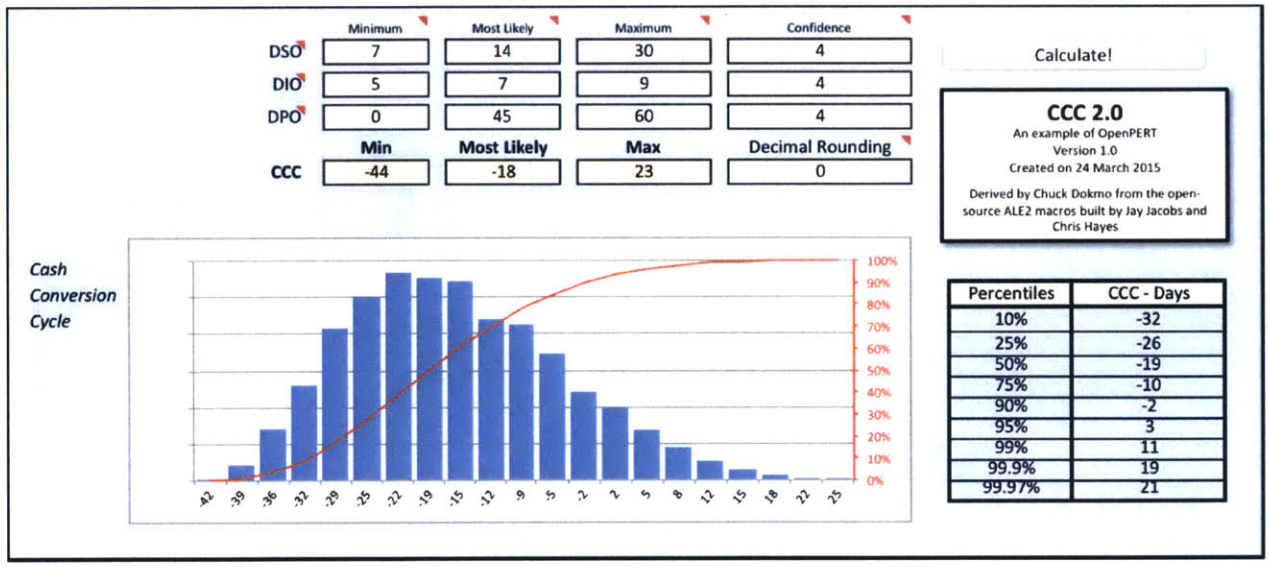


Figure 27. CCC Distribution of RC1

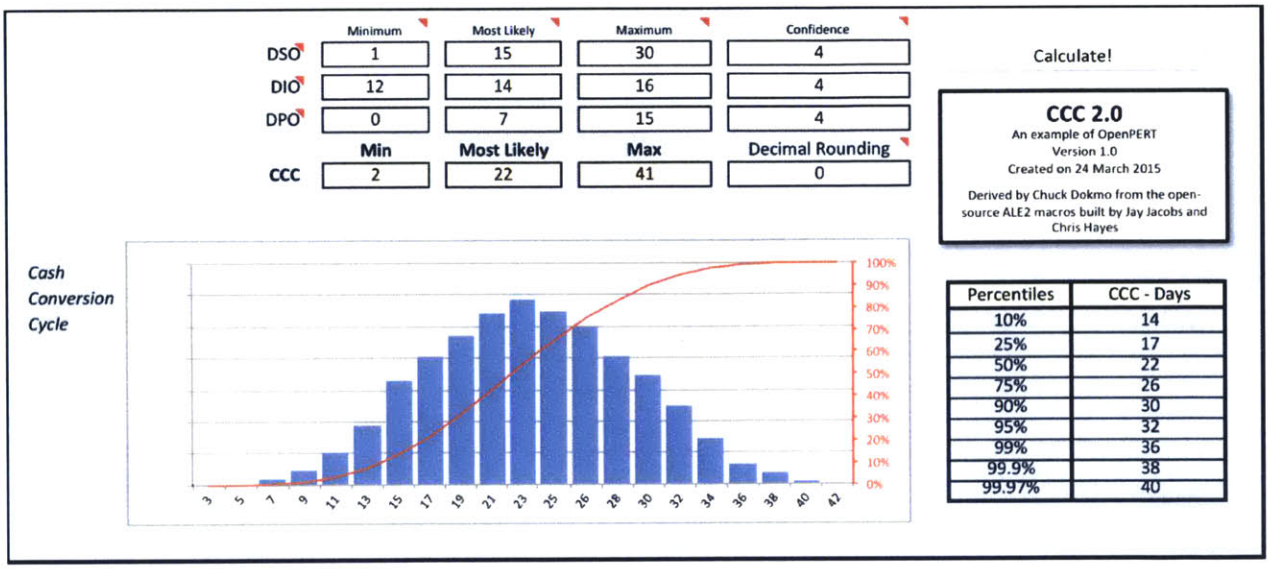


Figure 28. CCC Distribution of RC2

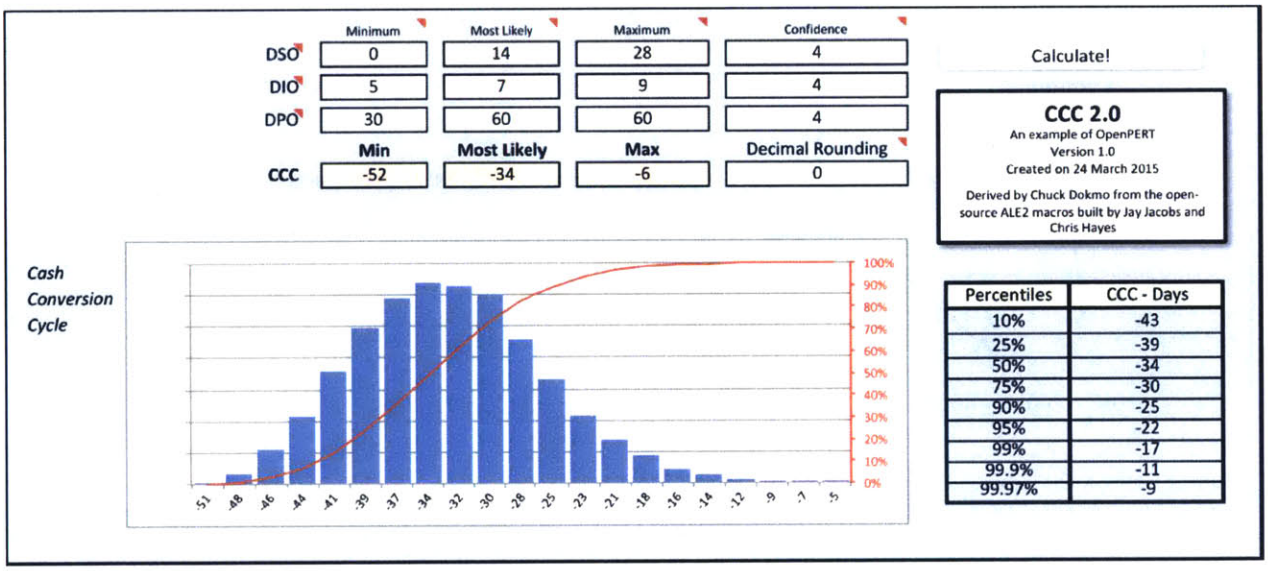
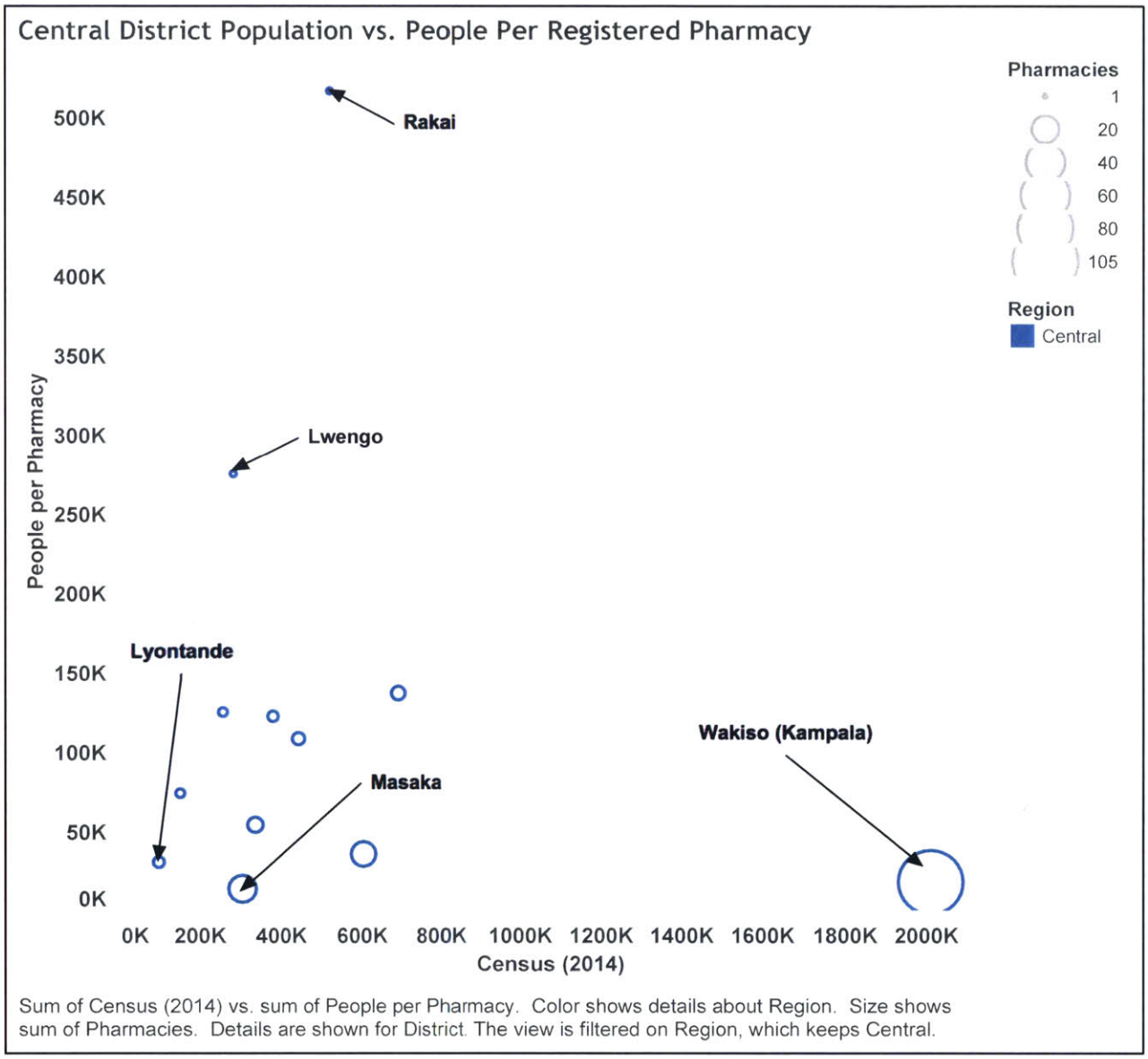
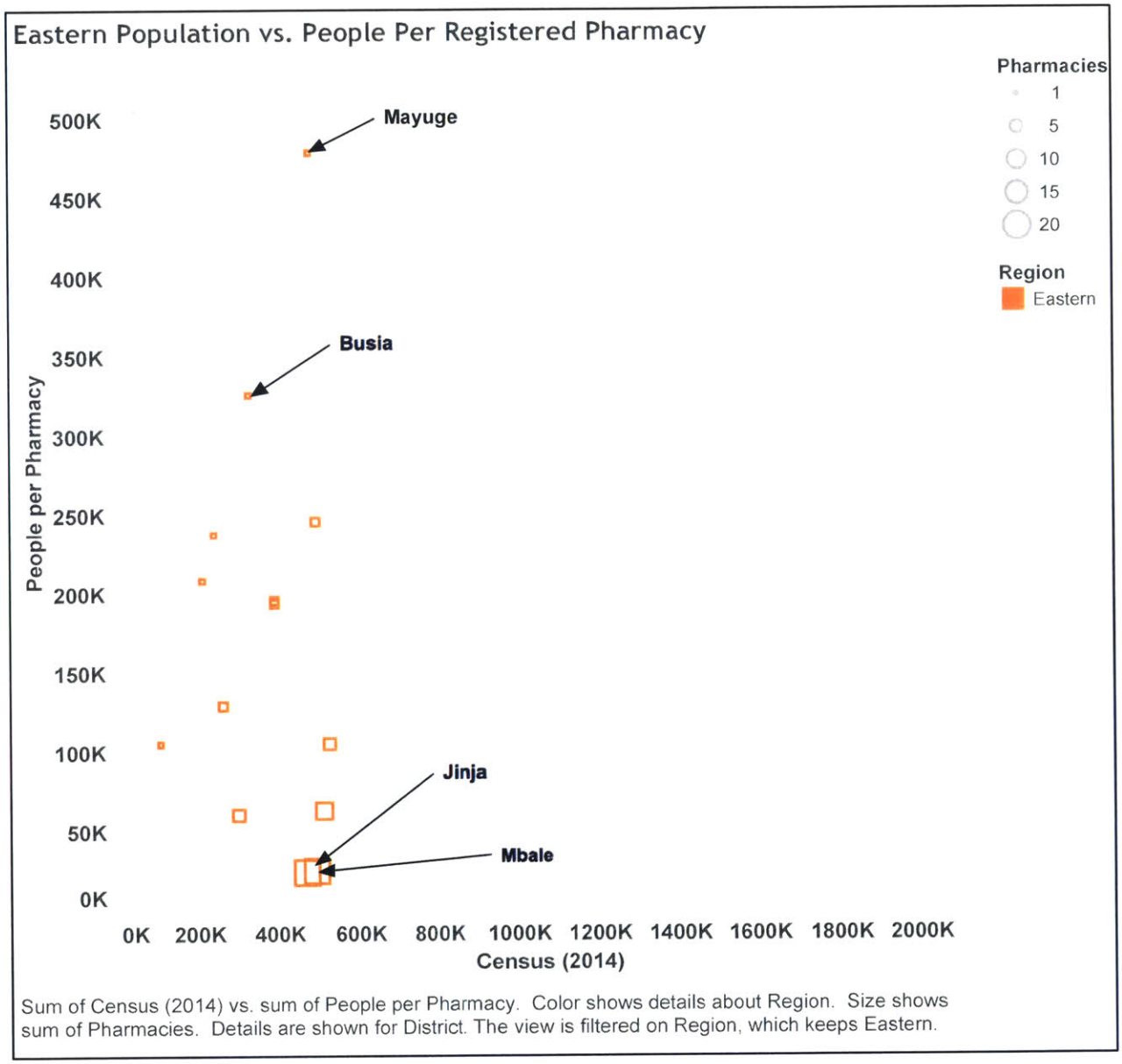
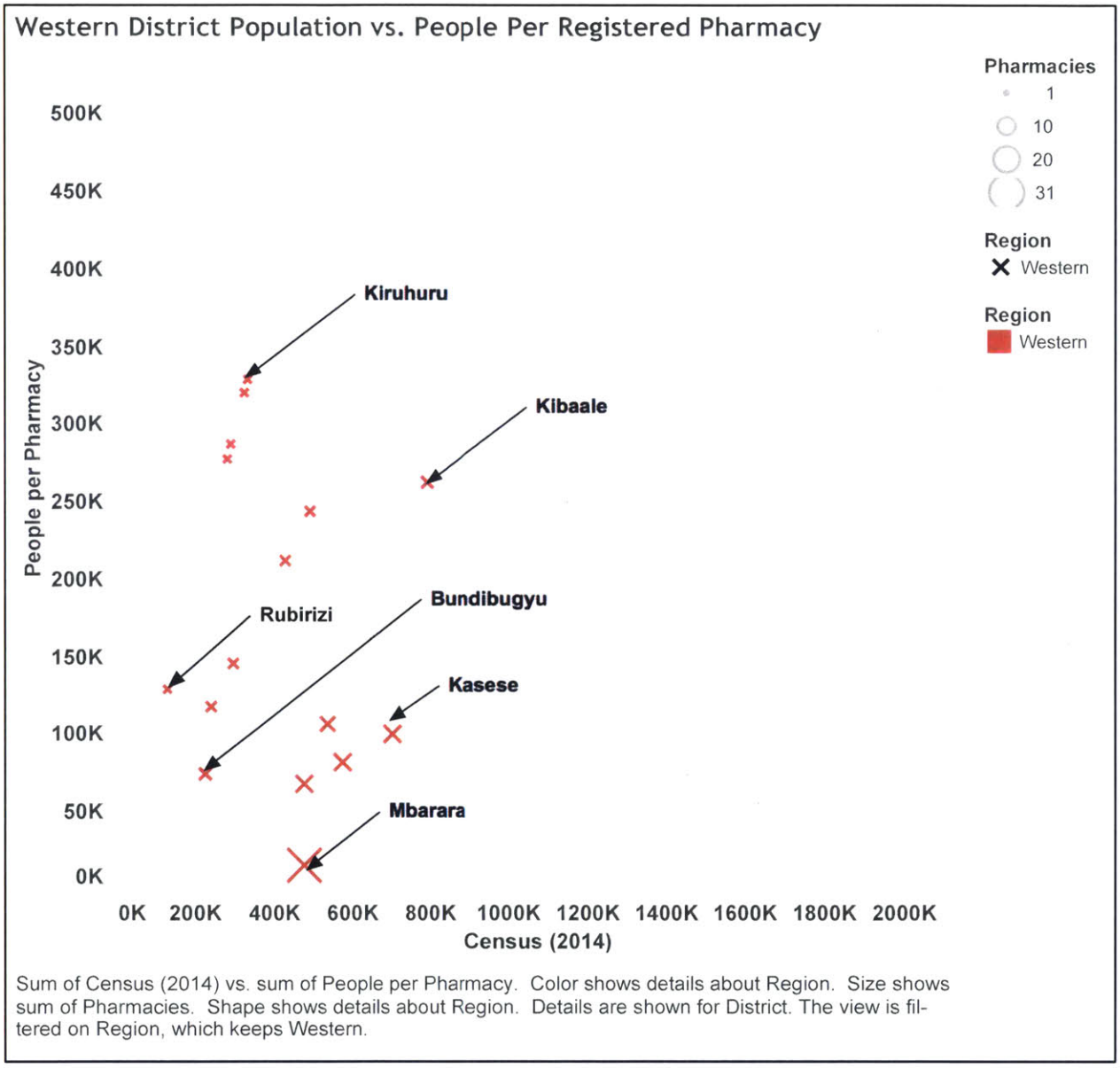


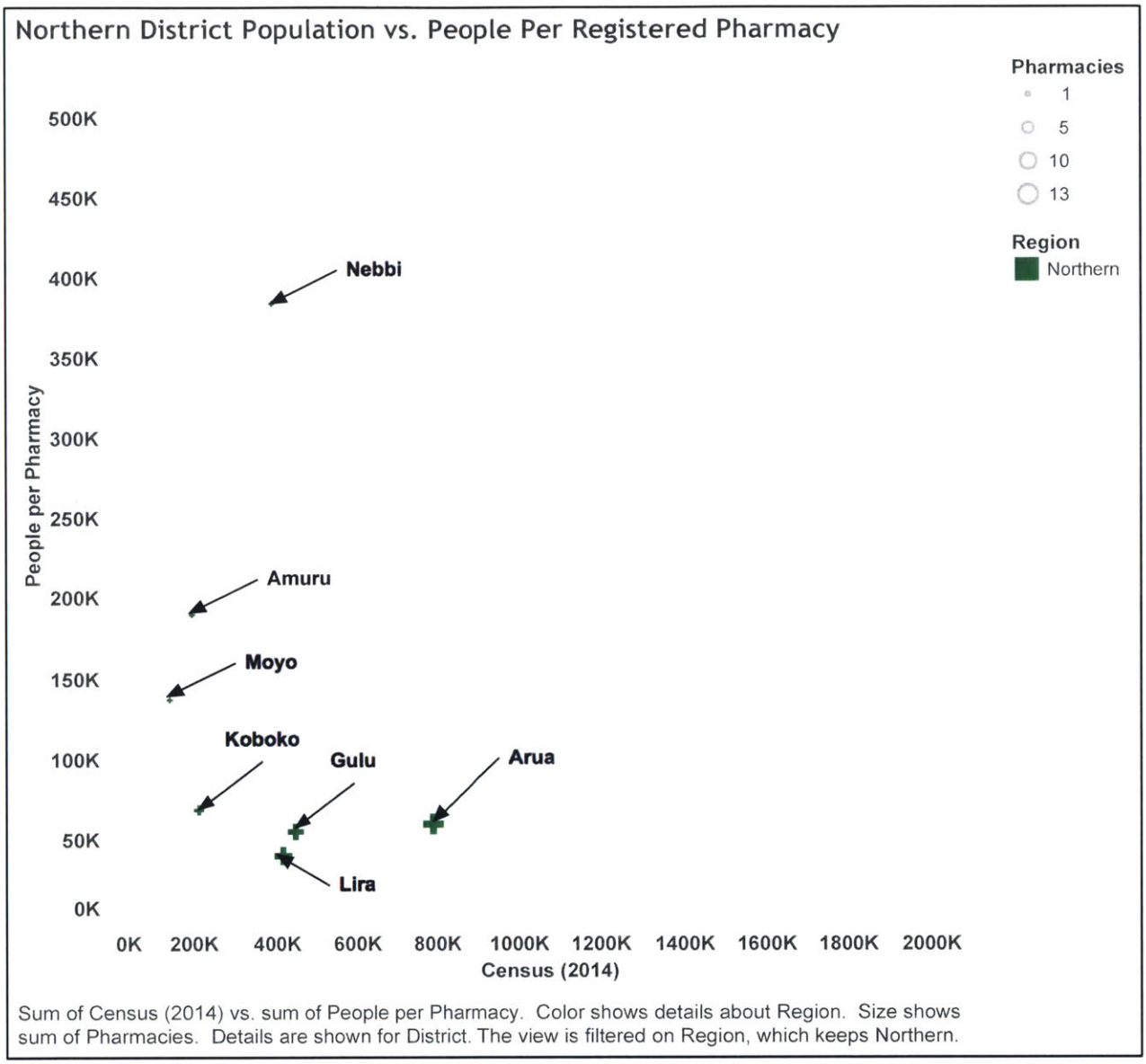
Figure 29. CCC Distribution of RC4

Appendix D – Statistical Analysis of Pharmacy Density in Uganda




Eastern Population vs. People Per Registered Pharmacy
Pharmacies
1
5
10
15
20
Region
Eastern
Mayuge
Busia
Jinja
Mbale
500K
450K
400K
350K
300K
250K
200K
150K
100K
50K
0K
People per Pharmacy
0K
200K
400K
600K
800K
1000K
1200K
1400K
1600K
1800K
2000K
Census (2014)
Sum of Census (2014) vs. sum of People per Pharmacy. Color shows details about Region. Size shows sum of Pharmacies. Details are shown for District. The view is filtered on Region, which keeps Eastern.


Western District Population vs. People Per Registered Pharmacy
Pharmacies
1
10
20
31
Region
Western
Region
Western
500K
450K
400K
350K
300K
250K
200K
150K
100K
50K
0K
People per Pharmacy
Kiruhuru
Kibaale
Bundibugyu
Rubirizi
Kasese
Mbarara
0K
200K
400K
600K
800K
1000K
1200K
1400K
1600K
1800K
2000K
Census (2014)
Sum of Census (2014) vs. sum of People per Pharmacy. Color shows details about Region. Size shows sum of Pharmacies. Shape shows details about Region. Details are shown for District. The view is filtered on Region, which keeps Western.


Northern District Population vs. People Per Registered Pharmacy
Pharmacies
1
5
10
13
Region
Northern
500K
450K
400K
350K
300K
250K
200K
150K
100K
50K
0K
People per Pharmacy
Nebbi
Amuru
Moyo
Koboko
Gulu
Arua
Lira
0K
200K
400K
600K
800K
1000K
1200K
1400K
1600K
1800K
2000K
Census (2014)
Sum of Census (2014) vs. sum of People per Pharmacy. Color shows details about Region. Size shows sum of Pharmacies. Details are shown for District. The view is filtered on Region, which keeps Northern.

Appendix E – Data Sources of Finclusion.org

- Data sources of financial services:
    - SACCO: 2011 SACCO Registry
    - Credit-only MFIs: 2011 Association of Microfinance Institutions of Uganda
    - MDIs: 2011 AMFIU Directory
    - Credit Institutions: Postbank Uganda, National Social Security Fund, AMFIU Directory
    - Commercial Banks: Respective banking branches across Uganda
    - Population Density: 'data.ug' (2014 data), 'Afripop'
    - Poverty: Spatial Trends of Poverty an Inequality in Uganda (2002-2005)
    - GRUMP: Socioeconomic Data and Economics Center at Columbia University
    - Infrastructure: 'Infrastructure Africa'
- Oversight of all data on Finclusion.org by:
    - The Uganda Ministry of Trade
    - Industry/Cooperatives (MTIC)
    - Department of Cooperative Development

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