MASTER

Distribution modeling for pharmaceutical supply chains in urban Ethiopia

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Abstract

This thesis concerns the analysis of the Ethiopian distribution system, mainly for the urban market, to study the inter-connected causes and effects that play a role in the pharmaceutical supply chain in this country. Afterwards a decision support tool containing an analytical and simulation model was built to measure the distribution systems performance, to estimate the effects of changes in the set-up for and to select the best performing design for the company.

Executive summary

Medicines are crucial for the well-being and prosperity of populations, consequently governments, companies, and NGOs alike seek to make them widely available, no matter the country or region. This, however, is still far away from reality in the developing world as there is a huge part of the population living in these countries that doesn't have access or can't afford the medicines they require. One of the main reasons is the lack of a proper distribution system, where there are several challenges specific to these regions that are not found in developed markets.

Nowadays perhaps Sub-Saharan Africa is the region that calls for a proper distribution of medicines most urgently, because despite having the highest burden from disease on a per capita basis, and some of the lowest average incomes, it has some of the highest branded drug prices and the lowest availability of medicines in the world (Cameron et al, 2011).

Ethiopia is the country selected for this thesis because it presents unique challenges for medicine distribution and has proper profit incentive for drug manufactures. Also as it is the most populated landlocked country in the world and the second most populated country in the African continent; it boasts a rapidly growing economy with a highly regulated government structure; and, it has a large rural population that is increasingly becoming urban. Learnings from Ethiopia could be used as a point of reference for comparison with other countries in the region, keeping in mind the variation of market characteristics from country to country.

To comprehend the distribution set-up in the country, the inter-connected causes and effects that play a role in the pharmaceutical supply chain are studied; where analysis of the relevant stakeholders, local population characteristics, income distributions, and other factors involved in the distribution were pertinent to the research. The current situation of the distribution set-up in Ethiopia for the company is revised and described. The analysis is divided into the three different sectors found in the country: public, private and donor sectors.

The data analysis performed afterwards concerns demand, leadtime and coverage estimations. For the demand estimation the relevant criteria on how to calculate the company's forecast is reviewed, as well as how to estimate the overall medicine requirement for the urban population of the country. In the subsequent part it is explained what the leadtime consists of and how it was calculated. And the current coverage of the company is approximated for the selected products for this thesis, the expected coverage for the future is also estimated considering the forecast results.

A simulation is built for the distribution to study the performance of the current system; to quantify the effects of changing the distribution set-up under varying sets of circumstances; and to provide performance estimations that will allow the company to design an efficient distribution system that satisfies customer demand, minimizes overall costs and has a high service level. Scenarios for different set-ups and cases, like value-added operations and logistics postponement, are simulated to measure how the each variable impacts the distribution system's performance and decide which specific settings work best for the intended strategy of the company.

It was found, in the approximated as-is situation, that the company had a 70% service level for a product *x* and a 59% service level for a product *z*, for the chain pharmacies with the highest sales in Addis Ababa in the private sector. When utilizing the optimal base-stock levels recommended in the simulation model, service levels of 98% and 97% could be achieved for products *x* and *z* respectively. A reduction of 94% for *x* and of 93% for *z* in terms of stockouts would be achieved by applying the recommended base-stock levels.

Afterwards the scenarios are compared in terms of expected costs, expected profit and service level in the evaluation and comparison of scenarios to rate and select which set-up works best under which circumstances. It was found that a substantial improvement for distributing into Ethiopia would be to locate the latter parts of the value-chain operations in the country. In the evaluation of scenarios it is shown that the distribution costs increase for the company but the profit on average increases by 56%, while the service level nears 100% as the response time is significantly shorter for delivering the products to the customers. This set-up is best when locating value-chain adding operations for high priced products with lower demand volume as it was seen with product *x*, which had the best results for this scenario (only increasing 4% in distribution costs but increasing profit by 77%). For the local production scenario in terms of distribution costs it was found that there would be on average a reduction of 58% and the price of medicines for the final customer could be lowered by 37%.

A sensitivity analysis was performed to evaluate the system behavior relative to changes in the system parameters. Therefore it is verified how sensible the outputs of the simulation model are, i.e. total costs, profit, backorders, inventory levels and service levels, when changes occur in the main decision variables, i.e. base-stock levels, and in the given inputs, i.e. holding, transport and backordering costs, and lead times.

Finally the improvement recommendations are given in relation to the current set-up of the company and the expected evolution of Ethiopia's pharmaceutical market: using the decision support tool to set optimum base-stock levels; moving a percentage of value-chain adding operations to the country or having local production; having better communication and collaboration with customers; reducing the number of 'middle men' along the distribution process; identifying the key distributors for urban and rural areas; further focus sales force teams and segment marketing; leadtime reduction; and, manage key relationships accordingly.

Preface

To begin with I would like to address a main concern when carrying out any type of research: there's never enough data and there never will be. Which means of course that an absolutely clear understanding of anything is impossible, only an approach to an understanding, an approximation to an actual understanding. We must make the best use of whatever there's available within a limited timeframe as there's a huge wide of possibilities in what to look for and what can be done, so you can easily lose yourself if you're not careful enough.

And now moving on to the acknowledgments, which to a few master students may come as an obligation to express a few trivial and pleasant words about their supervisors, but for most of us I am sure we whole-heartily mean them and are happy extend. Firstly, I appreciate all the advice and feedback my mentor Jan Fransoo provided me with in this long process the research took; his knowledge and guidance were always comprehensive and ever so useful. Most of all I am thankful for all that he had to put up with me and all his effort in helping me achieve a seemingly unattainable goal at times. Secondly, I would like to thank Karel van Donselaar for his respected assistance and recommendations for my work. Thirdly, I am thankful for all the help and time Maximiliano Udenio gave me as his much valued feedback was very useful for my research. Fourthly, I thank and owe much gratitude to Marcus Kapelle for giving me this opportunity and providing me with all the necessary resources and data for me to work comfortably at the company. And lastly, I am grateful for all the support and motivation my family and friends gave me.

I could close now with a phrase about moving onto new challenges, but I shall not include such clichés or delusional optimism, at this point I am not sure what will follow next. The question may still remain in how to go on at all, not in what respect and in what condition.

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1. Introduction

Medicines are crucial for the well-being and prosperity of populations, consequently governments, companies, and NGOs alike seek to make them widely available, no matter the country or region. This, however, is still far away from reality in the developing world as there is a huge part of the population living in these countries that doesn't have access or can't afford the medicines they require. One of the main reasons is the lack of a proper distribution system, where there are several challenges specific to these regions that are not found in developed markets.

Nowadays perhaps Sub-Saharan Africa is the region that calls for a proper distribution of medicines most urgently, because despite having the highest burden from disease on a per capita basis, and some of the lowest average incomes, it has some of the highest branded drug prices and the lowest availability of medicines in the world (Cameron et al, 2011). As each country in the region presents its own set of market and environment characteristics, it is necessary to study each nation separately while still considering the region as a whole. In this thesis Ethiopia was selected for the research.

Ethiopia is studied because this country presents unique challenges for medicine distribution and has proper profit incentive for drug manufactures. It is the most populated landlocked country in the world and the second most populated country in the African continent; it boasts a rapidly growing economy with a highly regulated government structure; and, it has a large rural population that is increasingly becoming urban. Learnings from Ethiopia could be used as a point of reference for comparison with other countries in the region, keeping in mind the variation of market characteristics from country to country.

Furthermore, for this thesis it is considered that people should not only have access to basic and essential medicines, but also to a wide range of pharmaceutical products that can vary on quality, presentation and treatment length. NGOs, donors and governments have very limited budget; therefore it is not possible for them alone to supply all the range of medicines to the markets, and hence a collaboration with the private sector is necessary. Private drug manufacturers and distributors, either local or international, are better equipped to establish sustainable distribution networks to these regions as they have resources and experience. Still, drug manufacturers and distributors depend on local infrastructure and local government restrictions, and lack data on market and distribution channels characteristics of developing countries, information which NGOs could have to some extent. Therefore a joint approach where all the mentioned parties cooperate would be ideal for an effective distribution of pharmaceuticals.

2. Present day SSA and Ethiopia

2.1. Sub-Saharan Africa

Sub-Saharan Africa has some of the harshest living conditions in the world, it has had widespread natural disasters such as droughts and floods, and a high disease burden, which contribute to the inhabitants having the shortest life span expectancy in the world (Kumar et al, 2008). For example, 75% of the world's HIV/AIDS cases are found in this region, as well as 90% of the deaths caused from malaria (Ababa, 2012), although non-communicable diseases (NCDs) will become the leading cause of death by 2030 (Ababa, 2012). NCDs include cardiovascular diseases (CVD), cancer, respiratory diseases and diabetes.

The population in the region is increasing rapidly, which contributes to an increase in demand for medicines. It is estimated that by 2030, the urban population of Sub-Saharan Africa will overtake that of India in 2035 and China in 2050, with significant wealth concentration and superior indicators of human development compared to rural regions (Logendra et al., 2013).

The growth in population and the high disease burden will result likewise in an increase of pharmaceutical spending in this region as it is expected to reach US$31 billion by 2016 (Logendra et al, 2013). Specifically, the growing prevalence of chronic and non-communicable diseases in Sub-Saharan Africa is forecasted to account for 42% of total African pharmaceutical sales by 2020 (Logendra et al., 2013).

2.2. Ethiopia

With over 96 million people Ethiopia is the second-most populous country in Africa after Nigeria and the most populated landlocked country in the world (CIA, 2014). It is forecasted that the country will have more than 120 million people by 2030 with an annual population growth of more than 2% (FDRE, CRGE, 2011). The major urban area is Addis Ababa, which is the capital of the country, with about 3 million people (CIA, 2011).

Most of the population of Ethiopia still lives in rural regions as only around 17% of the population is urban, whereas 83% is rural (WHO, 2014). However, the country is experiencing one of the fastest rates of urban growth in the world at 3.57% annual rate of change (2010-15 est.) (CIA, 2014), WHO estimates that by 2050, 42% of Ethiopia's population will be urban. A quarter of the urban population lives in the capital, Addis Ababa, which is eight times larger than the second largest city, Dire Dawa. About 80% of the poor and non-poor urban populations live in slums characterized by substandard housing and a lack of basic sanitation, services, and infrastructure.

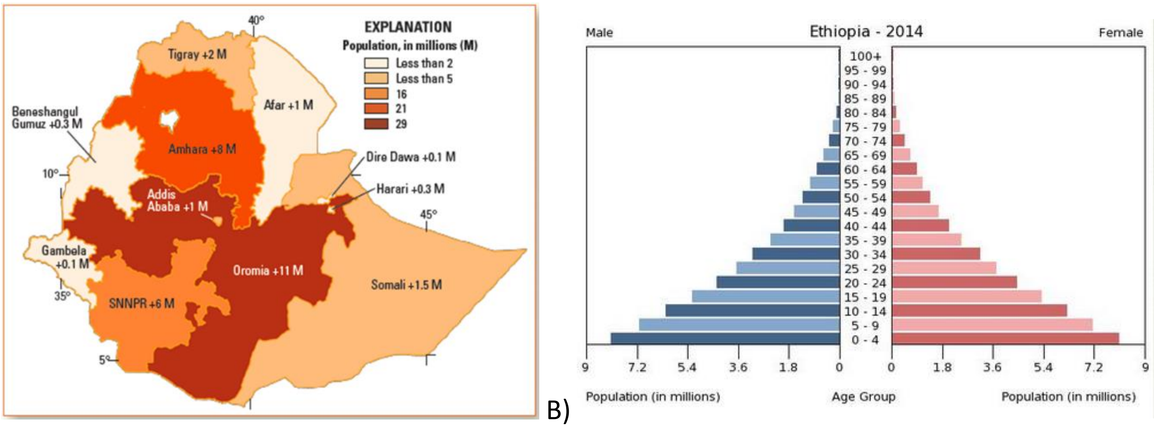
A)  B)

Figure 1. A) Ethiopia population density by region (ORNL, 2011); B) Population pyramid illustrating the age and sex structure (CIA, 2014).

The regions Oromia, SNNPR and Amhara are the most densely populated with most of the population living in rural areas (CIA, 2014) (figure 1, A). The age structure of the population is predominately young with 44% of the population under the age of 15 years and over half (52%) within the age group of 15 to 65 years (CIA, 2014) (figure 1, B). While the male-to-female sex ratio is almost equal, women in the reproductive age group constitute nearly a quarter of the population.

In terms of area Ethiopia is the tenth largest country in the continent, covering 1,104,300 km^2, and it's bordered on the north and northeast by Eritrea, on the east by Djibouti and Somalia, on the south by Kenya, and on the west and southwest by Sudan. It has a high geographical diversity as its topography shows a variety of contrasts that range from high peaks of 4,550 m above sea level to low depressions of 110 m below sea level, though more than half of the country lies above 1,500 m (CSA, ICF, 2012).

Ethiopia is classified as a low income country by the World Bank because even though the GDP growth has remained high, per capita income is among the lowest in the world, the country's GNI per capita is $470 as of 2013. Nevertheless, Ethiopia's economy has experienced strong and broad based growth over the past decade, GDP has nearly tripled since 1992, and averaging growth of 10.6% per year from 2004/05 to 2011/12, the current GDP is of 46.87 billion US dollars (World Bank, 2014). The main reasons for economic growth have been the formulation and implementation of programs and appropriate institutional arrangements, where the Government of Ethiopia has followed a market–based and agricultural led industrialization economic policy. Besides there has been progress with the expansion of the services sectors, while the manufacturing sector performance has been relatively modest. The number of policy initiatives and measures have included privatization of state enterprises and rationalization of government regulation, a process that is still ongoing, leading to private consumption having an increasingly important role in recent years.

Ethiopia's strong economic growth has also helped reduce poverty in both urban and rural areas, 38.7% of Ethiopians lived in extreme poverty in 2004-2005 and five years later this was 29.6%, which is a decrease of 9.1% (World Bank, 2014). This 29.6% of Ethiopia's population earns less than $1 per day.

Over the past two decades in the country, there has been significant progress in key human development indicators: primary school enrollments have quadrupled, child mortality has been cut in half, and the number of people with access to clean water has more than doubled (World Bank, 2014). Despite these major strides in improving the health of Ethiopia's population, the people still face high rates of death and disease; about 80% of diseases are attributable to preventable conditions that are related to personal and environmental hygiene, infectious diseases and malnutrition. Environmental risk factors alone account for 31% of the total disease burden in the country (WHO, 2013).

The degree of risk of contracting major infectious diseases is very high (CIA, 2013), where food or waterborne diseases include: bacterial and protozoal diarrhea, hepatitis A, and typhoid fever; vector borne diseases include: malaria and dengue fever; respiratory diseases include: meningococcal meningitis; animal contact disease: rabies; and water contact diseases include: schistosomiasis. For children specifically the most common causes of death are due to preventable or treatable causes such as pneumonia, diarrhea, malaria, malnutrition and HIV/AIDS. And in Ethiopia 29.2% of the children under the age of 5 years are underweight (CIA, 2011).

For the urban health picture in Ethiopia, it was noted that 51% of deaths in Addis Ababa were attributed to non-communicable diseases and 6% to injury. It was found that non-communicable diseases are the leading cause of death among adults in Addis Ababa, where the health system is still geared toward addressing communicable diseases (IMS, 2014).

The total health expenditure in Ethiopia was of 4.7% of GDP in 2011 (CIA, 2011), where Addis Ababa represents 14% of the total country's pharmaceutical expenditure (Logendra et al, 2013). Health expenditure per capita in Ethiopia is $16 (2010) as compared to around $8,000 in the US.

2.3. Defining pharmaceutical supply chains

Pharmaceutical supply chains consist of products like prescription drugs, generics, over-the-counter (OTC) products, health services, companion devices, and many other segments. Where companies use direct-to-consumer, direct-to-pharmacy, and other distribution channels, and they rely more on external partners for manufacturing, selling, and other services. Nowadays the Supply chain expenses account for nearly 25% of pharmaceutical costs and the annual spending is about $230 billion (Ebel et al., 2013).

Overall, the structure of pharmaceutical supply chains works as follows (Johnson Johnson, 2010): companies purchase raw materials for bulk synthesis of active and inactive ingredients; dosages are formulated and packaged; products flow through manufacturer, warehouses, wholesale distributors/3rd party logistics providers, retail points/ pharmacies, medical institutions, and are finally delivered to the patient; some products return to their manufacturers due to recalls and returns.

In contrast with developed nations, in Sub-Saharan Africa the supply chains are not controlled by drug manufacturers, instead they are regulated by wholesalers and importers that specialize in the rapid, reliable and secure movement of prescription medicines to hospitals and to retail pharmacies, bounded by regulation ensuring only approved channels dispense. In general, health delivery supply chains in developing regions involve a number of stakeholders, where the end consumers of these supply chains are the local communities, families, and individuals that need care (McCoy, 2013); usually a combination of local government, international aid agencies, non-governmental organizations (NGOs), and other local operators are involved in the process.

For the Sub-Saharan African region it is estimated that the average service level of drugs at public health facilities is less than 25%, and even at private outlets, where products are often unaffordable to most of the population, availability is under 65% (Cameron et al. 2009). This compares to an average service level of 92.5% at the point of access in the EU (Macarthur, 2007).

The performance varies substantially between countries, areas, programs, delivery channels, and sub-populations, where the most noteworthy challenges include: lack of proper infrastructure; lack of proper demand information; lack of distribution traceability along the supply chain; inequitable urban concentration of retail/community; significant potential disruptions; counterfeit and corruption; nonexistent drug regulatory authorities; shortage of health care workers; severe financial constraints; lack of awareness; and, poverty. Other significant challenges for transportation specifically are: high port costs and processing fees, high dwell time for inbound containers, poor road transport services with long transit times and unreliable service quality, as well as poor clearance and transit infrastructure with low capacity and quality (Feidieker T., 2011).

Two of the most important issues regarding distribution of medicines across sub-Saharan Africa, in both private and public sectors, are data availability and medicine affordability (IMS, 2014). Firstly, at both a national and sub-national level there is a void of price, volume and demand data, thus it's very difficult to assess these factors without the necessary data to take the appropriate decisions regarding distribution models. Secondly, medicines, particularly those with higher costs, may be unaffordable for large sections of the global population; WHO states that up to 90% of the population in developing countries purchase medicines through out-of-pocket payments, which makes medicines the largest family expenditure item after food. As a result the private sector is incredibly important in the role of providing affordable medicines for the population in these countries, and why one of the Millennium Development Goals for Africa includes the target: "In cooperation with pharmaceutical companies, provide access to affordable, essential drugs in developing countries."

2.3.1. Public sector

Public distribution systems involve the delivery of drugs which utilize public or governmental infrastructure. Most low and middle-income countries publicly own and operate central medical stores (CMS) and autonomous supply agencies, which are the most common used drug supply systems (Seiter, 2010). In consequence, there is usually a complex combination of institutions that specialize in funding, manufacturing, importing, wholesaling, retailing, and other auxiliary functions that have to join forces in order for a drug to be available to end-patients, where the logistics for distribution and supply often involve substantial fixed or sunk costs.

Governments and donors commonly only purchase essential generic medicines from the WHO and national essential drug lists (EDLs). Procurement is typically done at a national level, with most of the stock being distributed through centrally located warehouses in capital cities, and with public-sector entities implementing (or overseeing) distribution. Nowadays public distribution is increasingly moving to be outsourced to private companies, for example in Ethiopia.

2.3.2. Private sector

The private sector mainly consists of distribution networks that contain a few medium to large-scale wholesalers and numerous small private wholesalers, who can be considered as intermediaries (Tetteh, 2009). Traditionally distribution partners in Africa do more than just deliveries as they also handle regulatory affairs, sales force training, marketing, compliance and pharmaco-vigilance for their multinational partner (Rosen, Rickwood, 2014).

In the private retail pharmacy market the availability tends to be higher but prices are often also much higher (Cameron et al, 2011). The private pharmaceutical wholesalers are generally better at maintaining stock levels but they lack the appropriate information systems to keep track of their logistics as they mostly use older technologies or utilize paper-based records (Rosen, Rickwood, 2014).

2.3.3. Donor sector

The donor sector comprises international humanitarian organizations that aim to mitigate human suffering through relief operations and medicine distribution. These organizations are non-profit oriented, and report to three groups: donors (governments, private foundations, individuals and firms) who finance the operations and are the main funding source, beneficiaries representing demand, and the international community (Rachaniotis et al., 2013).

Humanitarian logistics differ from public and private pharmaceutical distribution because donors do not seek monetary profit maximization, and since the demand and supply are unknown and dynamic, a balance between equity and efficiency must be met (Van Wassenhove, Pedraza Martinez, 2012).

The key players in humanitarian logistics are: governments, the military, aid agencies, donors, non-governmental organizations (NGOs), and private logistics service providers. NGOs, in specific, who are significant providers of healthcare services in Africa, include actors ranging from influential and international players like CARE (a leading humanitarian organization fighting global poverty), to small and micro-organizations that develop within local communities (Cozzolino, 2012).

2.4. Ethiopia's healthcare system

The Food, Medicines and Healthcare Administration and Control Authority (FMHACA) regulates the pharmaceutical sector and sets up guidelines for registration, trials, and final production of medicines. The local and international procurement for the public health facilities is mainly done by two governmental agencies called PFSA (Pharmaceutical Fund Supply Agency) and Pharmaceutical Supply and Logistics Department (PSLD) of Federal Ministry of Health (FMOH). The PFSA and the PSLD along with private suppliers are responsible for the supply and distribution of pharmaceuticals to drug outlets in Ethiopia. PFSA can supply drugs to both Government and privately owned pharmacies. However, PSLD supplies drugs to only government owned pharmacies. The PFSA distributes drugs through its network of wholesale distribution branch offices located in different regions within Ethiopia. In addition to these two government distributors, there are private suppliers/wholesalers of drugs who distribute drugs to pharmacies and drug stores across the country

The dispensing of drugs in Ethiopia is done through general pharmacies, hospital pharmacies (special, in-patient and out-patient), drug stores and rural drug vendors and are owned by public health facilities, city council, private players and Red Cross Society. 90% of the Ethiopian drug market is financed by private sources, such as donors, households (or out-of-pocket) and NGOs making patient vulnerable to an economic crisis

What differs between the dispensing points is that for example the hospitals and health centers are required to have at least one pharmacist, while others like rural drug vendors do not. Pharmacies are obliged to be owned by pharmacists, whereas drug stores or rural drug shops can be owned by either pharmacists or pharmacy technician. Although public and private sector drug outlets and service providers are regulated by the Regional Health Bureaus and The Ethiopian Food, Health, Medicine Administration and Authority, no established standardized job descriptions or on-the-job training requirements for these providers exist.

Health care delivery is organized into a three-tier system (FMOH, 2011) (see figure 2 below). Service delivery is characterized by a Primary Health Care Unit (PHCU) comprising five satellite health posts and one health center to serve 5000 and 25,000 people respectively; a district hospital that serves 100,000 people; a general hospital that serves a million people; and a specialized hospital that serves 5 million people (WHO, 2013). The growing countrywide network of healthcare facilities has enhanced physical access to health services, particularly in respect of primary health care. Geographical coverage of public health centers is 86%, reaching most of the rural areas in the country. The rapid expansion of both profit and not for- profit private facilities accounts for about 11% of health service coverage and utilization and has enhanced public private partnerships in health (FMOH, 2011). However, at the health service delivery points, public health facilities account for about 89% of health care services in Ethiopia. While all primary health care activities, including priority national programs, are organized and integrated at the district level, challenges of this devolved system include local capacity for organization, planning and management and the service referral systems that have not developed as expected. Although Ethiopia is moving towards greater decentralization of the health care system, many aspects of hospital management, which are integral to hospital quality and efficiency, are largely still under the responsibility of government agencies at the regional and federal levels (WHO, 2013).

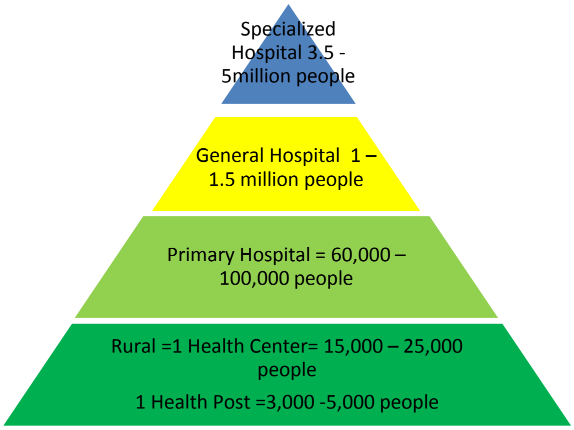


Figure 2. Ethiopia Healthcare tier system (FMOH, 2012).

The private health sector is still growing and currently being utilized by a sizeable portion of the population, but there is limited availability of drugs at private facilities, which presents significant barriers for fully utilizing the private health sector. The government of Ethiopia has committed itself to engage the private sector in order to increase access to health services an enabling environment, though this has not been fully realized. In effect, there are few clear policies or guidelines that foster real private sector involvement and ensure a private-public partnership (PPP) in health care delivery.

NGOs like USAID work in collaboration with the government through the Private Health Sector Program (PHSP) with the aim to increase demand and provision of high-quality public health services in the private sector by building sustainable PPPs. The goal of PHSP is to enable the Federal Ministry of Health (FMOH) and Regional Health Bureaus (RHBs) to effectively partner with private health providers to deliver public health services, while improving the quality and affordability of these services.

The points of sale are described as follows (WHO, 2013):

Table 1. Points of sale for drugs in Ethiopia.

Type of pharmacy	Owned by	Ran by	Type of products sold
General Pharmacy	City councils, Ethiopian Red Cross Society or private owners	Pharmacy degree graduates	Prescription and OTC drugs
Special Pharmacy	Public health care facilities	USAID/donor supported pharmacies	Prescription and OTC drugs
In-Patient Pharmacy	Public health care facilities	Pharmacy degree graduates	Prescription drugs only for the patients who are admitted in the parent healthcare facility
Out-Patient Pharmacy	Public health care facilities	Pharmacy degree graduates	Prescription and OTC drugs for patients affiliated to the parent healthcare facility's outpatient department (OPD)
Drug Store	City councils, Ethiopian Red Cross Society or private owners	Pharmacy diploma graduates	Prescription and OTC drugs
Rural Drug Vendor	City councils, Ethiopian Red Cross Society or private owners	Nurses, health assistants or pharmacy technicians	Prescription and OTC drugs

2.5. Company background

The research for this thesis took place in a well-known large multinational company that has an important health care division, where it researches, develops, manufactures and markets pharmaceutical and medical products. This division is by itself a global operating company that has over fifty thousand employees in more than a hundred countries, including developing and emerging markets, where local companies handle product distribution and are in close contact with their respective customers and local authorities. The main products sold to these markets that are considered in the thesis are prescribed pharmaceuticals and over-the-counter medicines, in addition to other products, that it manufactures and sells to and from these markets.

3. Motivation and research approach

Ethiopia, in spite of boasting a rapidly growing economy, still lacks proper distribution of medicines that result in low availability and unaffordability for the general population. As the Ethiopian government is further privatizing the health sector and creating public-private partnerships, and with multinational companies seeking to invest in the country, it is vital to understand the distribution systems in place to establish strategies for long-term growth.

3.1. First research question

Given the current state of pharmaceutical supply chains in Ethiopia it is relevant to study the distribution systems to find out how to improve access and availability of medicines. To achieve this it is essential to understand the Ethiopian market characteristics and the many inter-connected causes and effects that play a role in the distribution of medicines to overcome the particular challenges found in the country.

Therefore the first research question is:

I. What is the current pharmaceutical distribution set-up in Ethiopia and how does it work?

This research question aims to study the market characteristics in the country, to obtain relevant data to describe the current situation and to provide a clear picture on how the distribution channels and systems function. Analysis of the relevant stakeholders, local population characteristics, income distributions, markups, and other factors involved in the distribution is pertinent to the research, which will be reviewed in chapter 4. Other requirements for this questions, which help examine more closely the as-is situation for the company in Ethiopia, relate to specific data regarding leadtimes, demand and current coverage, these are specific to the company's products selected for this thesis, this analysis is found in chapter 5.

The scope and limitations for the first research question are based on the following parameters:

- Market coverage: urban market of Ethiopia (mainly Addis Ababa).

Mainly the urban market was assessed due to the local purchasing power, the company's interest, time limitations, and growing urbanization in the country. The rural market is left out of scope because it has a whole set of different characteristics that weren't fully investigated for time and resource limitations. An important issue that separates the urban market from the rural one is that reaching the population living in rural areas requires a different approach due to distance and accessibility to small towns. Income level plays an important role as well as mostly only essential medicines are distributed to rural areas and it's mainly in the public and donor sectors. Studying the urban market gives a wider breadth to the research as more stakeholders are present, the private sector is more involved, a wide variety of medicines can be distributed, and it has a higher profit incentive for pharmaceutical companies.

- Distribution channels and systems: mainly private sector, and public and donor sectors.

Mainly private sector because it is the most relevant one for the distribution in Ethiopia's urban market and for the company. This sector also has the most data available and more easily accessible. One of the problematics of including the public and donor sectors relies on the demand estimation, because the amount of medicines that will be sold through tenders is subject to the winning the bids, thus calculating the inventory levels is more difficult and not as beneficial, as after winning a tender enough time is given to supply the medicines and therefore having base-stock for these is not essential.

- Actors: stakeholders present in the distribution, i.e. multinational, distribution partners, Ethiopian government, retailers and NGOs.

The number of partners and agencies for the study was selected based on their relevance and willingness to provide data and information; there were three importers and a number of wholesalers studied. PFSA, the government entity in charge of public distribution of medicines was included in the study as well as NGOs like *Médecins Sans Frontières* (MSF) and USAID. The full list of sources from which information was obtained can be found in appendix B. Chapter 4 has the description and role of the stakeholders.

- Healthcare products: finished products that can be sold in Ethiopia.

The number of products considered for each division was evaluated, where priority was given to products with greater demand, shipped volume and with business concern for the company. For costs of distribution only finished goods were considered; costs of primary and secondary manufacturing were left out of scope. For the data analysis and simulation three cardiovascular products for the private sector were selected, products *x*, *y* and *z*, in chapter 5 the demand and leadtime for these products is estimated, and in chapter 6 the distribution is simulated using the data of these products.

- Market regulations: mainly out of scope.

Market and drug related regulations and authorities were for the most part out of scope, as it was assumed that the products used for the study can be legally sold in the selected countries and have the right characteristics such as ingredient mix and packaging. Nevertheless, interviews were done at the main regulatory entity, FMHACA, to obtain a basic understanding of the regulatory set-up in the country. Findings on this can be found in the as-situation chapter.

To obtain the necessary data, research on-site and in the company was performed. Interviews with local distributors, PFSA, pharmacists, and local experts were done in the country. From the company, forecast, sales, and shipment data were considered as well as in-company knowledge and experience. Data on-site was attained from sources like local public and private pharmacies, importers and wholesalers. For the list of sources and method employed to recover data refer to appendix B. Data recovered previously for the literature reviews and thesis proposal was also used, information for this was obtained from academic literature, practical cases and industry examples.

The first research question is reviewed in chapters 4 and 5 of this thesis; chapter 4 relates to the description and analysis of the as-is situation to present an overall state of pharmaceutical distribution in Ethiopia; and, chapter 5 has the data analysis for the demand, leadtime and coverage estimations, which contribute in illustrating the current situation of the company.

3.2. Second research question

After the current situation has been examined, an analysis should be performed to decide how to approach the distribution for the Ethiopian market, based on the findings from the first research question.

Thus the second research question is:

II. Which is the best way to set-up the distribution for urban Ethiopia to maximize profits, minimize costs, achieve high service levels, and improve coverage?

This research question relates to analyzing different design possibilities for the distribution set-up to quantify the effects of each one and find which performs best under which circumstances. The requirements for this is to first develop a tool which will allow to benchmark the current performance of the distribution system, with this it will be possible to then evaluate other designs and select the best performing one.

The scope for the second research question is limited from the scope of the first question. It is further limited in that only distribution set-ups for the private sector are reviewed, and only three products from this sector are contemplated for the analysis. Only the private sector was considered mainly because it was the primary interest of the company and there was more information available to be able to replicate the whole distribution process in the analysis.

To approach this question a tool is developed to review the performance of distribution set-ups to analyze different scenarios and select the most suitable arrangement for the company that will allow them to maximize performance, increase coverage and provide a better service to its customers in Ethiopia. Simulation is used as the tool to aid in reviewing the performance and testing different set-ups. Simulation modeling was used because it is suitable to analyze the current state of a system, its behavior over time, and the impact of any changes made to it. This modelling method was also selected because the distribution model had many variables and interacting components so it wasn't suitable for analytical methods; and because there were stochastic variables, such as demand and leadtime, for which simulation permits uncertainty and risk to be taken into account, where the model is able to reflect the randomness and interdependence present in reality in the system. For the simulation a sensitivity analysis was performed to review how the design set-ups perform under different circumstances and to compare the performance between them.

Chapters 6, 7 and 8 are pertinent to the second research question. In chapter 6 a simulation model is constructed and defined to be able to analyze different distribution set-ups; chapter 7 the different designs are compared and evaluated; and in chapter 8 changes on the parameters, conditions present in the distribution, are analyzed to see what would happen if some variables change and the resulting effects.

3.3. Third research question

Once both the first and second research questions are answered, which shed light on the current situation and ways to design an effective distribution suitable for the company in Ethiopia, then it is desirable to plan how to adapt or modify the distribution set-up for the future, based on how the Ethiopian market is evolving.

Then the third research question is:

III. How should the distribution be modified or adapted given the current and future market trends in Ethiopia?

This research question is about planning how to distribute medicines for the company based on predictions on how the Ethiopian market will evolve in various aspects e.g. economic and population growth, political changes, further privatization of the health sector, etc.

The scope for the third research question is limited by the scope for the first one, and it relies heavily on results and conclusions from the second question. Therefore the aim of the third question is to include the findings from all the chapters in this thesis.

To answer the third research question the findings from chapters 4, 7 and 8 are the most relevant. The as-is situation analysis was helpful to rate current state of the system and provide recommendations that would surely have a positive impact for the company's distribution in Ethiopia in the future. The simulation model and sensitivity analysis were useful to test the set-ups under various circumstances, and therefore is it possible to conclude how distribution designs would fair under settings that could be present in the following years. Further, when the future conditions are known in the company, the parameters can be modified and the simulation can be run again to analyze the system.

Mainly chapter 9 refers to the third research question where improvement recommendations are based on current and expected future conditions for Ethiopia. In chapter 4, the as-is situation analysis, already contains information on how the Ethiopian market has changed and how it is evolving.

4. The current state of Ethiopian pharmaceutical distribution

4.1. Overview

The as-is situation analysis concerns the study of the company's current set-up in Ethiopia and the general distribution system in the country. Firstly, it is described what the distribution process consists of. Secondly, the local infrastructure available in Ethiopia is reviewed. Thirdly, the distribution is examined independently per sector, i.e. public, private and donor, as defined in the background chapter. Data available at the company, research studies and local sources were used to define and analyze the current situation.

4.2. The distribution process

The distribution process has the end objective of delivering products at the right time and in the right quantities to satisfy the market's demand; it entails various activities along the supply chain, from demand planning to the physical delivery of medicines to the customers.

The process of planning the demand incurs building a rolling forecast for a specific timeframe into the future, usually 12 months. Demand planning is exercised in cooperation between a local sales party, the affiliate office in the region and headquarters. The local sales team in Ethiopia promotes products and collects market data from customers; the regional office serves as main contact point with customers in taking care of order management and also constructs the forecasts; and at headquarters this is all reviewed and production is scheduled. After the forecast is finished and reviewed by the relevant parties it is shared with other teams in the organization, e.g. the production planning and material procurement teams. Production is programmed with enough time to manufacture the products to cope with future demand.

Delivering pharmaceuticals to the end-customers means providing finished goods to meet and satisfy actual demand. This process, as described by IMS in figure 3, illustrates the steps included in the delivery cycle: pharmaceutical procurement, port clearing, receipt and inspection, inventory control, storage, requisition or allocation of suppliers, delivery, dispensing to patients.

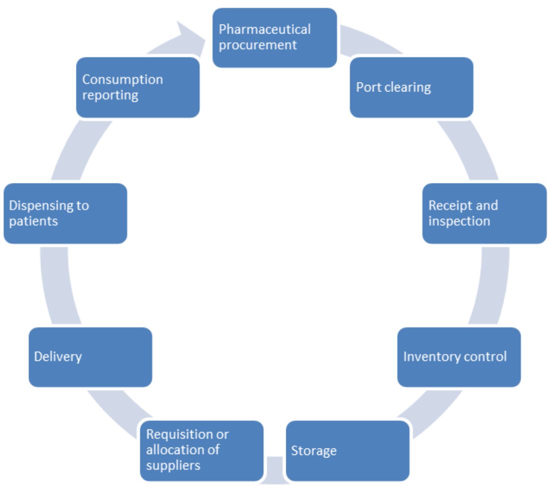


Figure 3. Distribution cycle (IMS, 2014).

The process includes receiving orders from customers and invoicing them once the desired products have been received. The delivery to customers includes warehouse replenishment and warehouse wave processing as well production supply. Warehouse replenishment means to ensure proper stocking of forward picking areas warehouse wave processing are grouping delivery line items e.g. considering material handling equipment or case/unit picking. The value added services are typically labeling, packaging for transportation or kitting. The delivery item is linked with packaging and labeling specification which contains the details for the execution of such a service.

There is export documentation and declaration that play an important role in shipping and custom clearance (Import) as well as in getting VAT refunded or applying for duty draw back. Additionally, there is an import process that requires information on the invoice as well on added documents which can be very complex, time intensive and costly, and requirements vary from country to country, i.e. Ethiopia has its own specific ones.

Transportation management encompasses management of inbound transportation and outbound transportation. In broad terms, it also consists of the management of areas such as shipment scheduling, routing, freight cost management, shipment tracking and parcel management in an optimal way.

The supply chain costs includes logistic costs (warehouse and transportation cost), and supply chain organization unit costs. Transportation cost measures the sum of all transportation costs related to a specific transportation mode, carrier (if outsourced), route, or region/district/facility during a defined period of time. The warehousing costs comprise all costs related to warehousing, such as warehouse rent, mortgage payments, utility bills, equipment, material- and Information-handling systems, etc. Supply chain organization unit cost is all costs which are linked to the SCM functions at different levels of the SCM organization, such as supply center, country, divisional and global level (OPEX e.g. personnel cost, rent, heating, travel, etc.).

4.3. Available local infrastructure

Road transport is the dominant transport system in Ethiopia, it connects urban to rural areas and the country to regional ports in neighboring countries. Since the early 1990s, there has been significant improvements in the restoration and expansion of Ethiopia’s road network, the total road network in the country has increased on average by about 4.2% each year, by June 2010 the total classified road network had increased to 36,469 km (excluding community roads) (EPA, 2012). The road density is 44.4 km per 1000 km^2 and 0.58 km per 1000 population. The roadways are mainly unpaved, out of the current total 44,359 km of roadways, only 6,064 km are paved (CIA, 2007). By 2014/15 the road network was expected to reach 136,004 km (MoFED, 2010), but the World Bank estimates that by 2015 there will be 64,500 km of road. The railway sector on the other hand is not developed, but the government of Ethiopia has a railways development program to considerably expand the network by 2015 (EPA, 2012).

Ethiopia's main airport is Bole International Airport near Addis Adaba, followed by Dire Dawa's Aba Tenna D. Yilma International Airport, and other international airports in Mekele and Bahir Dar. In total Ethiopia has 57 airports out of which only 17 are paved (CIA, 2013). As the country is landlocked it has no ports, but it mainly uses the ports of Djibouti, Djibouti and Berbera, Somalia (Malaver, 2009).

4.4. Public sector distribution

The public sector involves the distribution systems where the delivery of medicines utilizes public or governmental infrastructure. The main stakeholders in the process are the government of Ethiopia (GoE), where the public agency in charge of buying and distributing medicines is the PFSA, and the agency in charge of regulating the process is the FMHACA; NGOs and pharmaceutical companies supply the medicines to the PFSA.

The supply chain in the public sector is illustrated below in figure 4, it follows the steps and parties involved in the distribution process. It begins with the company that sends the drugs from the production plant or warehouse located in Europe, these arrive at the PFSA central warehouse in Addis Ababa, then they are shipped to the hub in the region where they are required, afterwards the drugs are sent to local hospitals or health centers and health posts, which in turn serve patients.

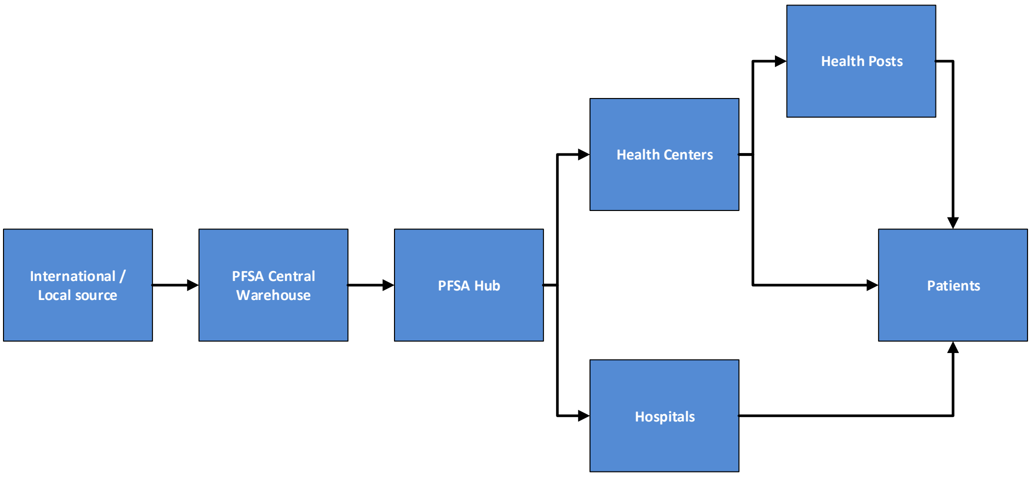


Figure 4. Public sector supply chain.

Pharmaceuticals are ordered every two months by hospitals and health centers and delivered by the PFSA to these facilities. Health posts report to health centers on a monthly basis and collect pharmaceuticals from those health centers; the health centers use the data in the Health Post report to calculate consumption and re-supply quantities. Health centers and hospitals manage their own budgets for the purchase of pharmaceuticals. Logistics information is collected and reported monthly by health posts and every other month by health centers and hospitals on logistics management information system. Table 2 contains the specific review periods and amounts of stock that should be kept at these locations; where the maximum months of stock is the largest amount of each pharmaceutical a facility should hold at any one time; the minimum months of stock is the level of stock at which actions to replenish inventory should occur under normal conditions; and, the emergency order point is the level where the risk of stocking out is likely, and an emergency order should be placed immediately.

Table 2. The maximum months of stock, the minimum months of stock and emergency order points for the different levels of the health logistics system.

Level	Review period	Maximum months of stock	Minimum months of stock	Emergency order point
Health centers and hospitals	Every other month	4 months	2 months	0.5 months
Health posts	Monthly	2 months	1 month	0.25 months

The PFSA buys medicines through a tender system and then distributes them throughout the country to hospitals, health centers, health posts and pharmacies. Tenders are especially important in Ethiopia as it is presently through these that mostly all drug distribution occurs in the country. In brief, a tender is a single sales opportunity where the buyer, in this case the PFSA, negotiates the lowest price to pay for a pharmaceutical drug, and purchases a specific quantity that can be delivered in the agreed time period. It is often that when winning a tender, the supplier of the drug gets its product listed on the public drug plan and often becomes the sole tender, meaning that their drug is the only one available in an entire class of drugs to patients on the public drug plan. For tenders the suppliers compete with each other based mainly on price, but the PFSA also considers quality when selecting the winner of the tender.

Figure 5. Public hospital and its pharmacy.

A formal tender process includes: determination of the tender format and scope; requirements definition (selection and quantification of medicines and supplies); preparation of tender documents and contracts; notification and invitation to bid; formal opening; collation of offers; adjudication and supplier selection; contract award; performance monitoring of suppliers and clients; and, enforcement of contract terms if necessary.

The tender process is normally an annual cycle, though it is sometimes conducted two or three times per year. The time required for developing or revising a tender varies widely, but may require two to six months in some settings, normally the negotiation and the evaluation lasts between one and two months (this is once the paperwork and application are submitted), after this the notification of the award is given if the company wins the tender. The lead time requirement of the tender orders normally comes with a three to four month supply notification to provide the products to the country. Therefore, as the manufacturing process normally lasts from four to six months depending on the product, then immediately after the tender award is given a notification is sent to production. The fixed quantity is set since the beginning of the contract, as well as the delivery times for when the goods should be delivered (can be multiple during the period of the tender). A contract normally lasts between one and two years and after the contract is terminated and if the PFSA requires products again, even if it's of the same type, then they open a new bidding process.

In terms of defining purchase quantity the PFSA uses the traditional fixed quantity, scheduled-delivery purchasing contract. This contract specifies guaranteed quantities and delivery in either one large shipment or smaller, separate shipments over the life of the contract. Here, the PFSA accepts the risk that quantities for specific items may be too high (resulting in overstocks) or too low (resulting in shortages). If the PFSA actually needs more than the projected quantity, the price may be adjusted for additional quantities, depending on the contract.

In Ethiopia the national pharmaceutical industry produces only a very limited range of products, therefore most products must be procured via international markets. One common constraint on international procurement is pharmaceutical registration. It is required that all medicines purchased in the country are registered with the FMHACA; the registration process can be very lengthy and take over a year.

Tenders at the company are managed differently than the rest of the sales, so these are not forecasted within the regular demand planning process and only orders are entered into the system once the tender is won. Therefore tenders require a supply feasibility check by the respective supply center prior to bidding to know if is possible to manufacture the amount requested in the given timeframe. In case that the efforts in the supply center connected with that tender exceed defined thresholds, a product supply management approval is part of the feasibility check.

The PFSA distribution covers over 86% of the population, and is particularly focused to rural areas. Besides the central hub in Addis Ababa, there branches located in highly populated regions, and sub-branches located further away from the center and that are supplied by their respective branch. The available health care facilities are unevenly distributed across regions. Figure 5 shows the PFA's distribution network in Ethiopia.

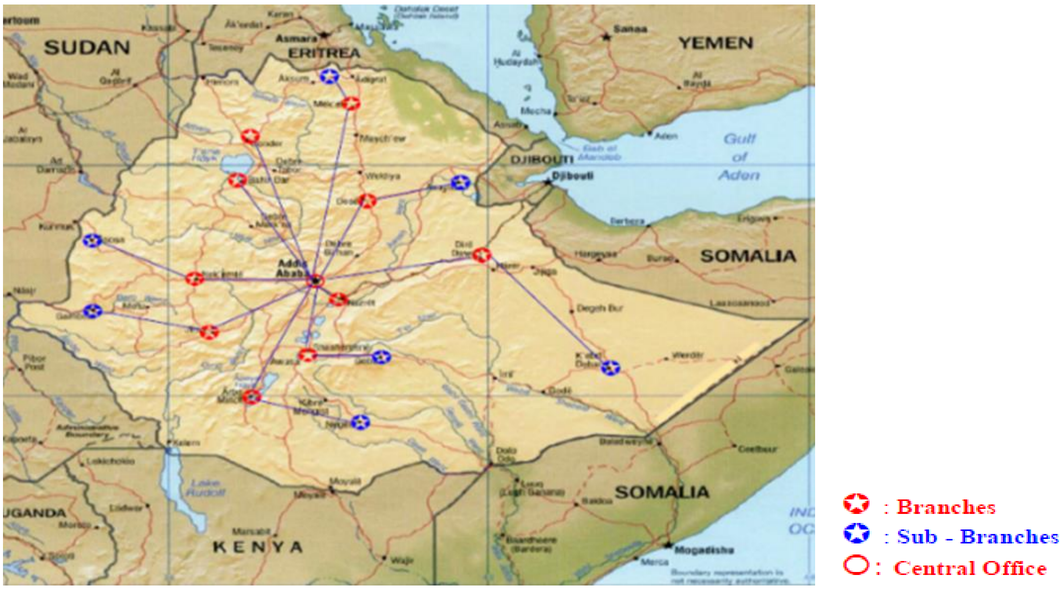


Figure 6. PFSA distribution network in Ethiopia.

4.5. Private Sector distribution

The private wholesale market in Ethiopia is also regulated by the FMHACA, however the distribution follows a different process. The stakeholders involved are multinational pharmaceutical companies, local manufacturers, importers, wholesalers and sub-wholesalers, and retailers (private hospitals, pharmacies, etc.). The private sector supply chain is depicted in figure 7.

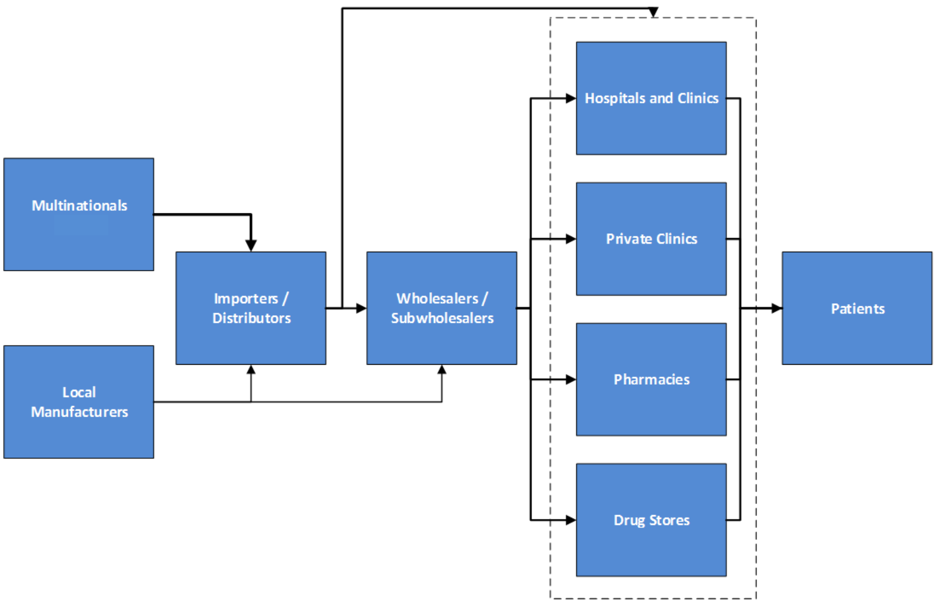


Figure 7. Private sector supply chain.

It was not possible to obtain ordering policies and review periods for the private sector like in the private sector as these vary amongst importers, wholesalers, retailers, as well for the products, e.g. for a retailer pharmacy fast moving products can be ordered every month, medium moving products every two months and slow moving products every 6 months. The inventory review periods also vary depending on the available technology at the stakeholder, can be continuous review with an information system or paper-based every one or two months.

The stakeholders that participate in distributing medicines within Ethiopia are described as follows:

- **Importers**: the importer's role is to purchase pharmaceuticals for Ethiopia and receive the deliveries directly from multinationals in other countries. Importers and distributors/wholesalers need to have a license to import medicines, this is regulated by the FMHACA. Up to three importers can sell one kind of medicine at a time (one medicine can be registered only for three sellers). Some importers have warehousing capacity and many run a vertically integrated wholesale business. When a pharmaceutical company doesn't have a direct presence in the form of a local office, and often when they do, the multinational typically distributes their products through a single distributor that has market exclusivity. This will be the last step where multinationals have visibility of the distribution of their medicines, as they do not see how the products are handled and delivered from this stage on. Importers have a very high cost of credit and a slow product and payment cycle, often as long as 10 months in the case of an importer with an integrated wholesale business, between purchase from the manufacturer and payment from the retailer, this process can be often delayed in Ethiopia due to shortage of foreign currency. Most importers order containers of drugs at large time intervals to reduce transport costs rather than have smaller, more regular, deliveries; for example in Ethiopia, importers might just order three or four times a year. These containers must be bought on credit with a letter of credit from a bank (costing 2% of the order value) and while having to borrow money at a typical borrowing rate between 18-24% per annum. An importer on average adds a mark-up of 25%-30% when selling onto a wholesaler. Importers can directly supply the pharmacies, hospitals, etc. and normally have continuous stock revision and ordering periods when stocks are low.

Figure 8. An importer's warehouse and delivery unit.

Figure 9. An importer's warehouse temperature control.

- **Wholesalers**: the next logistical step of moving the products from the importer to the retailers, or to other sub-wholesalers, can be handled by wholesalers, if the importers do not have direct links with a particular retailer; each importer and wholesaler will have their own network of customers. These organizations often also supply a sales force to sell the product to prescribers. Because so many importers operate a vertically integrated wholesale business, in effect many wholesalers have market exclusivity for certain branded drugs. Wholesalers are important in the market as they maintain a large number of smaller relationships with hospitals, clinics, pharmacies and are able to extend credit facilities to these players to provide much needed liquidity and importantly leverage with the retailer. Wholesaler mark-ups are highly variable but typically range between 25-50%, and will order once products are out of stock.
- **Sub-Wholesalers**: because distribution in Ethiopia is so fragmented and rural areas are so difficult to reach, there is no single importer or wholesaler that covers all retail outlets, thus there are sub-wholesalers that specialize in certain geographies or therapy areas; especially for rural areas sub-wholesalers will be the ones distributing to these areas. Wholesalers often sell onto multiple sub-wholesalers to ensure greater coverage and to more rapidly shift their stock in order to be able to have the cash flow to order more. This step is not visible to the multinationals, at the stage when products leave the main wholesaler or importer, the parent pharmaceutical company has lost all compliance, marketing and pricing visibility on the product. Depending on the number of sub-wholesalers that products travel though the mark-up can rapidly escalate but an assumption of 25% per additional middle man is reasonable. Ordering occurs only when the products run out of stock. Paper-based stock management with a periodic inventory review is utilized.

Figure 10. Sub-wholesaler warehouse and refrigerator.

- **Retailers**: the retailer is the final step in the distribution chain before a medicine reaches the end-patient and can include clinics, registered or un-registered pharmacies and hospitals. Mark-ups at this level tend to be high as the total value and volume of pharmaceuticals sold is relatively low and overheads remain high. The largest overheads are transport (if the retailer collects their own products), staffing, rent, refrigeration (assuming the pharmacy has this) and credit. Low levels of liquidity and cash flow makes retailers reluctant to stock higher value products, for fear that if they don't sell their exposure will be much higher. A retailer with little capital or credit will typically choose to stock generics, if just to fill the shelves, despite there being the demand for branded medicines. Typically wholesaler mark-ups increase the more rural the setting but retailer mark-ups reduce in the poorer less urbanized areas as affordability and overheads go down. Retail mark-ups can be between 25-500% for original branded medicines but mostly operate around 50-80% in a free pricing environment. Depending on the retailer it can have either continuous review of stock with an information system or periodic review with a paper-based system. Ordering policies varies depending retailer and product.

Figure 11. Local chain pharmacy store and warehouse.

The private market is increasingly gaining importance as the economy of Ethiopia experiences further growth and greater part of the population has enough purchasing power to buy medicines. Another factor that influences is the urbanization of the country, in cities there has been a steady increase of pharmaceutical retailers and distributors over the past decade. Practically all drug vendors and drug stores are privately owned, as are more than 70 percent of pharmacies.

One particular issue in the private sector is the shortage of available amount of foreign currency in local banks, so when importers request it to pay for medicines from multinationals it is not always available, this leads to a limited supply of drugs in the Ethiopian private health sector and stock-outs along the supply chain when this factor is not taken into account. The shortage occurs when there is no foreign currency (USD/Euro, etc.) available at local banks and the distributors/importers have to wait to obtain it for them to be able to pay and import products from multinationals.

4.6. Donor sector distribution

The donor sector, as defined in this thesis, compromises the pharmaceutical supply chains utilized by international humanitarian organizations. The distribution of medicines in this sector is funded by donors and the delivery process is either done by the humanitarian organizations or they make use of public infrastructure in cooperation with the PFSA.

The first case of donor distribution considers an entirely owned network by the humanitarian organization. Organizations usually set up programs that consist of delivering specific medicines or range of medicines to a particular location in the country. The medicines are purchased or supplied by multinationals. The whole delivery process is done with infrastructure and vehicles owned by the organization or locally outsourced. In Ethiopia, there are also just under 200 NGO health clinics and 8 NGO hospitals operating throughout the country, particularly in rural areas.

The usual lead time that is managed for the region by humanitarian organizations varies a lot depending on the organization and program (its location and the required medicines). For example, in the case of MSF in Ethiopia, a normal program has a lead time of 6 months and it consists of the following: 2 months for forecast to ordering; 4 months for ordering to production; and 1 month from production to delivery. As it is important to provide lead times to production centers to manufacture in time, the production notice occurs normally as soon as the order is received and confirmed.

Humanitarian organizations assess their vehicle needs for distribution by calculating the fleet size required according to on-going demand. Thus, for these organizations, setting up an efficient supply chain in general and more specifically a last mile distribution network is very important. The last mile distribution is the means transporting relief supplies and services from local distribution centers (depots or hubs) to beneficiaries. The lack of stability, security, local infrastructure and facilities, coupled with the huge difficulty in gathering reliable field data, makes the fleet optimization hard, though fleet costs are high, transportation is the second largest cost in humanitarian operations after personnel.

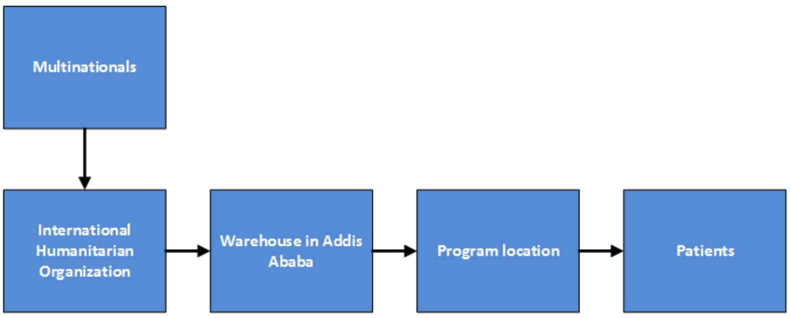


Figure 12. Donor supply chain with self-distribution, case 1.’

The second case considers distribution in cooperation with the PFSA. In this case the distribution is very similar to the public sector one as it utilizes the same local network and infrastructure. The difference is the supplier of the medicines, which in this case is an international humanitarian organization that donates them. The supplier can also be multinational pharmaceutical company that donates the medicines through their own corporately owned humanitarian program.

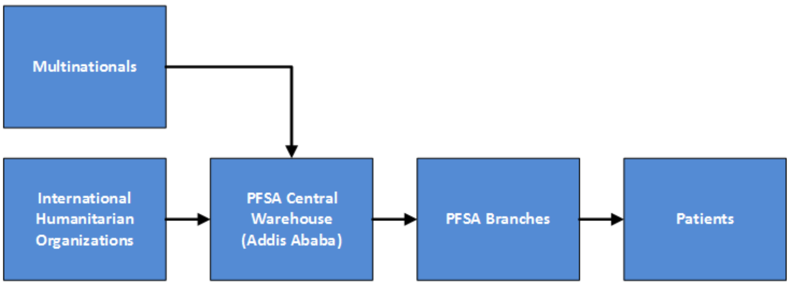


Figure 13. Donor supply chain with PFSA distribution, case 2.

5. Pharmaceutical demand planning, leadtime analysis and coverage estimation

5.1. Overview

This chapter contains the analyses of the parameters relevant to Ethiopia's distribution for the company, several of which will be used afterwards in the simulation modeling chapter. The analysis is divided in demand, leadtime and coverage estimations. In the demand estimation subsection, the relevant criteria on how to calculate the company's forecast are described, as well as how to estimate the overall medicine requirement for the urban population of the country. In the subsequent part it is explained what the leadtime consists of and how it was calculated. In the last subsection the current coverage of the company is approximated for the selected products, expected coverage for the future is also estimated considering the forecast results. This section relates to the first research question as analyzing demand, leadtimes and coverage helps to give a clear picture on the current state of the company in the Ethiopian market.

5.2. Demand estimation for the company and overall medicine requirements for urban Ethiopia

Estimating the demand for pharmaceuticals in Ethiopia, as in most of sub-Saharan Africa, is very difficult due to scarcity of market data; therefore in this thesis several methods were used to obtain approximations and construct a forecast from a variety of sources, i.e. local market information related to population numbers and disease burden; company's historical sales data; and, on-site stakeholders information. Two demand estimations were made, i.e. for the private and public sectors, for cardiovascular products *x*, *y* and *z*. A timeframe of ten years is considered for these estimations. Data used for this estimation like population figures and points of sale information can be found in Appendices A and B respectively. The results for this section, the demand estimation, can be found in the Appendix E.

5.2.1. Estimation for the private sector

Two separate calculations were made for the private sector, firstly the demand estimation for the company to construct the forecast (what the company is expected to sell); and secondly, the overall demand for the selected medicines for the urban population of Ethiopia (the overall need of medicines for the population).

For the analysis three cardiovascular medicines were selected; these vary in demand volume, specific target treatment, production lead times, shelf life and dosage. These medicines were chosen since they represent a high volume demand for the company and because of the prevalence of CVDs in Ethiopia and in the sub-Saharan region. In broader terms, CVDs are the second leading cause of death in Sub-Saharan Africa (only surpassed by HIV/ AIDS) and about 80 % of the global burden of CVD deaths occurs in low- and middle-income countries. CVD is predicted to be the leading cause of death and disability worldwide by 2020 mainly because it will increase in low- and middle-income countries.

The demand estimation for the forecast was made with the use of the company's historical sales data, the inventory data of a local chain pharmacy and local market information related to population numbers and disease burden. For two out of the three products selected (products *x* and *z*) there was no reliable historical data available at the company so an estimation of demand using inventory data of a local chain pharmacy was performed. For the other product (*y*) the historical sales data were utilized.

The most relevant market parameters for the forecast construction were population figures and growth percentages. Population size estimates were obtained from the CSA for the year 2013; even though the last census in Ethiopia was performed in 2007, the CSA estimates every year how much the population has grown. A population increase of 0.26% per year was utilized, this percentage was obtained from the average increase per year on population over the last 15 years and CSA predictions for future growth.

The sales and inventory data of the local chain pharmacy included stock levels of its 7 stores in the Addis Ababa area; these pharmacies have the highest amount of sales in the city in the private sector. A total of 12 months of consumption data was obtained from this chain pharmacy. With the inventory data the amount of company's products that were sold there was calculated using an adapted version of the consumption-based method defined in WHO guidelines (WHO, 2014). This method is utilized to estimate the demand of products *x* and *z*, for product *y* the historical sales data was available at the company so a different calculation was made using that information.

Using the local chain pharmacy's inventory data the demand for products *x* and *z* was calculated. The adjusted average monthly consumption was obtained with the following formula (this is used for the twelve months consumption data of the chain pharmacies):

$$C_A = \frac{C_T}{\left[R_M - \left(\frac{D_{OS}}{30.5}\right)\right]}$$

Where C_A is the average monthly consumption adjusted for stock-outs; C_T is the total consumption during review period, in basic units; R_M is the total consumption review period, in months; D_{OS} is the number of days an item was out of stock during the review period (this was obtained by calculating the days from which the inventory balance reached cero up until the central chain pharmacy was replenished).

The adjusted average monthly consumption figures obtained from the previous calculation only accounted for the chain pharmacy's sales therefore it was necessary to find a way to calculate the demand at other retailers as well to obtain the overall monthly demand for urban Ethiopia. Therefore to estimate this, firstly the amount of people served by this chain in Addis Ababa was calculated. The pharmacies can be found in three zones of the city: Bole, Kirkos and Nefas Silk-Lafto, these contain 30.90% of the total population living in Addis. As these chain pharmacies have the highest sales it is assumed that they represent 80% of the entire sales in these zones; which results in them having 24.72% of the total sales in Addis. The sales estimates obtained for this 24.72% is later extrapolated to the rest of the population living in the city, assuming there is a similar demand pattern.

Afterwards the entire urban population of Ethiopia is considered, this is regarding to customers living outside the capital city that come into Addis to purchase (indirect sales). Even though Addis accounts for over 31% of the total urban population of Ethiopia, it is assumed that 80% of the sales are direct from local customers and 20% indirect from customers outside the city as it goes in line with information that was obtained on-site from distributors, though depending on the specific wholesaler these percentages could vary up to 60% local customers and 40% customers outside Addis.

It was possible to start constructing the forecast after calculating the estimate for the overall monthly demand for urban Ethiopia from the previous year and obtaining expected sales growth percentages from the company. In the company a recent analysis had already been made for future pharmaceutical demand in Ethiopia with sales growth percentages for the next ten years for every product sold in the country. The analysis was done by the head supply chain manager for the region using primarily historical sales data, the current company forecast and his own experience with the African market, other factors that were considered were expected population growth, increased market access and company strategy. The issue of these growth percentages is that given the circumstances it is very difficult to calculate accurate demand estimations for subsequent years, even more so for dates further into the future like 5 to 10 years from now, therefore predicting what will happen when the company increases significantly its presence in the country is highly uncertain, nevertheless the growth percentages are useful for constructing a forecast because they are based on current sales data and on company and region experience. This is also the reason why these growth percentages were used instead of calculating different ones for this thesis, there was not enough data available that would help to make arguably better predictions. And thus the growth percentages were used to calculate a 10 year forecast using the monthly demand data estimated previously. The results from the calculations can be found in Appendix E. The following graph depicts the demand expectation for the three products:

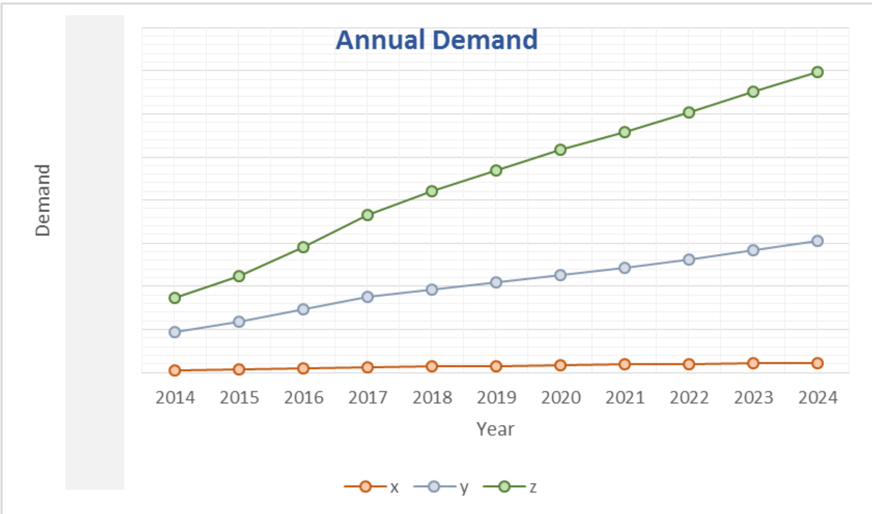


Figure 14. Expected demand growth per year (total annual demand) for products x, y and z.

The overall need of the three products for the urban population of Ethiopia was calculated with population estimates, growth percentages, local purchasing power and disease burden percentages; and using a combination of WHO's consumption-based and morbidity-based methods.

First the overall urban population with CVD prevalence was computed, for afterwards calculating the amount of medicines needed to satisfy the demand. For this the previous population figures and growth percentages were once more employed. The purchasing power of the population was taken into account to consider what percentage of the inhabitants could actually afford to buy the company's products in the private sector, and the remaining who would not be able to and concern mainly the public sector. According to the World Bank, in 2014, 29% of the population lives under the poverty line, therefore this segment was taken out while estimating the demand for the private market as it is assumed that these persons won't be able to buy the company's products. The opposite would occur for the public sector estimation, which would include primarily the population living in poverty. The decrease in poverty per year is set at 0.469%, this percentage was obtained from the average of decrease in poverty levels from 1994 up to 2013 (a period with a very high economic growth for the country) and a slightly decelerated economic growth for the next decade, given World Bank expectations. The following graph outlines the decrease in poverty during this period, the successive graph takes into account the predicted decrease in poverty for future years.

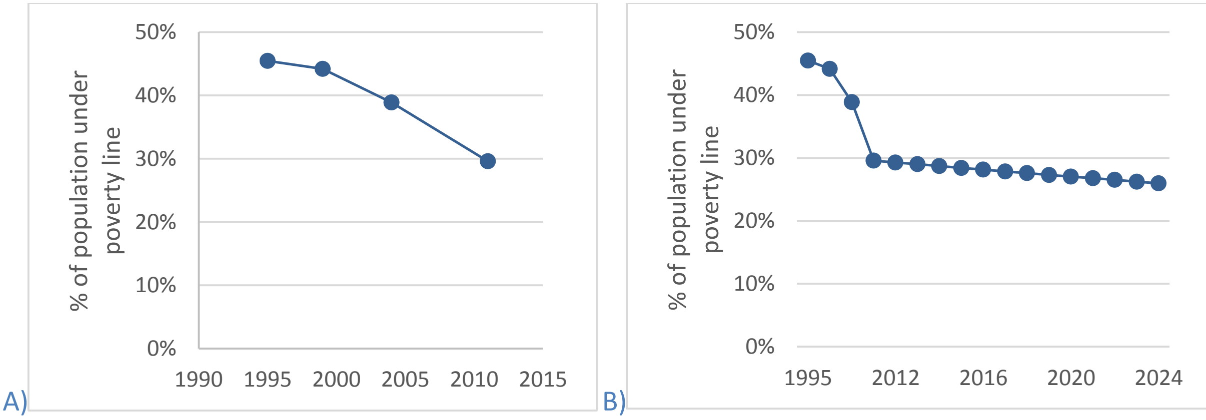


Figure 15. A) Percentage decrease in poverty (years 1994-2013) (WB, 2014). B) Estimated percentage decrease in poverty until year 2024, given a slightly decelerated economic growth in Ethiopia.

The disease burden was measured relative to the Ethiopian population and the specific therapeutic area in question, for products *x*, *y* and *z* only diseases related to cardiovascular are investigated. Cardiovascular diseases (CVD) were found to have a prevalence of between 3 and 12.6% in the urban population of Ethiopia, these figures were recovered from various studies of CVD prevalence in hospitals and clinics in Addis Ababa and other Ethiopian cities in the last 10 years (Misganaw et al. 2014). A 7.8% was used for the CVD prevalence in urban Ethiopia as it is the average figure from the studies.

The overall population in need of CVD medicines for Addis Ababa, the urban areas outside Addis and for the overall total urban market in Ethiopia was obtained using the numbers from the calculations of population figures, purchasing power and disease burden. The results can be found in Appendix E.

With the overall urban population in need of CVD medicines it was possible to obtain the number of medicine packages required for each of the company's products. For this the morbidity-based calculations described in the WHO guidelines (WHO, 2014) are utilized. These calculations seek to obtain the following:

- Quantity of medicines needed per treatment episode
$$Q_E = D_{CU} \times N_D \times L_D$$
- Expected total number of contacts (in thousands)
$$C_E = C + (C \times A_U)$$
- Expected treatment episodes
$$E_T = C_E \times F$$
- Total quantity of medicines needed
$$Q_T = E_T \times Q_E \times P_T$$

Where

- Q_E: Quantity of each medicine needed for each treatment episode
- D_{CU}: Basic units per dose
- N_D: Number of doses per day
- L_D: Length of treatment in days
- C: Past total number of contacts
- A_U: Utilization adjustment
- C_E: Expected total number of contacts
- F: Frequency of health problem (per thousand)
- E_T: Expected treatment episodes
- Q_T: Total quantity required
- P_T : Percentage of cases expected to be treated

The results of the estimations for the overall urban population in need of CVD medicines for products x, y and *z* can also be found in Appendix E.

5.2.2. Estimation for the public sector

To estimate the demand of the public sector data from PFSA procurement figures for the past six years was used to estimate the demand for the next decade, given the purchase trend continues into the future. Tenders are normally included in the forecast in the company, but demand planning is still necessary to estimate expected sales.

For this sector product *v*, an anti-infective product, was selected. The demand for anti-infective products is currently high and is similarly expected to increase considerably in the following years. The demand estimation is solely based on what the PFSA has procured in previous years. No monthly demand is considered as the tender system is an annual or biannual cycle.

The donor sector is not further considered in the analysis as there was not enough data to provide satisfactory approximations for future demand. It is also not considered for the simulation model which is described afterwards as the distribution set-up in the first case (see As-is situation chapter) doesn't vary sufficiently from the one for the public sector (in both the company sends medicines to the PFSA); for the second case there is insufficient data about the distribution process of the NGOs that collaborate with the company.

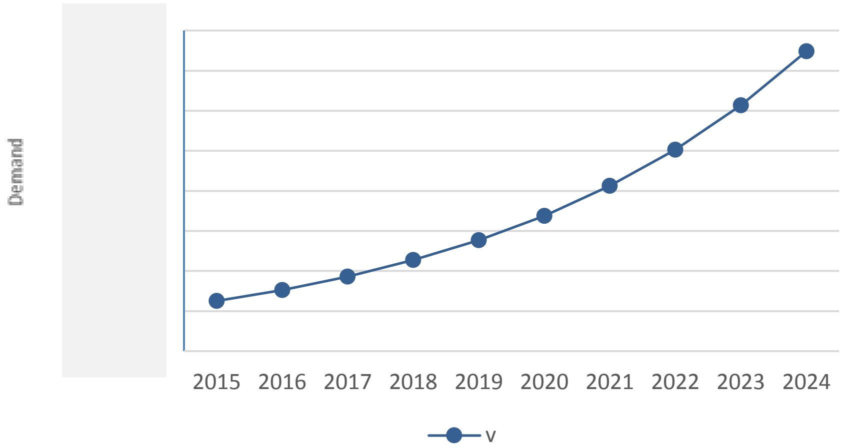


Figure 16. Expected demand per year for product v.

5.3. Leadtime estimation

The leadtime estimation was broken into two parts, production times per product and delivery times. Subsequently delivery times is divided into international delivery time and local delivery time. Production times and international delivery times are common to all sectors, the company has control over both of these; on the other hand, local delivery times vary between sectors as there are different stakeholders in charge of this part of the distribution, i.e. government for public sector, private distributors for private sector, and NGO's/government for donor sector.

Production lead time considers both the manufacturing and packaging processes. Production time differs per product, it was fixed for *x* and *z* (at 4 months each), and it varies for product *y* (from 5 to 6 months).

Delivery times consider international delivery time (from Europe to Ethiopia i.e. company to importer or company to PFSA); and local delivery time (local deliveries, i.e. from importer/wholesaler to retailers). International delivery time consists of the time needed to ship products from a warehouse/plant in Europe to a local customer's warehouse, which includes port clearance (time spent in customs). Time spent in customs can take up to three weeks if there is missing paperwork or there is some mistake for example in quantities specified, normally it takes only a couple days. Local delivery time is for shipments that are delivered to customers in Addis Ababa.

For international delivery times data was reviewed from local the shipments of the last two fiscal years at the company. Outliers were removed from the calculations as there seemed to be several input errors in the system, a remaining total of 20 shipments were considered to calculate the delivery time average for international delivery time. It was found that it follows a gamma distribution with an Alpha of 3.81 and a Beta of 10.00 (μ=38.2, δ^2=19.71). In spite of removing the outliers the leadtime seemed to be quite long as there is only air shipments, therefore in the company it should be checked if the order delivery dates are being input with the corrects date of departure and arrival at the customer.

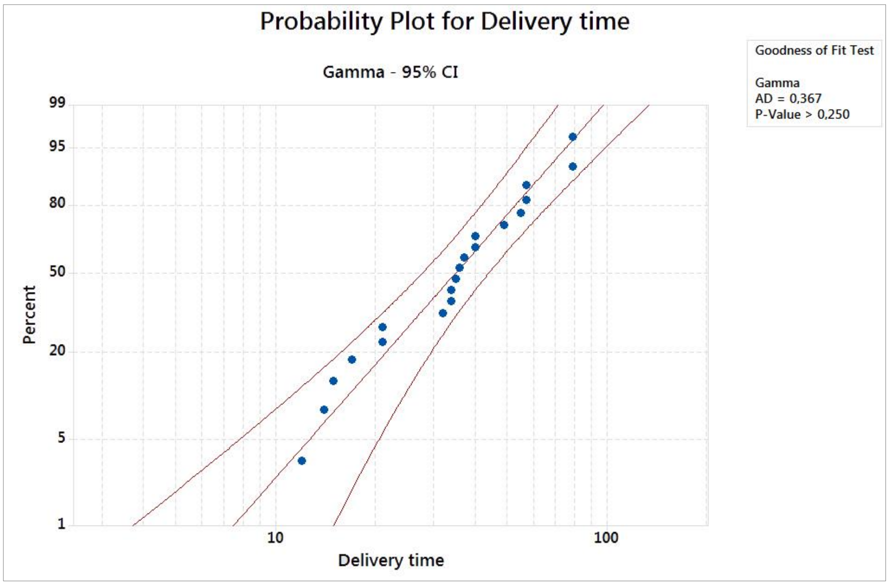


Figure 17. Probability plot for delivery time for international shipments.

For local delivery time there was no available data to analyze, from interviews with importers, wholesalers and pharmacies it was found tha it takes from one to two days to deliver the medicines once the order is placed by the customer (this is assuming that the seller has sufficient stock when the order is placed). It was not possible to estimate local delivery times within the PFSA distribution network, as the process is not visible once the company provides the products to the PFSA.

5.4. Coverage estimation

The coverage estimation consisted of calculating, for the private sector, the amount of urban population currently covered by the company and the expected coverage for the next decade. Three series of measurements were made, one for each product, with the use of the results from the demand estimation section (the company’s forecast, the overall population with CVDs in need of medicines and their required amount of packs of each product). The results are given as percentages of population covered and can be found in Appendix F.

6. Modeling the Ethiopian urban market distribution

6.1. Overview

Simulation modeling was used to analyze the as-is distribution set-up and estimate the effects of changing designs. This method was selected because it is suitable to analyze the current state of a system, its behavior over time, and the impact of any changes made to it. Furthermore simulation was chosen over analytical methods due to the distribution model having many variables and interacting components e.g. the company ships to a number of importers that in turn deliver to numerous retailers. As there are stochastic variables such as demand and leadtime the simulation model is able to reflect the randomness and interdependence present in reality with resources and other system elements by using a very high number of iterations, instead of using an analytical model where only it is possible to run few times taking into account only the average of the stochastic demand and of the leadtimes. Finally, for ease of use as it is possible to program the simulation to run automatically and record the results of the high amount of runs every time the scenario parameters are changed.

Only the private sector was simulated because it was the primary interest of the company; there was more data available; the whole delivery process from company to end-customer (patients) can be mapped and studied; the demand can be forecasted and is not dependent on winning tenders; and, the distribution set-up is more complex and flexible than in public and donor sectors.

6.2. Objectives

The main objectives of the simulation are to study the performance of the current system; to quantify the effects of changing the distribution set-up under varying sets of circumstances; and ultimately, to provide performance estimations that will allow the company to design an efficient distribution system that satisfies customer demand, minimizes overall costs and has a high service level.

6.3. Model formulation

The simulation model was adapted from the heuristics and findings from Shang & Song (2003); Özer & Xiong (2008); and, Rong, Zümbül & Snyder (2012), regarding base-stock levels in multi-echelon distribution networks. The notation and definitions of the model can be found in the Appendix G.

The simulation was made to resemble the previously described as-is situation for the private sector. Therefore a multi-echelon distribution system was modeled with three echelons: the company, the importers/wholesalers and the retailers. The flow of goods is from the company to the retailers; each stage can hold inventory and each sells products to the subsequent stage until the retailers sell them to the end-customers or patients. The company stage has the production and packaging processes and the company's warehouse (from where the products are delivered to the next stage). The importers stage consists of the wholesalers that have a license to buy the company's products and sell them locally. The retailers stage contains all the pharmacies, hospitals, private clinics, etc. where the medicines can be sold directly to the end-customers. The second step of wholesalers and the sub-wholesalers were taken out to simplify the simulation, moreover there was not enough available information about them. To further ease the modeling, importers are all grouped into one stage, as well as the retailers, due similar characteristics between them and not enough data to differentiate them, the purpose for this is to be able to calculate the demand for each stage. Subsequent simulations are also run for changes made to the as-is situation to consider different scenarios for different set-ups (the scenarios are described in subsection 6.5. Scenario designs).

It is considered that inventory optimization is locally controlled, and that it is a continuous-review distribution system with stochastic customer demands at the last stage. Each node follows a base-stock policy and a first-come, first served allocation policy, so medicines with the least amount of shelf-life remaining are sold first. The company's warehouse is indexed by $j = 1$, and the next stages are indexed by $j = \{2,\ldots, j\}$. Each location incurs a holding cost per product inventory. The local holding cost at stage j is h_j per unit of on-hand inventory. Due to value-added operations, holding inventory at later stages is more expensive than holding it in the company's warehouse; i.e., $h_j \geq h_1$. It is assumed that holding costs are charged on items in transit as well. Demand is satisfied through on-hand inventory, otherwise, unsatisfied demand is backordered at each stage. Unsatisfied demand at each location is backordered, but only the retailers pay penalty costs for unsatisfied demands which is equal to stock-out costs. The company's warehouse replenishes from a source with ample supply. Whenever the inventory position at stage $j \geq 0$ falls below base-stock level s_j, each location orders from its immediate upstream location to bring its inventory position back to s_j. Shipments from an upstream location arrive at the downstream location after time L_j. Each shipment requires a leadtime to arrive to next stage but no fixed costs. The transportation leadtimes between all the locations are deterministic or stochastic depending on the product and stage, and waiting times are stochastic due to backorders. Demand at each retailer j is independent and follows a Poisson process $\{D_j(t),\ t \geq 0\}$ with rate λ_j. Hence, the warehouse's demand process is Poisson with rate $\lambda_0 = \sum_{j>0} \lambda_j$.

The model was modeled using a continuous review distribution system as there are importers and retailers that are able to use these kind of systems and to be able to monitor the flow of goods. But also it was modeled this way because all the results for this model formulation still hold for the periodic-review models with independent and identically distributed (i.i.d.) demands as Shang & Song (2003) point out in their analysis; exhaustive proofs and details on this can be found in Chen and Zheng (1994), Gallego and Zipkin (1999), and Zipkin (2000). Finally, this model is useful because for the N-stage system it is well known that an echelon base-stock policy is optimal for this kind of systems (Shang & Song, 2003). I.i.d. demands are considered because it was not possible to estimate the distribution of each demand for every stakeholder in the system so it is assumed that these are identical even though in reality these vary, but is it still useful as the result is average of these distributions and the model details how much demand occurs at each stage, which helps the company and importers know how much base-stock level they need. Shang & Song (2003) also point out that the model works with normal distribution and negative binomial distribution with slight error margins, i.e. an average error of 0.5% and 0.23%, respectively for these distributions, in addition to the Poisson distribution that is utilized in the model.

The state of this system is defined by the stochastic processes $\{B_j(t),\ t \geq 0\}$, the backorders, and by $\{I_j(t),\ t \geq 0\}$, the on-hand inventory at each location $j = \{1, \ldots, j\}$. Under the Poisson demand arrival assumption, the limiting distribution for these processes exists. Following a top-down approach, in equilibrium:

$$B_0 = [D_0 - s_0]^+$$

$$B_j = \left[B_{j-1} + D_j - s_j\right]^+$$

$$I_i = \left[B_{j-1} + D_j - s_j\right]^-$$

Where D_j is lead time demand to stage *J*.

The total expected long-run cost of the system per unit time given an *s* is evaluated by the following:

$$TC = \sum_{i \in N} h_j E\left[I_j + \sum_{j \in S(j)} IT_j\right] + \sum_{i \in N} E\left[h_j I_j + b_j B_j\right]$$

Where IT_j is the inventory in-transit to stage *J*. The first sum is the expected cost of holding inventory at non-retailer stages and in-transit, and the second sum is the total holding and penalty cost at the retailers.

Effective demand has a Poisson distribution and at stage 1 is defined by: D_j; at stages 2 and 3 it is: $B_{j-1} + D_j$; with means: $\lambda_j(L_1), \lambda_j(L_1 L_2), \lambda_j(L_1 L_2 L_3)$, respectively.

The decision variables are the base-stock levels s_j, which are modified accordingly to reach a desired outcome in the performance of the system. In order to obtain an approximated optimum level for s_j in all stages in the model a heuristic adapted from Shang & Song (2003) is used. This heuristic provides closed-form expressions for the echelon base-stock levels and allocates inventory to all stages by solving newsvendor-type problems. It also permits the study of the effects of system parameters on the optimal cost and policies analytically, which in turn provides guidance on how to allocate critical resources to improve system performance. The heuristic follows a downstream to upstream approach. For the retailers stage the optimum base-stock level can be derived from:

$$s_j = F_j^{-1}\left(\frac{b_j + \sum_{i=2}^{N} h_j}{b_j + \sum_{i=1}^{N} h_j}\right), \quad j = R$$

Where F^{-1} is the inverse Poisson cumulative distribution function. For obtaining the optimum base-stock level for the rest of the stages the following separate newsvendor-type cost function (lower and upper bounds for the echelon cost functions) is applied:

$$s_j = \frac{1}{2}\left[F_j^{-1}\left(\frac{b_j + \sum_{i=j+1}^{N} h_j}{b_j + \sum_{i=1}^{N} h_j}\right) + F_j^{-1}\left(\frac{b_j + \sum_{i=j+1}^{N} h_j}{b_j + \sum_{i=j}^{N} h_j}\right)\right] \quad , \; j = 2, \cdots, N$$

Therefore the heuristic develops an upper and lower bound on the average total echelon cost function of each stage, provided all downstream stages follow the optimal policy. These cost bounds are the convex cost function of certain single-stage inventory problems. The minimizers of the bounding functions form an upper and a lower bound for the optimal echelon base-stock level. The simple average of these bounds in turn forms the heuristic solution for the optimal echelon base-stock level. The end result is a closed-form solution involving the original problem data only. This approach provides efficient computational methods to obtain close-to-optimal and feasible solutions, Shang & Song prove this by demonstrating that the average relative error of the heuristic is 0.24% in their numerical analysis, with the maximum error less than 1.5%. It is also shown that the upper bound function for stage-N provides a convenient quick estimate for the optimal system cost.

6.4. Simulation programming

The simulation was programmed based on the previously formulated model, in this subsection it is explained what it does when it runs and the ordering logic. The simulation was built and programmed using Microsoft Excel VBA (2013 version).

The three private sector products considered in the previous section *x*, *y* and *z* follow the same distribution process, so the simulation model remains identical for all, however the parameter values differ depending on the characteristics of each product. The simulation is run for these products to estimate the effects of demand volumes and other parameter differences in the performance of the distribution system. Products *x, y* and *z* vary only in demand volume, price and production times (*x* having a stochastic one and y and *z* having a fixed one).

Firstly the stages are programmed, as each scenario design has its own characteristics, each design varies on either amount of stages or from where the products are ordered and sent. For instance for the current situation set-up the stage 1 is the company abroad, which sends products to stage 2 that are the importers and finally to stage 3 that are the retailers. In other designs there is either only two local stages, i.e. company local and retailers, or three stages, i.e. where the company owns the first two stages.

The base-stock levels are first calculated analytically for every stage in the distribution process using the heuristic adapted from Shang & Song (2003) with the values of the parameters for each specific case. These parameters are modifiable to be able to calculate new base-stock levels and it's not necessary to run the simulation for this first step. After the calculation of the base-stock levels the simulation can be run to find out how the distribution set-up performs with the desired parameters and respective near optimum base-stock levels. Parameters like demand rate, leadtime, unit holding costs and unit backorder costs have direct effect on base-stock levels, thus when modified the base-stock levels also change. If the local base-stock level at stage *N* changes then subsequent base-stock levels at stages further downstream also change. The parameter values in the simulation program are easily modifiable for when new data is obtained or for different settings. The values for the base parameters for the current situation regarding scenario A, and for the proposed scenarios B and C, can be found in subsection 6.8. Parameter values. Parameters can also be modified to estimate the effects they would have on costs, profit, and inventory and service levels, this is studied in the following chapter.

The ordering logic is that in the simulation each stage will order to replenish its base-stock up to level based on the forecasted demand occurring at the stage closest downstream, i.e. stationary random demand occurs at stage N, which obtains resupply from stage N-1 and so on. There are linear ordering and inventory holding costs at all stages. However, because the long-run average ordering cost is a constant this cost is ignored in the model. The echelon-inventory position IOP_J for each stage j is monitored continuously, whenever it falls below the target level s_j, an ordered is placed from stage *j+1* to bring it back to this target and considering the forecasted demand for the given period. Even though in the model formulation a continuous replenishment is considered, the results still hold for a periodic review system with i.i.d. demands and with other types of demand distribution with a slight error percentage as previously mentioned. When applying this result to periodic-review systems, the model assumes that inbound and outbound shipments occur at the beginning of each period, while inventory-backorders costs are assessed at the end of the period. The optimal echelon base-stock policy s^* minimizes the long-run average system wide cost. For each stage j the optimal base-stock level s_j^* is completely independent of the decisions at its upstream stages. Thus s_j^* depends on the upstream stages only through the sum of the echelon holding cost rates at these stages.

As the retailers are grouped in the same stage if there is product available the patient will find the medicine at one of the retailers, if there is no availability in the model means no retailer has any product. If a patient doesn't find a medicine at a pharmacy then they will find it at another or there will be a stockout. The company has an ample supply from the manufacturing process $IP_J = IOP_J$.

The simulation was programed to perform twenty-four thousand iterations every time it is run, so this means it runs twenty-four thousand times for each twelve month period for a time frame of eleven years, which consists of the current year plus ten years into the future (from 2014 to 2024). The reason for having such a high number of iterations is because a certain level of stability is sought for the simulation. While working with stochastic inputs a simulation will and should always give slightly different results as the inputs are random, e.g. in this case the demand has a certain distribution but the values themselves will not always be the same when the simulation is ran for each period. Therefore if the simulation is run a sufficiently high number of times then it will reach a stable enough state where the behavior can be explained without a wide margin of error due to uncertainty. The simulation commences with values from the previous period with demands already occurring and base-stock levels set, and there is only an increment every twelve months. The simulation was first constructed with ten thousand iterations and then expanded to its current number, the changes in the results from ten thousand to twenty-four thousand iterations was found not to be significant and thus the simulation was left with the existing number of iterations.

6.5. Scenario designs

Three scenarios were considered for the simulation, each having a different distribution system design. For the analysis in subsequent sections, first the performance of the scenarios is evaluated to identify the one that generates the greatest value for the company (evaluation and comparison of scenarios section). Afterwards all scenarios are run various times with modified parameters to estimate the effects and verify if the previously selected scenario is still the best choice under different circumstances (sensitivity analysis chapter). The three scenarios are:

A. International distribution. The as-is distribution set-up, which consists of the company distributing its products from abroad to the local importers, and these in turn distribute to the retailers. This is a three-echelon system.

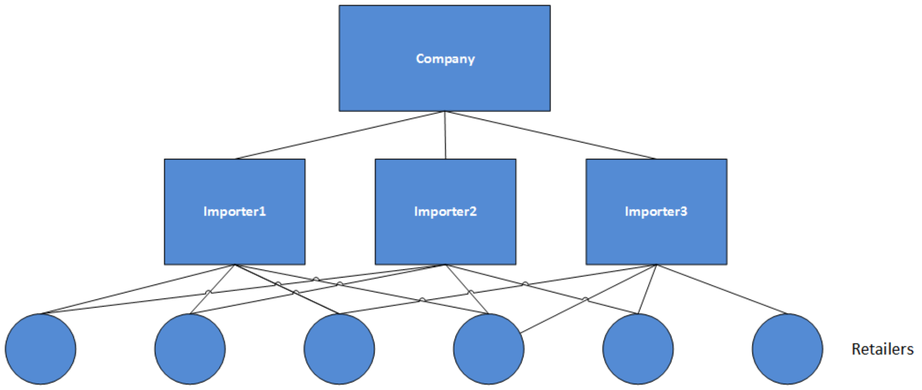


Figure 18. Scenario A (three-echelon distribution system).

B. Local distribution from local production. This set-up considers the distribution process starting in Ethiopia, where the company is able to distribute directly to retailers by having a local production plant and warehouse in Addis Ababa. The importer stage is removed from the simulation, and the retailer stage contains pharmacies, hospitals, clinics and wholesalers (which could include the importers from the previous scenario now acting solely as wholesalers). This is a two-echelon system.

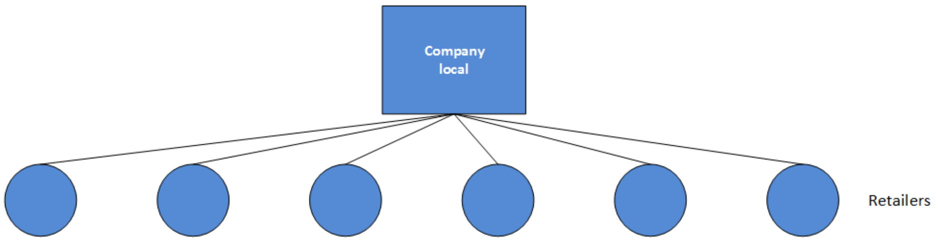


Figure 19. Scenario B (two-echelon distribution system).

C. Delaying value-chain operations. A set-up design where part of the value-chain is located in Ethiopia (Addis Ababa); value-added operations handled locally could be part of the manufacturing process or packaging. This would require logistical postponement where unfinished products are shipped from abroad to the company's local plant/warehouse and afterwards finished on-site and distributed. The importer stage is removed from the simulation, but a local company stage is added for the company's plant and warehouse in Addis. This is a three-echelon system.

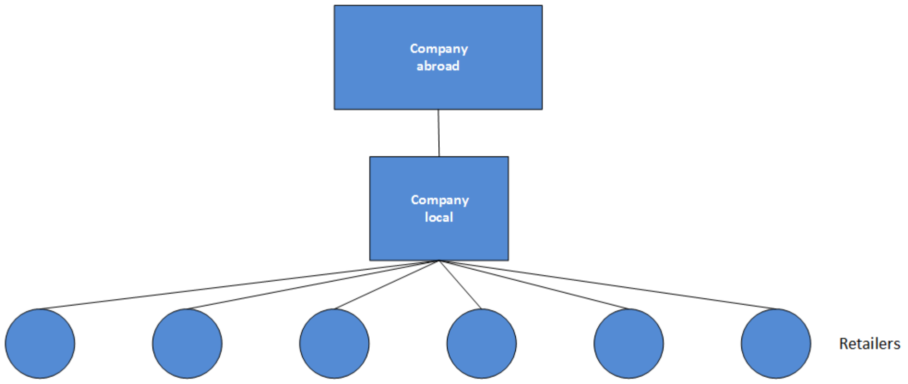


Figure 20. Scenario C (three-echelon distribution system).

6.6. Assumptions

The simulation involves a series of data and structural assumptions:

i. The estimated demand in the data analysis chapter is assumed to follow a Stationary Poisson distributed demand with an increase every twelve periods (twelve months).

While in reality demand may increase every month, in the simulation it is assumed it only increases every year. This is done to simplify the simulation to only calculate the base-stock levels every twelve months instead of every month. The base-stock levels are obtained with the forecast estimation, which is for the average demand of every whole year, and thus the stock kept should be able to cope with the variations of demand. Poisson distribution is assumed as from literature it has been found that it fits with various demand models in these types of systems, and because from the demand distribution of the chain pharmacy and from the company which were investigated.

ii. Importers and retailers share similar enough leadtimes, markups and cost parameters (handling, transportation, inventory), thus they can be grouped together in their respective stages.

There was not enough information recovered to accurately differentiate the importers or the retailers in terms of local leadtimes, operating costs and markups. And from the available data it was found that most of these were comparable, thus it is assumed that they share similar enough values for these parameters in the model. Importers are grouped in one stage, retailers in another.

iii. There is no significant cost difference between handling direct and indirect sales for the importers/distributors.

This was assumed to be able to consider the entire demand in the simulation, the difference in costs of handling direct sales and indirect sales is presumed to be negligible, since local transportation costs for the distributors in Addis Ababa are low in relation to other costs.

iv. No change in price of medicines over the entire simulation time frame.

Calculating price changes was out of scope for this thesis, in any case the variations in price were not relevant to analyze the behavior of the system in the way it is intended, and in addition leaving this out further eases the running of the simulation.

v. For scenarios B and C the company is allowed to commercialize its products locally without passing through importers, either by having local production or by having a percentage of its value chain in Ethiopia.

For the company to distribute its products in Ethiopia in both B and C scenarios it is assumed that the necessary permission from local regulatory authorities, FMHACA, has been given. For scenario C the percentage of value-chain adding operations done locally is assumed to be at least between 30 and 40%.

vi. Scenario's C unit holding cost for stage 2 (local company stage in Addis Ababa) is lower than Scenarios A's unit holding cost for stage 2 (importers stage).

Without the additional markup from the importers and by having a local company owned warehouse it is reasonable to assume that the holding costs would be lower for scenario C than scenario A.

6.7. Performance indicators

The indicators to measure the performance of the different distribution set-ups are:

- Expected costs. The expected long-run costs of a particular distribution set-up, which include holding costs, transport costs, handling costs and backorder costs.
- Expected profit. The expected long-run profit obtained from a given particular distribution set-up.
- Service level. The proportion of total demand which is delivered without delay from on-hand inventory. This is given as a percentage, and because it is relative to demand satisfied on time, then fewer backorders mean higher service level.

6.8. Parameter values

The values for the parameters were set according to the estimations made in the data analysis chapter and on the assumptions listed previously for the simulation model. Some of these values vary between the different scenarios to adjust to the characteristics of each design; the parameter configurations for each scenario and product are the following:

Table 3. Parameter values for scenario A.

	Product	x	y	z
L'_j	Leadtimes			
up_j	Unit price for product in euros			
sl	Shelf life for product in months			
b_j	Unit backordering cost			
h'_j	Unit inventory holding cost			
h_j	Echelon inventory holding cost			
m_j	Markup %			

Table 4. Parameter values for scenario B.

	Product	x	y	z
L'_j	Leadtimes			
up_j	Unit price for product in euros			
sl	Shelf life for product in months			
b_j	Unit backordering cost			
h'_j	Unit inventory holding cost			
h_j	Echelon inventory holding cost			
m_j	Markup %			

Table 5. Parameter values for scenario C.

	Product	x	y	z
L'_j	Leadtimes			
up_j	Unit price for product in euros			
sl	Shelf life for product in months			
b_j	Unit backordering cost			
h'_j	Unit inventory holding cost			
h_j	Echelon inventory holding cost			
m_j	Markup %			

Demand rate is equal in all scenarios, the rest of the parameters may differ. The manner leadtime is distributed among the stages relies on the set-up properties and the number of echelons present in the design. Backordering cost is equal to markup percentage times the product's unit price, therefore a backorder/stock out matches the value of a lost sale. The unit holding cost increases as stages come closer to the end-customer, i.e. downstream, and is calculated considering the unit value of products at each stage.

Scenario C considers at least 35% of the value-chain operations done locally in Addis Ababa, and consequently leadtimes and markups are adjusted proportionally to allocate the appropriate production time and unit value in both company locations.

6.9. Model performance approximation

To approximate the model performance the simulation results were compared with actual inventory data from a set of chain pharmacies, from which last year's records were retrieved on-site (data that was also used for the demand estimation). This was done to verify if it was possible to replicate the behavior of the chain pharmacy's inventory system by using the simulation model. With the inventory data the performance of the as-is situation, in terms of service level, is approximated analytically; afterwards the simulation is ran with adjusted parameter values until the simulated service level matches the approximated as-is one.

The simulation was adapted to replicate how the distribution would happen from the company to the chain pharmacies. Scenario A, the current situation, is considered, where the first two stages remain as previously described, whereas the third stage represents only the chain pharmacies and not the entire demand from all retailers in urban Ethiopia. The assumed demand distribution for products *x* and *z* for the previous year was used and adjusted to the chain pharmacy's historic demand. The rest of the parameter values remained the same. The historic demand that was retrieved from the chain pharmacy was for one year, from July 2013 to June 2014. The simulation was not run for product *y* as its demand was estimated solely with company sales data and not from the chain pharmacy, so there was no available data for this case. The parameter values used for the validation therefore are the following:

Table 6. Parameter values for validation.

	Product	x	z
L'_j	Leadtimes		
up_j	Unit price for product in euros		
sl	Shelf life for product in months		
b_j	Unit backordering cost		
h'_j	Unit inventory holding cost		
h_j	Echelon inventory holding cost		
m_j	Markup %		
λ	Monthly demand rate		

The base-stock levels in the simulation model are optimized, however in reality this wasn't the case, as it was found that most importers and retailers only order when the products are out of stock or the on-hand inventory is very low. In the chain pharmacy's historic data orders were made only when the on-hand inventory had reached cero. Similarly the company didn't carry the same optimized base-stock levels the simulation provides, but some base-stock level was indeed considered. Consequently five different cases with varying base-stock levels were simulated and analyzed to compare which one was closer to the historic figures. The cases used for the validation are:

Table 7. Cases and values for validation product *x*.

Case	λ	h'_1	L_1	L_2	L_3	b_1	b_2	b_3	s_1'	s_2'	s_3'
Optimal											
s_3'=0											
s_2'=0, s_3'=0											
s_1'=0, s_2'=0, s_3'=0											
s_2'=0, s_3'=0 / 50% less stock than opt											

Table 8. Cases and values for validation product *z*.

Case	λ	h'_1	L_1	L_2	L_3	b_1	b_2	b_3	s_1'	s_2'	s_3'
Optimal											
s_3'=0											
s_2'=0, s_3'=0											
s_1'=0, s_2'=0, s_3'=0											
s_2'=0, s_3'=0 / 75% less stock than opt											

The performance indicator that was used for the comparison between the as-is situation and the simulated one was the service level at the third stage (chain pharmacies). Therefore inventory levels and stock-outs (in this case referred as backorders) were measured. Expected costs and profit were not considered because actual data for these was unattainable.

The simulation was run for all cases and the ones that matched the as-is approximated service levels for both products are shown in tables 3 and 4. The full model validation results for all cases can be found in Appendix H.

Table 9. Validation results for product *x*. Simulation was run with case: no base-stock at last 2 stages and 50% less than optimal stock at stage 1 (s_2'=0, s_3'=0 / 50% decrease at s_1').

As-is approximation Results

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	10	118
Stockouts	3	35
Service level	70%	70%

Simulation Results

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	10	118
Stockouts	3	34
Service level	71%	71%

Table 10. Validation results for product *z*. Simulation was run with case: no base-stock at last 2 stages and 75% less than optimal stock at stage 1 (s_2'=0, s_3'=0 / 75% decrease at s_1').

As-is approximation Results

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	285	3416
Stockouts	117	1400
Service level	59%	59%

Simulation Results

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	285	3415
Stockouts	117	1404
Service level	59%	59%

From these results it is found that the cases that are closer to the as-is approximation when running the simulation are the ones that have the base-stock levels for the last two stages set at 0 (they only order when the inventory level reaches 0), and for the first stage the base-stock levels reduced 50% and 75% for products *x* and *z* respectively. The approximated as-is service levels were found to be 70% and 59% and the nearest simulated matches were 71% and 59% for *x* and *z*.

When running the simulation with the optimal base-stock levels for both products the following results are obtained:

Table 11. Simulation results for case with optimal base-stock levels for product *x*.

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	10	118
Stockouts	0	2
Service level	98%	98%

Table 12. Simulation results for case with optimal base-stock levels for product *z*.

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	285	3416
Stockouts	8	97
Service level	97%	97%

From the results shown in the previous tables it can be seen that the distribution system performs significantly better than the approximated as-is situation when the optimal base-stock levels are utilized. For product *x* the service level increases from 70% to 98%, while for product *z* it increases from 59% to 97%. In relation to amount of stockouts there is a reduction of 94% for *x* and of 93% for *z*. Therefore running the simulation with optimal base-stock levels will lead to an increased availability of products at the retailers, in this case the chain pharmacies, and result in much fewer stockouts and higher service level.

7. Evaluation and comparison of scenario designs

For the evaluation and comparison of scenarios the simulation model was run for every product for every scenario with the parameter values found in Appendix H, and afterwards the output was assessed using the performance indicators defined in the simulation modeling chapter. As the outcomes were similar with all three products, the results shown and described in this chapter are in regard to product *z*, the results for all the products can be found in Appendix K.

The scenarios are compared in terms of expected costs, expected profit and service level. Firstly, the long run expected costs of the system as a whole are compared between scenarios, then the expected costs the company would incur alone are considered. Secondly, the expected profits for the company for each scenario are assessed, note that these are company profits given a scenario, not system profits. Thirdly, the service levels for the system are evaluated, these service levels are taken from the stage 3 results for each simulation, as it is the stage closest to the end-customer, and where it most significant to measure the backorders/stock outs.

7.1. Costs

In terms of total system costs for product *z*, scenario C is the most expensive one to operate, followed by scenario A and scenario B. Scenario B costs 66% less to run than scenario A, and scenario C costs 75% more to run than scenario A. This can be explained by the corresponding unit holding costs at each stage and the length of the leadtimes. Even though the unit holding costs at stage 2 and 3 are lower in scenario C than in scenario A, the end system costs are higher because the leadtime to the last stage is increased, so it is necessary to have a higher base-stock level at the last stage where is more costly to keep products. Scenario B only has two local stages so distribution costs for this set-up are the lowest.

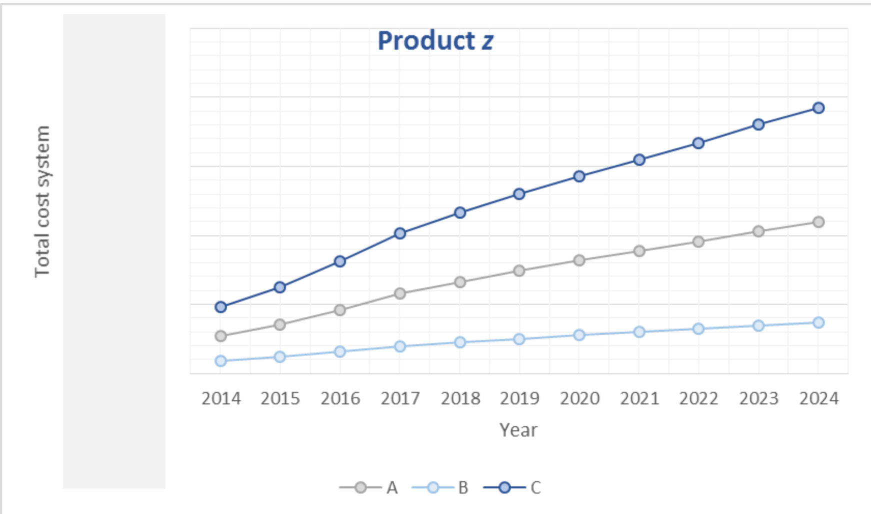


Figure 21. Total system costs per year for distributing product z for scenarios A, B and C.

Note that for product *x* (see in the Appendix K) the total system cost is higher for scenario A than for scenario C, this relates primarily to unit holding costs; the difference with the previous case is that product *x* has a very high unit price in contrast to product *z* that is quite inexpensive, product *x* additionally has a higher markup percentage in the importers stage, which is removed for scenario C, so both of these parameters contribute in making the unit holding cost at stage 2 much more expensive for scenario A than for scenario C, and slightly more costly at stage 3; the end result is that scenario A has higher running costs than scenario C even though the same increase in base-stock levels occurs in the last stage due to modification of leadtimes.

When considering only company costs, scenario C is again the most expensive, followed by scenario A and B. Scenario B costs 49% less to run than scenario A, while scenario C costs 173% more to run than scenario A. The company operates stages 1 and 2 (the warehouse abroad and the local one) so incurs in higher costs than the other scenarios where it is only located either abroad or locally. Therefore local distribution only would be the least expensive for the company.

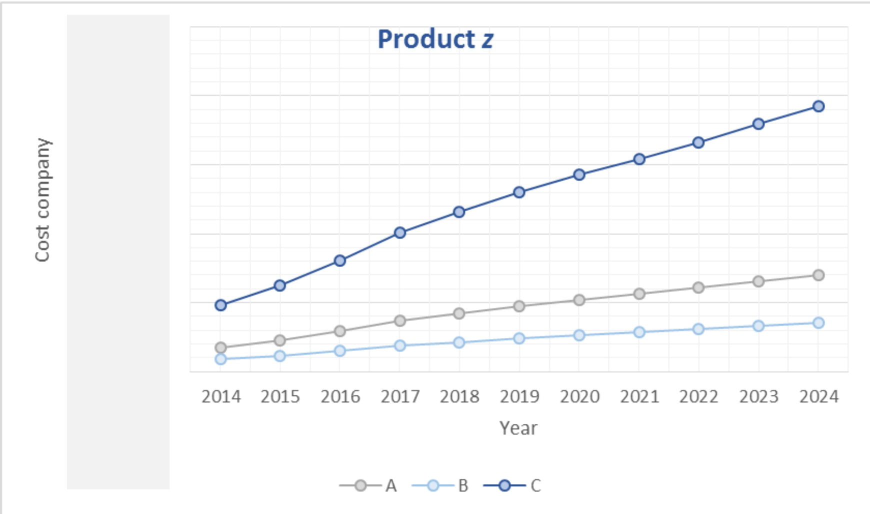


Figure 22. Total costs for company per year for distributing product z for scenarios A, B and C.

7.2. Profit

In relation to profit for the company scenario C has the highest earnings, followed by scenarios B and A, respectively. There is on average a 56% increase in profit from scenario A to C, and a 22% increase from A to B. The calculation of profit already takes into account the revenues and costs of running a distribution system, therefore even though scenario C has the highest costs for the company it's also the one that returns the most profit. Nevertheless, by having the value-added operations in Addis Ababa and having more running costs the company sales the product at a higher price to its customers (this unit price is still lower than the one offered by importers in scenario A). The product's unit price for the end-customers is the lowest in scenario B, then increases for scenario C, and scenario A has the highest. So if in scenario B the company would sell the product at the same price than in scenario C, meaning having a higher profit margin, it would result in the scenario with most profit as the costs of running it are lower.

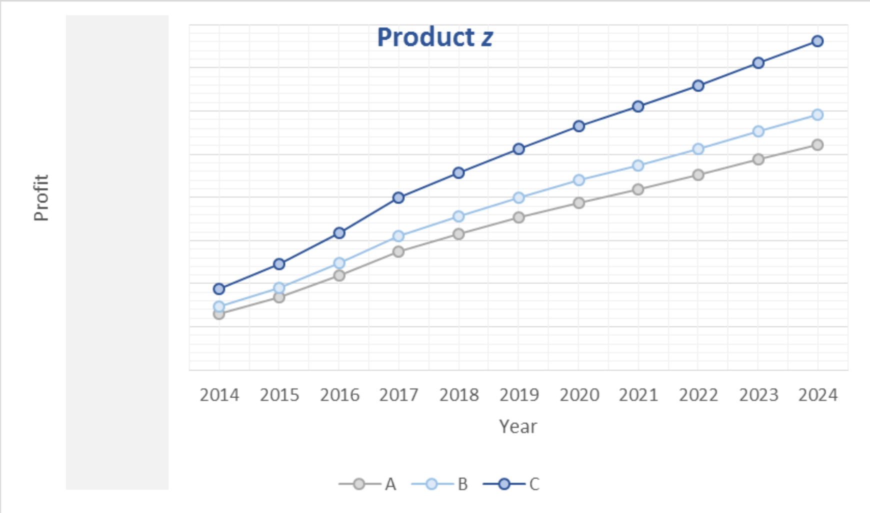


Figure 23. Total profit for company per year for distributing product z for scenarios A, B and C

7.3. Service level

The service levels are very high for all scenarios when setting the base-stock levels at near optimum levels; scenarios B and C have near 100% and scenario A has around 97%. Shortening leadtimes and postponing value-chain operations closer to the customer reduces the bullwhip effect, fluctuations occurring along the supply chain, so both scenarios B and C have the greatest service levels. A longer leadtime furthest from the customer leads to a slightly lower service level for scenario A.

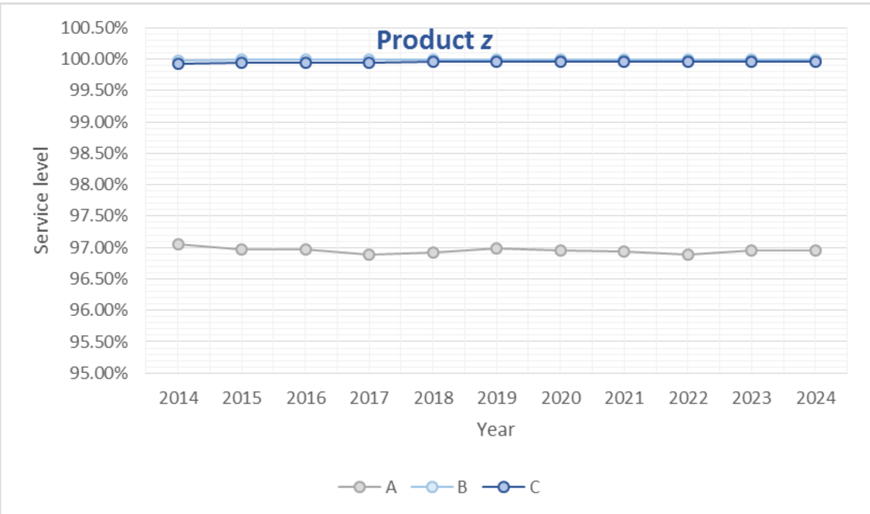


Figure 24. System's service level per year for distributing product z for scenarios A, B and C.

7.4. Effects of modifying parameters on distribution system performance

An exhaustive analysis was performed to evaluate the system behavior relative to changes in the system parameters. Hence it is verified how sensitive the outputs of the simulation model are, i.e. total costs, profit, backorders, inventory levels and service levels, when changes occur in the main decision variables, i.e. base-stock levels, and in the given inputs, i.e. holding, transport and backordering costs, and lead times. The latter is done for the individual scenarios and in comparison to other scenarios to verify if the previously best performing scenario, scenario B, is still the best choice under different circumstances

To perform the sensitivity analysis the simulation is ran each time with a different set of parameter values, these are modified versions from the values found in Appendix H, and the results (simulation output) are recorded for later examination. The reason to perform the sensitivity analysis was to check if the model performs according to the logic that was considered while building the simulation, also to revise if the results hold in respect to what literature says about multi-echelon distribution systems, and finally to check if the solutions still hold and are satisfactory when modifying the parameters. Specifically, parameters are increased and decreased 25, 50 and 75 percent from their initial value, except for the case where having no base-stock at a specific stage or stages is investigated, for this one 100% of the stock level is reduced for a given stage(s). It is expected that the simulation will behave similarly for all products so the analysis was done only for product *z* for the current year (2014), as it has the highest volume demand, and for the proposed three scenarios. It should be taken into account that as the simulation works with stochastic inputs then every time it is ran it gives slightly different results even while running it with the same parameters, so these very minimal differences in the results are considered to occur inherently and not due modifications in the parameter values, identifying and differentiating these is important while interpreting the behavior of the system.

To run the sensitivity analysis it was divided into three parts, one per scenario, and these in turn were divided into one for every parameter that was being analyzed. The results and graphs are found in Appendices M, N and O. Firstly, variation in holding costs is revised where an h'_j is increased and decreased 25, 50 and 75 percent. Secondly, variation in leadtimes is studied where an L_j is increased and decreased 25, 50 and 75 percent. Thirdly, variation in backorder costs is examined where a b_j is increased and decreased 25, 50 and 75 percent. Lastly, variations in base-stock levels are analyzed considering two cases, one where a s_j is increased and decreased 25, 50 and 75 percent; and another where there is no base-stock at the stage furthest downstream and the rest of the s_j are set to optimum, then no base-stock at the last two stages, and finally no base-stock at all stages. Even though the sensitivity of every parameter is studied, modifications for every single one at every stage is not, e.g. for scenario A, h'_1 is examined whereas h'_2 h'_3 are not. The latter is due to time and space limitations, as well as redundancy; the parameters and stages that were selected for each scenario were the ones deemed the most relevant in aiding the company's decision making capabilities.

The analysis is supported visually by graphs that depict the behavioral changes that occur when modifying the parameters, these are found in Appendices M, N and O; each graph illustrates the changes to a specific output with respect to a parameter. If there is no graphic for a particular output, then the output is not sensitive relative to changes in the parameter in question. The horizontal axis always contains the parameter that was modified, while the vertical axis always has the output of interest. For examining these graphs it should be noted that the middle value in the horizontal axis is the initial value, the values on the left of it are its decreases, and the values on the right are its increases. There are cases where displaying the graph with the labels, as it is represented in this section, doesn't properly explain the behavior visually.

It was found from the sensitivity analysis that the two most sensitive parameters were leadtime and then holding costs. Leadtimes affect dramatically as more or fewer products have to be kept in stock wherever the increase or decrease in leadtime occurs. Modifying holding costs also influence results importantly because if the cost of having products in inventory is too high then the simulation will choose to hold much less inventory, and the opposite would occur if the holding cost is very low. Reducing holding cost at stage N is most effective because it carries the reduction to subsequent stages further downstream. Reduction of leadtime at stages further downstream is more effective than at stages further upstream. So in conclusion the company can significantly increase performance by reducing its currently longer leadtimes times and finding ways to reduce holding costs.

8. Improvement recommendations for the company

In this chapter the improvements and recommendations for the company are listed and described, these were determined from the current situation analysis and the results of the simulation model. The improvements focus on increasing the distribution coverage of the company in Ethiopia, and on optimizing the performance of the distribution process. In addition, issues like improving collaboration and information sharing between stakeholders, increasing the amount of information recovered on-site, and other topics that support the distribution planning processes are also accounted for.

I. Use decision support tool to set optimum base-stock levels

The first recommended improvement is to set the base-stock levels to a near optimal level at each stage of the distribution process using the decision support tool built for this thesis and the company. As shown in the simulation model results, this would allow the company to increase profit and service level while lowering costs. Depending on the distribution strategy and the set-up the optimum base-stock levels will differ as calculate how much stock should be kept at each location. Having this safety stock will also act as buffer in case there is insufficient foreign exchange available at a certain point in time. For example it was found, in the approximated as-is situation, that the company had a 70% service level for a product *x* and a 59% service level for a product *z*, for the chain pharmacies with the highest sales in Addis Ababa in the private sector. When utilizing the optimal base-stock levels recommended in the simulation model, service levels of 98% and 97% could be achieved for products *x* and *z* respectively. A reduction in stockouts of 94% for *x* and of 93% for *z* would be achieved by applying the recommended base-stock levels.

II. Move a percentage of value-chain adding operations to Ethiopia

A substantial improvement for distributing into Ethiopia, and potentially for the company's strategy in neighboring countries, would be to locate the latter parts of the value-chain operations in the country. As it was found in the simulations the distribution costs increase for the company but the profit on average increases by 56%, while the service level nears 100% as the response time is significantly shorter for delivering the products to the customers. This set-up is best when locating value-chain adding operations for high priced products with lower demand volume as it was seen with product *x,* which had the best results for this scenario (only increasing 4% in distribution costs but increasing profit by 77%); it is also suited best for products with long leadtimes as with better response time the service level is higher. This set-up would also allow for logistical postponement of other products from the company that are distributed in the country but manufactured entirely abroad. The distribution network for this design would permit direct contact with an increased number of customers and thus increasing local coverage of the company, as the importer stage wouldn't be necessary for products with value-added locally. This would also allow for lower credit costs as the products are held in-country while still technically owned by the company, and thus effectively removing the need for credit to be given to the importer through the shipping and storage phase of distribution

III. Transfer full manufacturing activities to Ethiopia

From a production standpoint, the company could transfer the manufacturing process of some of their products to Addis Ababa. From the simulation results it was found that there would be on average a reduction of 58% regarding distribution costs. Additionally the price of medicines for the final customer could be lowered by 37%, this while maintaining markups proportional to current ones; if the final price remains the same then there would be a higher profit margin for the company. The lower costs of transport, the faster response time, the direct contact with customers locally and the increase in network coverage would justify the higher costs of establishing a local plant. The local knowledge and distribution strength that would be acquired would be essential to establish an extended network of customers and covering more areas of Ethiopia. In the case of achieving a lower final price it could mean being able to increase demand for the products as a larger part of the population would be able to afford them; or in the case where it is found that lowering price would not be perceived positively by customers, then profit percentage would be higher while maintaining the same final price.

IV. Implement an inventory check at retailer level

From an information perspective, there is a lack of data in Ethiopia about availability of medicines at retail points and inventory levels throughout the supply chain. Therefore the use of systematic information collection regarding demand and supply, specifically inventory check, at retailers and other customers would be very beneficial to be able to calculate and optimize the base-stock levels that are researched throughout in this thesis, as well as for planning the demand (forecast) which is necessary to estimate the necessary base-stock levels. Higher frequency reporting to the company by having a system in place, for example having retailers call or text the company with their product availability or current inventory level every day or every week depending on the sales volume. This would also reduce the need for sales teams to visit physically the retailers as the communication and information sharing would improve. Finally this would help to ensure better logistical and financial planning and would deem valuable for the company in order to obtain a better knowledge of the size, income levels, and location of various populations across Ethiopia.

V. Reduce number of 'middle-men'

Whether the medicines are delivered from abroad or locally reducing the number of distributors or steps the products have to go through in the distribution system will allow for lower distribution costs. From the simulation model it was noted that by skipping a level of local distributors would allow for lower costs of distribution and higher profits. The reduction in final price of medicines by removing the importers in the scenario B was in average of 37%, and in scenario C was in average of 28%, these were only approximated based on how the current markups are applied along the supply chain, but indeed prove that lower prices for end customers can be achieved by having less steps in the distribution process. Even if the medicines are distributed through importers it is beneficial to reduce the number of wholesalers and sub-wholesalers that go afterwards. Furthermore, the importers or distributors will be able to increase their sales as well if they are able to buy and sell medicines at lower price.

VI. Identify key distributors for rural areas

A key objective for increasing coverage and distributing to rural areas would be to identify the main buyers and wholesalers that deliver products to these areas. Currently it is unknown who are the key distributors so it is important to identify them to be able to deliver effectively to these areas. Also would be beneficial to understand the kind of characteristics retailers have in the rural market and which products they are able to carry and have high demand for. The product assortment and demand is very different from the private sector due to income level and rural population conditions. Thus, the company could work on creating new retail opportunities in rural Ethiopia by spending time trying to understand the revenue and profit mix of its rural retailers and their business drivers.

VII. Focus sales force team and segment marketing

The sales force team should be focused accordingly to the specific market segments that are desired. And the marketing should be localized for the Ethiopian population in particular, because using the same kind of market strategy for other countries might not always work for Ethiopia. From the on-site research it was found that an advertisement that was used in Kenya and later in Ethiopia was not effective, in Kenya the population saw the woman in the advertisement as happy and healthy, in Ethiopia people thought she looked depressed and unhealthy. Therefore researching appropriate marketing strategy and modifying it for Ethiopia would work best for an increased interest of the population in the company's products.

VIII. Manage key relationships

It is recommended to manage key relationships accordingly, from the on-site research it was found that connections and relationships were the most important factor for retailers when selecting which medicine to buy, even more vital than price or quality. The key relationships are with the main stakeholders involved in the process like PFSA, distributors, importers, retailers, and NGOs. Giving enough face time and providing good service and communication to these stakeholders will be beneficial in the long run to increase the amount of products distributed in the country.

IX. Identify main bottleneck of leadtime and reduce delivery times

The last recommendation is to study the delivery times to find out exactly where the bottleneck is as these play a major factor in the performance of the entire distribution system, as it was described in the sensitivity analysis results. From this thesis it was found that currently there are products that stay in customs longer than expected due to inappropriate paperwork so an obvious way to reduce this is to have employees and importers have their papers in order by establishing a common framework in the system that everybody can work with. However these problems are not a common rule and air shipments should take about two weeks at most to reach the customer and not around a month so from order pickup to delivery there could be additional bottlenecks. It should be noted than in the system there may be discrepancies from reality due to date input errors so these should also be revised if in fact these are explaining reality.

9. Conclusions and implications on Ethiopian urban distribution

9.1. Conclusions

To develop an effective pharmaceutical distribution model for Ethiopia, as it is for sub-Saharan Africa, there are numerous factors to be considered, for example available local infrastructure, stakeholder metrics, distribution channels, and target population. Additionally the company's strategy should be aligned to specific objectives for the market to design the most suitable distribution set-up. However, there is no one single design that fits all due to the different local conditions, e.g. the urban market vs. rural market, and the requirements of each pharmaceutical product, e.g. sales volume, demand volatility, product characteristics, life cycle maturity, customer needs, market variation, and competitive differentiation, so inevitable tradeoffs occur and the company has to determine their business priorities for each product and each customer segment.

The improvement recommendations that are given are in relation to the current set-up of the company and the expected evolution of Ethiopia's pharmaceutical market: setting optimum base-stock levels; moving a percentage of value-chain adding operations to the country or having local production; having better communication and collaboration with customers; reducing the number of 'middle men' along the distribution process; identifying the key distributors for urban and rural areas; further focus sales force teams and segment marketing; and, manage key relationships accordingly.

9.2. Contribution to literature

This thesis contributes to literature by providing an overall description and analysis of the current state of distribution systems in Ethiopia, mainly Addis Ababa and the urban market, which is also helpful for understanding healthcare supply chains in Sub-Saharan Africa and other emerging markets. Academic research on this topic is relatively nonexistent, therefore this thesis sets an initial outline for the pharmaceutical distribution process for Ethiopia, which could serve as a base level from which other researchers can start their investigation on.

The analysis of the relevant stakeholders, local population characteristics, income distributions, markups, and other factors involved in the medicine distribution contributes to define the as-is situation in Ethiopia, and sets the analysis in a point in time which can be referenced and compared for studying future situations. Particular methods and results regarding leadtimes, demand and coverage can be useful as ways to approximate them with the use of various sources due to an overall lack of specific data, and as benchmark for further points in time.

One of the main points in which this thesis contributes is by defining an approach on how to model and analyze distribution systems over time in the Ethiopian private sector, an approach that can be adapted to the public and donor sectors in the country or to other countries in the Sub-Saharan region with similar characteristics. By designing a decision support tool which is part analytical and part simulation that allows for setting near optimum base-stock levels, for evaluating the impacts of modifying set-ups, and for measuring the behavior of the variables involved in the distribution process and their impact on the overall performance. The simulation model is heavily simplified but the results should still hold for determining the necessary base-stock levels for the company and for revising the demand volume and product flow in the latter stages of the supply chain. The variable analysis specifically on leadtimes and holding costs are also useful for determining the impact of these in the distribution process. Finally, this thesis aids literature by providing solutions and recommendations for the future regarding the private sector, and to some extent to the public and donor sectors, in the Ethiopian market.

9.3. Limitations and directions for further research

The limitations of this thesis are mainly about the procedures that were employed to carry out the research due to the amount of available time, resources and data. The directions for further research are provided to fill in the gaps where data was unavailable for the present thesis or given as ideas on how to move forward.

Firstly, regarding the limitations of the overall research and analysis of the current situation. The thesis was done in a company which has a certain set-up in place, not all companies will have the same conditions, and even in the same company changes occur. The demand estimations were done with a small set of data, public figures and several assumptions, so these are only approximations. Planning based on historical sales data when available would be more precise to estimate the forecast. As some of the information was gathered by performing interviews on-site, factual data should be revised to provide more precise figures in the future. The scope of the research could be expanded to include the rural market of Ethiopia which has a different set of settings not found in the urban market.

Secondly, the limitations and directions for future research concerning the simulation model are mentioned. The simulation of the distribution systems is a mere representation of reality that is heavily simplified, so even though it is a useful benchmark and provides valuable information on the performance of the system, in reality there may be a gap between simulated figures and actual figures. The simulation model was done for the private sector but could be adapted to the other sectors, however it depends on the specific case; for public sector it would be appropriate for the company to set it up to delivering the products to the PFSA and not the final customer (the company can’t see or modify the PFSA distribution network); and for the donor sector would depend through which set-up the medicines are distributed to decide until which customer/stakeholder is pertinent to model. Lastly, the analysis of changes in price and their impact on the distribution could also be an attractive topic for the simulation, e.g. how do variations in price affect the distribution, or what is the impact on demand if a lower final price of medicines can be achieved.

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11. Appendices

Appendix A: List of abbreviations

- CSA - Central Statistics Agency of Ethiopia;
- CSL - Customer service level;
- CVD - Cardiovascular disease;
- EDL - Essential drug list;
- FMHACA - The Food, Medicines and Healthcare Administration and Control Authority;
- FMOH - Federal Ministry of Health of Ethiopia;
- GDP - Gross domestic product;
- GOE - Government of Ethiopia;
- GNI - Gross national income;
- NCD - Non-communicable disease;
- NGO - Non-governmental organization;
- OTC - Over-the-counter medicine;
- PHCU - Primary Health Care Unit;
- PHSP - Private Health Sector Program;
- PPP - Public-private partnership
- PSLD - Pharmaceutical Supply and Logistics Department;
- PFSA - Pharmaceutical Fund Supply Agency;
- RHB - Regional Health Bureau;
- SOP - Standard operation procedures;
- SSA – Sub-Saharan Africa;
- USAID - United States Agency for International Development;
- WHO - World Health Organization.

Appendix B: List of sources

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Appendix C: Population data

Table 13. Population of Ethiopia (CSA, 2013).

Name	Abbr.	Status	Capital	Area (km^2)	Population (2013-07-01)
Addis Ababa	AA	City	Adis Abeba	527	3,103,999
Afar	AF	St	Asayita	72,053	1,649,999
Amhara	AM	St	Bahir Dar	154,709	19,211,994
Benishangul-Gumuz	BE	St	Asosa	50,699	1,027,994
Dire Dawa	DD	City	Dire Dawa	1,559	395,000
Gambela	GA	St	Gambela	29,783	406,004
Harari	HA	City	Harer	334	215,000
Oromia	OR	St	Adis Abeba	284,538	32,220,001
Somali	SO	St	Jijiga	279,252	5,318,000
Tigray	TI	St	Mek'ele	84,722	5,061,991
SNNP	SN	St	Awasa	105,476	17,887,005
Total	**ETH**	**Fed Rep**	**Adis Abeba**	**1,063,652**	**86,613,986**

Table 14. Urban population of Ethiopia (CSA, 2013).

	Name	Population		Name	Population
1	Abiy Addi	21,400	76	Hagere Hiywet (Ambo)	61,900
2	Abomsa	18,800	77	Hagere Maryam [Hagere Mariam]	35,700
3	Adet	24,500	78	Harer [Harar]	112,800
4	Adigrat	76,400	79	Hartisheik [Hart Sheik]	17,000
5	Adis Abeba [Addis Ababa]	3,103,700	80	Himora [Humera]	28,700
6	Adis Zemen [Addis Zemen]	20,600	81	Hosaina [Hosaena]	100,500
7	Adwa	53,800	82	Hurata	17,000
8	Agaro	32,700	83	Inda Silase	62,800
9	Aksum [Axum]	59,300	84	Injibara	27,000
10	Alamata	44,100	85	Iteya	19,300
11	Alemaya (Haromaya)	39,500	86	Jijiga	152,700
12	Aleta Wendo	31,700	87	Jima [Jimma]	155,400
13	Arba Minch	107,500	88	Jinka (Bako)	29,100
14	Areka	45,100	89	Kebri Dehar [Kebri Dahar]	35,500
15	Arsi Negele	60,800	90	Kembolcha [Kombolcha]	75,100
16	Asasa	26,600	91	Kemise	24,900
17	Asayita [Asaita]	24,300	92	Kibre Mengist (Adola) [Kebri Mangest]	29,500
18	Asbe Teferi (Chiro) [Asebe Teferi]	43,300	93	Kobo	31,800
19	Asela [Asella]	86,400	94	Kofele	17,300
20	Asosa	40,700	95	K'olito (Alaba K'ulito)	38,600
21	Awasa (Hawassa)	225,700	96	Korem	22,400
22	Awash Sebat Kilo	22,500	97	Lalibela	22,200
23	Awubere	13,100	98	Leku	17,000
24	Ayikel (Chilga)	19,400	99	Logia	21,200
25	Babille	22,800	100	May Cadera (May Kadra)	17,100
26	Bahir Dar	198,900	101	Maych'ew	31,100
27	Bako	21,100	102	Mek'ele (Debub & Semen Mek'ele)	286,600
28	Bati	21,400	103	Mekhoni	18,300
29	Bedele	25,100	104	Mek'i	46,600
30	Bedessa	23,400	105	Mendi	18,000
31	Bekoji	22,800	106	Mer Awi	23,900
32	Bichena	20,700	107	Mersa	20,600
33	Boditi	34,700	108	Metu	37,000
34	Bonga	30,000	109	Mieso	17,100
35	Burayu	62,800	110	Mizan [Mizan Teferi]	33,200
36	Bure	26,100	111	Mojo	38,000
37	Butajira	48,000	112	Mot'a	33,500
38	Chagne [Chagni]	29,700	113	Moyale	35,800
39	Chuko	26,500	114	Nazret (Adama)	283,000
40	Dangila	31,800	115	Nefas Mewcha	25,100
41	Debark' [Debarq]	26,700	116	Negele [Negele Boran]	45,300

42	Debre Birhan [Debre Berhan]	83,500
43	Debre Markos [Debre Marqos]	80,000
44	Debre Tabor	71,100
45	Debre Zeyit (Bishoftu)	128,400
46	Deder	16,700
47	Degeh Bur [Degehabur]	36,400
48	Dembi Dolo	37,800
49	Dera	19,000
50	Derwernache [Derwonaji]	13,900
51	Dese [Dessie]	153,700
52	Dila	85,000
53	Dire Dawa	269,100
54	Dodola	26,800
55	Dolo	31,900
56	Dubti	22,300
57	Durame	35,100
58	Este (Mekane Yesus)	17,800
59	Fiche	35,300
60	Finote Selam	33,200
61	Gambela	64,500
62	Gebre Guracha (Kuyu)	25,500
63	Gelemso	21,200
64	Genet (Holata)	29,900
65	Gidole	18,900
66	Gimbi	39,800
67	Ginchi	23,300
68	Ginir	22,000
69	Giyon (Waliso)	48,700
70	Goba	41,200
71	Gode	52,400
72	Gonder [Gondar]	265,000
73	Guder	18,900
74	Gutin	17,500
75	Hadero	25,600
117	Nejo	24,400
118	Nekemte	96,700
119	Robe (Bale Zone)	57,000
120	Robe (Arsi Zone)	19,500
121	Sawla (Felege Neway)	32,600
122	Sebeta	63,400
123	Shakiso	29,500
124	Shambu	19,300
125	Shashemene [Shashamane]	129,100
126	Shewa Robit (Kewet)	22,500
127	Shinshicho	20,500
128	Shiraro	22,600
129	Shone	22,400
130	Sodo	109,200
131	Sok'ot'a [Soqota]	28,600
132	Tepi	35,700
133	Tis Abay	22,200
134	Togo Chale (Tog Wajaale)	17,500
135	Tulu Bolo	18,600
136	Weldiya	59,000
137	Welenchiti	19,500
138	Welkite	41,500
139	Wenji Gefersa	18,100
140	Werota [Wereta]	27,200
141	Wik'ro [Wukro]	40,100
142	Yabelo	22,500
143	Yirga 'Alem	43,600
144	Yirga Chefe	21,700
145	Ziway	56,100

Table 15. Population of Addis Ababa (CSA, 2013).

Zone	area (sq.km.)	Density	Total Population		
			Male	Female	Total
Addis Ababa	**526.99**	**5,890**	**1,479,000**	**1,624,999**	**3,103,999**
Akaki Kaliti	118.08	1,739.40	100,513.00	104,872.00	205,385
Nefas Silk-Lafto	68.3	5,246.80	168,798.00	189,561.00	358,359
Kolfe Keraniyo	61.25	7,933.90	235,257.00	250,695.00	485,952
Gulele	30.18	10,047.20	146,605.00	156,621.00	303,226
Lideta	9.18	24,896.20	109,076.00	119,471.00	228,547
Kirkos	14.62	17,145.30	117,265.00	133,400.00	250,665
Arada	9.91	24,181.40	112,354.00	127,284.00	239,638
Addis Ketema	7.41	39,047.80	141,509.00	147,835.00	289,344
Yeka	85.98	4,568.30	183,083.00	209,698.00	392,781
Bole	122.08	2,867.80	164,540.00	185,562.00	350,102

Appendix D: Points of sale data

Table 16. Private sector points of sale and number of importers, wholesalers and manufacturers (CSA, 2013.

	Pharmacy	Drug Shop	Rural Drug Vendor	Total	Import & Wholesalers	Manufacturer
Addis Ababa	189	232	1	422	169	8
Affar	0	30	26	56	0	0
Amhara	46	353	134	533	19	0
Benishangul-Gumuz	2	7	28	37	0	0
Dire Dawa	11	21	2	34	7	0
Gambela	2	6	21	29	0	0
Harari	7	25	1	33	3	0
Oromia	85	545	618	1248	19	2
Somali	10	175	205	390	0	0
Tigray	7	129	113	249	9	2
SNNP	19	139	244	402	20	0
Total	**378**	**1662**	**1393**	**3433**	**246**	**12**

Table 17. Public sector points of sales (CSA, 2013). (Others include all others except under Ministry of Health, Police and defense.)**

	Hospitals			Clinics	Health Centers	Health Posts	Pharmacies
	MOH	Others**	Beds	MOH			
Addis Ababa	6	30	1199	650	52	0	140
Affar	4	0	385	9	57	272	55
Amhara	19	4	3796	1004	673	3093	817
Benishangul-Gumuz	2	2	196	80	32	339	39
Dire Dawa	1	4	309	35	15	34	24
Gambela	1	0	381	40	30	175	14
Harari	2	4	453	29	7	23	48
Oromia	42	13	9936	1649	1057	6053	729
Somali	7	2	168	28	111	951	92
Tigray	14	5	3690	124	196	552	462
SNNP	**20**	8	1210	581	592	3603	502
Referral hospitals	4	6	23311				19
Total	**122**	**78**	**45034**	**4229**	**2822**	**15095**	**2941**

Appendix E: Demand estimation

Appendix F: Coverage estimation

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Appendix G: Simulation model notation

Table 18. Simulation model notation

Network topology
N: set of all stages
R: set of retailers of stage j, $\{R \in N\}$
Inputs and parameters
λ_j: monthly demand rate at stage j
L_j: leadtime at stage j to $j+1$
D_j: leadtime demand at stage j
h'_j: unit local holding cost at stage j
h_j: echelon inventory holding cost at stage j
b_j: unit backordering cost at stage j
B'_j: local backorders at stage j
sl_k: shelf life of product k in months
up_k: Unit price for product k in euros
m: markup percentage at stage j
s'_j: local base − stock level at stage j
s_j: echelon base − stock level at stage j
Outputs and cost functions
I'_j: on − hand inventory at stage j
I_j: echelon inventory at stage j
IN_j: echelon net inventory at stage j
IP_j: the inventory position at stage j
IT_j: inventory on transit to stage j
IO_j: outstanding order process at stage j
ITP_j: echelon inventory transit position at stage j
IOP_j: Echelon inventory − order position at stage j
BC: total expected cost of backorders in the system per unit time
HC: total expected holding cost of the system per unit time
TC: total expected cost of the system per unit time
β_j: service level at stage j

Appendix H: Validation model results

Table 19. Validation model results for product *x*.

As-is approximation Results

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	10	118
Stockouts	3	35
Service level	70%	70%

Simulation Results

Optimal

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	10	118
Stockouts	0	2
Service level	98%	98%

No base-stock at last stage

$s_3'=0$

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	10	118
Stockouts	0	6
Service level	95%	95%

No base-stock at last 2 stages

$s_2'=0$, $s_3'=0$

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	10	119
Stockouts	2	22
Service level	82%	82%

No base-stock at 3 stages

$s_1'=0$, $s_2'=0$, $s_3'=0$

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	10	118
Stockouts	5	59
Service level	50%	50%

No base-stock at last 2 stages 50% less than optimal stock at stage 1

$s_2'=0$, $s_3'=0$ / 50% decrease at stage 1

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	10	118
Stockouts	3	34
Service level	71%	71%

Table 20. Validation model results for product *z*.

As-is approximation Results

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	285	3416
Stockouts	117	1400
Service level	59%	59%

Simulation Results

Optimal

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	285	3416
Stockouts	8	97
Service level	97%	97%

No base-stock at last stage

$s_3'=0$

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	285	3417
Stockouts	15	184
Service level	95%	95%

No base-stock at last 2 stages

$s_2'=0$, $s_3'=0$

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	285	3417
Stockouts	59	703
Service level	79%	79%

No base-stock at 3 stages

$s_1'=0$, $s_2'=0$, $s_3'=0$

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	285	3416
Stockouts	144	1724
Service level	50%	50%

No base-stock at last 2 stages 50% less than optimal stock at stage 1

$s_2'=0$, $s_3'=0$ / 75% decrease at stage 1

	Mid 2013 - Mid 2014	
	monthly	annual
Demand	285	3415
Stockouts	117	1404
Service level	59%	59%

Appendix I: Evaluation and comparison of scenarios method I

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Appendix J: Evaluation and comparison of scenarios method II

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Appendix L: Cases and values for sensitivity analysis

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Appendix M: Sensitivity analysis scenario A

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Appendix N: Sensitivity analysis scenario B

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Appendix O: Sensitivity analysis scenario C

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