Developing an industry solution to service bottom-end markets in South Africa

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Executive Summary

Logistics and distribution services have been around since the early 1950's. During this time it was only thought of as military services, but since then it has developed into a system that can give any company a competitive edge, if the network is designed efficiently.

Due to the increasing competition in the logistics and distribution industry, it has become increasingly important for companies to gain a competitive advantage over their competitors. This entails exploring untapped markets, such as the BOP (bottom of the pyramid) market segment.

The aim of this project is to determine whether there is a market opportunity in South Africa to service this segment. The market evaluation can be broadly classified into the market size, structure, and preferences of the consumers constituting this market segment. The problem investigation phase of this project evaluated the market opportunity, which concluded that the BOP market consists of four billion people, which constitutes 72% of the global population. In South Africa the BOP market consists of approximately 30 million people, which is 47% of the population. This validates that there is a great market opportunity for food producers and distributors to enter the market.

Servicing and distributing to the BOP market comes with added complexity, thus traditional supply chain thinking will not suffice. The complexity in this market are due to a few contributing factors, such as the cash poor consumers constituting the BOP market, the lack of infrastructure, longer time frames and limited product awareness. Numerous companies have tried to improve their profits and overcome the challenges in distributing to the BOP market by bridging the infrastructure gap through selecting the appropriate technologies and controlling costs through differential or layered distribution networks.

The BOP market has a relatively high success rate in terms of market penetration (5% to 10%) but operation in this market proves to be difficult. A literature review based on companies who have successfully entered the BOP market segment proved that it is possible to operate successfully in this market segment. The key success factors of these distribution companies were noted and the distribution models implemented were further researched. The literature case studies presented in this report validate that traditional distribution channels will not be sufficient to service the BOP market in African countries. Alternative distribution channels need to be developed which are innovative and based on inclusive business models.

An evaluation framework was developed based on key criteria in order to evaluate the several distribution models. The distribution models were further evaluated based on technical and financial aspects. Based on the results of the evaluation framework, technical and financial evaluation, the applicable distribution method was modelled in order to make an effective recommendation.

The dataset was reduced in order to create a proof of concept for the model, as the probability that this can be replicated on a larger set of data is very likely. The ideal location for the hub was determined by using the centre of gravity method with the respective inputs as discussed in the literature review. The dataset was further reduced to form clusters in order to conduct spoke location analysis. The ideal spoke locations were determined by using the centre of gravity method, as for the hub location, thus creating predefined locations for the spokes to be situated at. The optimal number of spoke locations was determined by creating an optimization model, through the use of the Operations Research approach, to minimize the number of spoke locations, which was formulated using Lingo. Through the use of the optimization model, an entire distribution network was developed based on the test case data. The developed model was validated by conducting a sensitivity analysis, which proved that the model behaves as expected.

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Chapter 1

Introduction

1.1 Problem Introduction and Background

The first informal documentation of logistics and distribution services was in the early 1950's. During this time logistics were thought of as military services. These services consisted of maintenance, procurement and transportation of military equipment and personnel. Around the 1960's the first text book (Smykay et al., 1961) and college course at the Michigan State University appeared (Ballou, R.H., c2017).

The study and implementation of physical logistics and distribution appeared in the 1960's and 1970's. Because of the lack of information and attention paid to logistics and distribution, the costs were extremely high. In later years more emphasis were placed on distribution and logistics and thus the term supply chain management emerged (Ballou, R.H., c2017).

The CSCMP states that logistics management is that part of supply chain management that plans, implements and controls the efficient forward and reverse flow and storage of goods, services and related information between the point of origin and point of consumption in order to meet customer requirements (Ballou, R.H., c2017).

According to Shukla, S. and Bairiganjan, S. (2011) a distribution channel can be visualized as a series of intermediaries who pass the product down the chain to the next operation until it finally reaches the consumer. Each element in the chain has its own specific need, motivation and ability to deliver in a unique environment.

Distribution services may be conducted by the manufacturing company itself, or it can be outsourced to third party logistics providers (3PL). Through the use of a 3PL, the company looking to outsource have the ability to focus solely on their core business which results in improved performance and reduced costs (Yadavalli, V.S.S., Balcou, C., 2017). According to the work done by Yadavalli and Balcou (2017) the logistics and transportation industry has experienced significant growth, which means that the need for a company to differentiate themselves from their competitors operating in the same environment have become increasingly important. One of these differentiating factors may be to reach into untapped markets.

The general trend in market entry is to target the consumers situated at the top tier of Prahalad's BOP model as the market and structures are already in place. This tends to create a 'Red Ocean' phenomenon, as multiple companies are competing for the same customers. The 'Red Ocean' is characterised by exploiting existing demand, competing in an existing market space and fierce competition. In order to grow a business, companies should aim at creating a 'Blue Ocean' strategy. This entails entering a new, unexplored market to create new demand in an environment characterized by low competition, as this market is generally more complex to penetrate and operate within.

The focus of this project will be on the business opportunity which the BOP (bottom of the pyramid) market potentially holds for the logistics industry. The project will also aim to develop a distribution strategy to successfully service this market segment as it tends to be more complex than urban distribution.

The consumers comprising this market segment are characterized by unmet basic needs. Most companies have not considered consumers at the BOP as potential consumers due to the low level of individual incomes and all the challenges associated with entering this market. Business at the BOP is characterized by high volume sales and small profit margins. The large volumes of products require distribution models which are effective and capable of delivering to the market segment at scale. In South Africa the majority of the consumers are situated in the BOP market, showing that there is business potential to service this market. The BOP market has significant developmental needs which should be evaluated.

The competition in this market segment is also relatively low due to the complexity of the market. The development and maintenance of distribution networks can be challenging due to the fact that the BOP consumers are typically located in areas which are harder to reach, the infrastructure is poor and populations are scattered, which means that the traditional methods as used in urban distribution will not suffice.

Figure 1.1 shows the average household expenditure of consumers which form the BOP market. This figure indicates that the biggest expense is food, thus it would be beneficial for food manufacturers and distributors to successfully service this market segment.

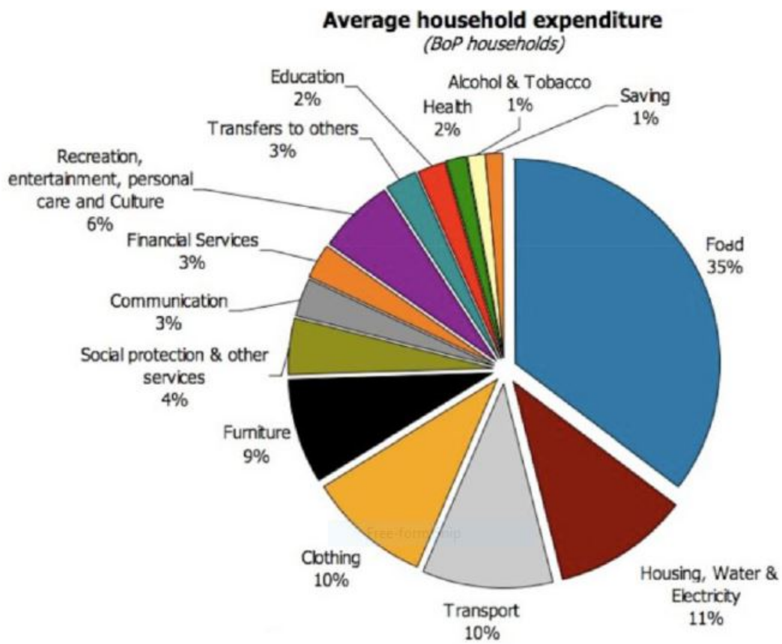

Figure 1.1: Average Household Expenditure (DI International Business Development, 2010)

Other reasons to target the bottom-end market include:

- reaching into untapped markets;
- providing sustainable living;
- brand recognition; and
- community enrichment and development.

1.2 Problem Statement

Due to advancing globalisation, declining trade barriers and an increasingly mobile workforce, the transport and logistics industry continues to enjoy above-average growth. According to the work done by Yadavalli and Balcou (2017), the industry of third party logistics providers (3PL) as highlighted by the work of numerous authors, is a highly competitive environment. Numerous different criteria is used when potential clients select a 3PL. The growing and developing list of criteria used in selecting a 3PL highlights the fact that the smallest inability is viewed as the lack of quality of service, which is ranked as the top criteria when choosing a 3PL provider. It is therefore very important to explore untapped markets in order to remain competitive in this industry.

In order to secure future growth and profits, companies should aim to explore the 'Blue Ocean', as these markets tend to be uncontested with a latent demand and growth potential. Strategic moves such as entering a new market create value for the company and its customers by avoiding rivalry. Companies face obvious competitive advantages in the 'Blue Oceans' at the BOP if they succeed in using innovative strategies for production, distribution, marketing and sales (DI International Business Development, 2007).

It is a common belief that the consumers situated at the bottom of the pyramid have no significant purchasing power and therefore do not represent an attractive market, however this assumption ignores the high volume of this market segment. According to research conducted by DI International Business Development (2007) the BOP market represents an immense business opportunity for companies aiming to enter the market for the following reasons:

- the extensive size of the market;
- potential cost-saving opportunities;
- a less competitive environment; and
- opportunities for innovation.

The global population per capita income is depicted in Figure 1.2. This figure indicates that four billion people live on low incomes which can be classified as the BOP market globally, emphasizing the volume of consumers which constitute the BOP market segment. Recent data also suggests that BOP markets have the fastest population and market growth rate.

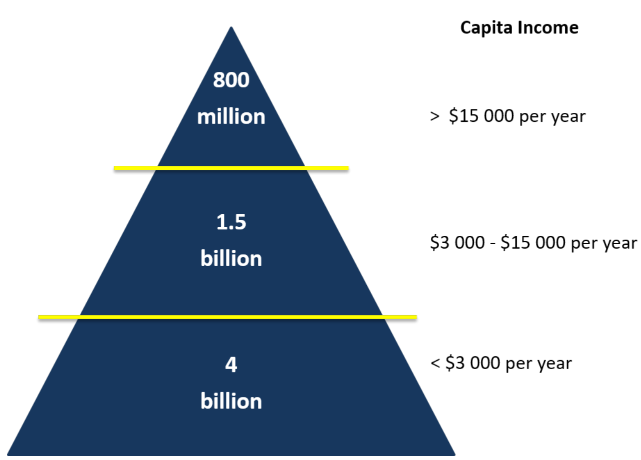

Figure 1.2: Global Population per Capita Income

The BOP market in South Africa consists of approximately 30 million people out of a population of around 45 million people (DI International Business Development, 2010). To be classified as a BOP consumer, the purchasing power of the individual has to be less than $3 000 annually. At the current exchange rate this is approximately R37 311,00 per year. The BOP in South Africa represents a $40 billion market (DI International Business Development, 2010), which is a market of approximately R510 billion.

Servicing the bottom-end markets are generally more complex and expensive, because stores are usually very small and the order and delivery quantities are low. The order and delivering quantities are low because the bottom-end markets usually have little to no storage space on premises (such as spaza shops, garage shops, etc.). The challenges to successfully service the BOP market broadly fall into three categories. Figure 1.3 shows a graphical representation of these three categories and the contributing factors to the complexity of the market.

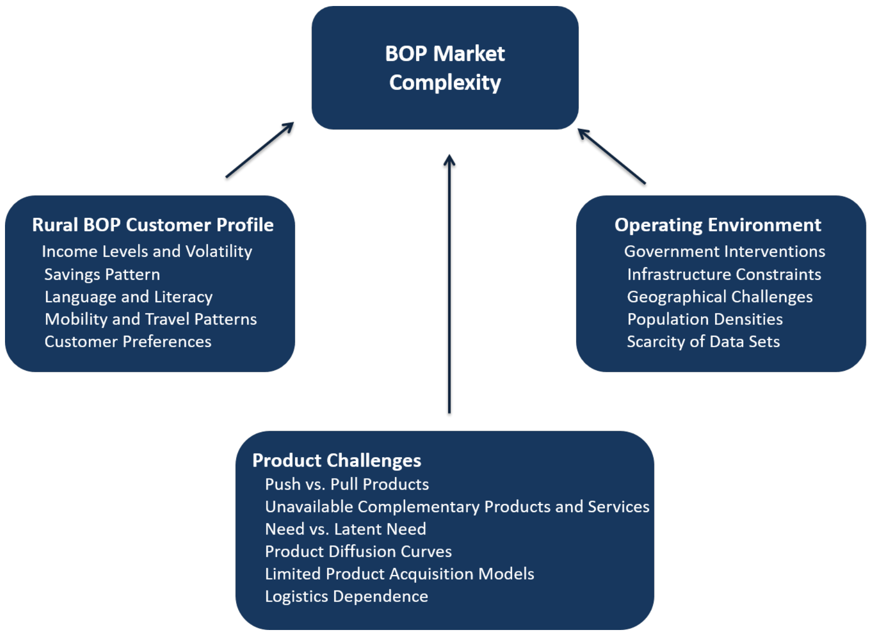

Figure 1.3: BOP Market Complexity and Contributing Factors

Prahalad identifies the BOP market as a source of radical innovation (Wanasika, I., 2013). The main challenge is to develop viable business structures to service a market segment which is unorganised and fragmented. Unique solutions for unique BOP markets would have to be developed within constraints to create an innovative and viable solution.

According to Simanis, E. (2012) the documentation of commercial ventures that could not make a sustainable profit is a common occurrence in the bottom-end markets, despite healthy penetration rates. The Harvard Business Review (Simanis, E., 2012) notes that a few venture pilots have been run and the findings of all of these projects were that the costs to service these markets were too high. The customer acquisition and retention of new products in this market demands intense and costly levels of high-touch engagement. As a result of covering the high costs, the volumes needed to break-even is much higher.

1.3 Project Aim and Scope

The aim of this project is to develop an industry solution to service bottom-end markets in South Africa and to determine why companies would want to target this market. It is important to understand the as-is service to this market, in order to suggest a to-be industry solution of servicing this market in the future.

Factors which need to be taken into consideration when evaluating the as-is market are:

- product characteristics;

- product quantity (demand) and size;
- how manufacturers and logistics providers are successfully servicing the market in a financially viable manner;
- available distribution channels to service the market (direct distribution vs. wholesale channel, etc.);
- evolution of bottom-end markets;
- the influences in the market;
- how other African countries service the BOP market segment;
- the value proposition to service the bottom-end market; and
- the geographical layout in terms of the distance of informal settlements to the main regions.

The key considerations in the BOP market are:

- small volumes (small individual store drops/deliveries);
- limited but a very specific product range/SKU;
- very little storage space at stores; and
- low adoption rate of technology and electronic payment systems.

Other key aspects to take into consideration are:

- the profit margin will be low, but the unit sales can be very high due to the large number of consumers constituting the BOP market;
- profits in this market segment are driven by volumes rather than high margins;
- infrastructure need to be investigated to effectively service the bottom-end market;
- consumption in the rural market differs from consumption in the urban markets; and
- differences between the urban and rural markets are significant.

The main differences between the urban and rural markets can be seen in Table 1.1.

The BOP markets in South Africa rest on low margin per unit and high volumes, thus companies striving to chase high margins would fail in this market (DI International Business Development, 2010).

1.4 Project Approach and Deliverables

A phased approach would be used to execute the project with associated key deliverables as discussed below.

Phase One: this phase would consist of researching the global and South African BOP market to ensure a clear understanding of the market trends, entry barriers to the market, constraints and opportunities. A very intensive literature study will be conducted on logistics providers who have successfully entered the BOP market in Africa, noting the hurdles which were overcome to service the market, the success factors and the related industrial engineering mechanisms applied to the ensure success. The research based on previous work would assist in evaluating and understanding the as-is scenario, which is important to develop the to-be. The deliverables of this phase are:

- detailed analysis of the BOP market both globally and locally;

Trait	Urban (Latin)	Rural (African)
Macro Environment		
Size	800 million	1 200 million
Micro Environment		
Channel Structure	Primitive in informal segments Modern in formal segments	Primitive
Competition	Foreign	Local
Prices	Higher prices for FMCG Lower prices for produce	Higher prices for FMCG Lower prices for produce
Language	National language	Multiple
Consumer Behaviour		
Segmentation	Demographics, lifestyle	One size fits all
Family Structure	Weak/matriarchal	Strong/extended
Values	Modern	Traditional
Shopping Occasions	Varied in dual markets	Continuous for daily needs
Relative Importance Of		
Low Prices	Constraints purchase	Determines choices
Brands	High	Nil
Convenience	High for employees	Low

Table 1.1: Key Urban and Rural Traits (Ireland, J., 2008)

- evaluation of the market potential in South Africa;
- a literature study based on other logistics providers who have successfully penetrated the BOP market;
- key considerations in developing a distribution model;
- the various distribution channels to service a market segment; and
- modelling approaches to develop alternative distribution networks.

Phase Two: This phase would consist of the application of knowledge, tools and techniques as developed through the industrial engineering course. Further research would be conducted on successful distribution models to service this market segment. A detailed analysis of these models will be performed to determine the relevance of each model to the problem statement, previous work and the objectives of the project. It is also important to take into consideration the alternative distribution channels which are available to service the BOP market segment as it is known that this segment has a fragmented and scattered market structure. A framework for evaluating the various distribution models will be created based on key criteria. The distribution models will then be evaluated based on the framework to select the most efficient route to market. The deliverables of this phase are:

- research and evaluation of distribution models based on alternative distribution channels;
- development of a framework to identify key criteria that will establish the most effective route to market;
- evaluation of the various distribution models based on the developed framework.

Phase Three: During this phase the recommended solution will be developed based on real data. The developed model will then be analysed and validated. Thus the deliverables of this phase are:

- model development;
- model validation; and
- a detailed analysis of the results as obtained in the model.

Chapter 2

Literature Review and Problem Investigation

2.1 Problem Investigation

The problem investigation phase aims to determine the market potential. If the market potential exists, this phase would also outline where in South Africa the market potential is situated. Furthermore this phase evaluates the preferences of the consumers constituting the BOP market segment globally and in South Africa in order to determine the industry market potential for logistics providers.

2.1.1 Global BOP Market

The BOP market consists of approximately four billion people, which constitutes 72% of the global population. The individuals who form the BOP segment represent the majority of the population in developing countries of Asia, Latin America, Eastern Europe and Africa. Table 2.1 presents the BOP population, income and market size of each of the previously mentioned countries.

Region	BOP Population (millions)	BOP Population (share of total population)	BOP Income (billion $)	BOP Share of Total Market
Africa	596	95%	429	70.5%
Asia	2 858	83%	3 470	41.7%
Eastern Europe	256	64%	458	36.0%
Latin America	360	70%	509	28.2%
Global BOP	**4 000**	**72%**	**5 000**	

Table 2.1: BOP Population, Income and Market Size (DI International Business Development, 2007)

Table 2.1 demonstrates the business opportunity to enter the BOP market. The results from Table 2.1 explicitly show the business potential in Africa, where the BOP market constitutes 95% of the population and 70.5% of the total market. Sources note that the BOP market in Africa is smaller when compared to other African countries but it is still the dominant consumer market.

Following the market potential evaluation, the spending patterns of the consumers constituting the BOP market segment need to be evaluated. Spending patterns in the various BOP regions differ from one another and thus influence the market potential within the main BOP sectors. As can be seen from Table 2.2 the food market represents the largest BOP market segment and thus the largest share of household expenditure. It has an estimated value of $2.89 trillion, which is a lot higher when compared to other market segments.

Market Sector	Market Size (billion $)
Food	2 894
Power (Energy)	433
Housing	332
Transportation	179
Health	158
Information and Communication Technology	51
Water	20

Table 2.2: BOP Sector Markets (DI International Business Development, 2007)

2.1.2 BOP Market in South Africa

The main theme which can be taken from various researched sources is that there is a lack of information to fully understand the trends of the BOP market, consumer behaviour and distribution strategies to service the BOP market in a financially viable manner (Osborn, D., 2011). Evidence which is clear from the research is that an enormous business opportunity in South Africa does exist to successfully service this market segment, given enough time and effort is spent to fully understand and anticipate potential market entry barriers.

The market potential in South Africa is relatively large as South Africa is categorised as a developing country, which means that the income of the population is expected to be lower than in the developed countries, such as France and Switzerland. Approximately three million individuals live on less than R5.00 a day in South Africa and nearly 18 million people live on under R20.00 a day (Osborn, D., 2011). About 20.9 million people in South Africa can be categorised into the bottom tier of Prahalad's BOP model, which is depicted in Figure 2.1. This represents about 47% of the population of South Africa, thus companies cannot afford to ignore this significant category and the preferences of the consumers within it.

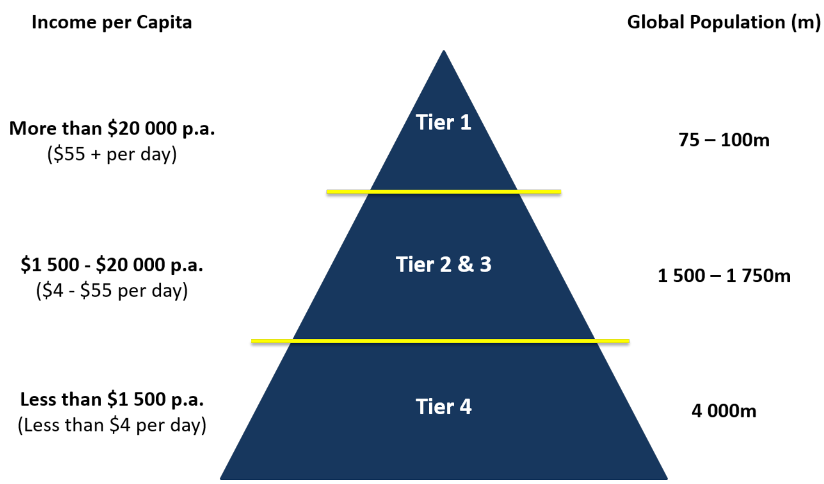

Figure 2.1: Prahalad's BOP Model (Prahalad, C.K., 2004)

It is clear that a market potential do exist in South Africa to service the BOP market segment. Consequently it would be beneficial to evaluate the expenditure of the consumers constituting this segment. Figure 2.2 depicts the market for consumer goods in South Africa. As can be seen from Figure 2.2 the market consists of predominately beverages and food, furniture, clothing and personal care items. Grocery purchases constitutes between 35% to 60% (Gomez-Arias et al., 2008) of a household's income, thus causing South African retailers, manufacturers and distributors to compete in trying to capture more market share.

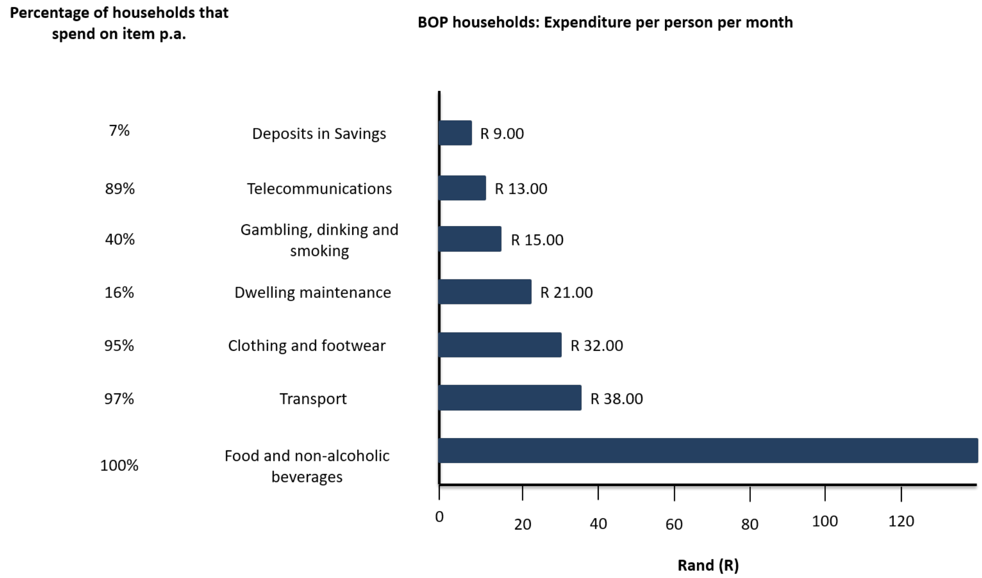

Figure 2.2: Individual Expenditure per Month

Taking into consideration the market potential and expenditure patterns of consumers constituting the BOP segment, it is important to determine where the market potential is situated in South Africa in order to target the applicable areas. Figure 2.3 depicts the population density of South Africa. From this figure it can be seen that the majority of the population is situated in the provinces of Limpopo, North West, Mpumalanga, Gauteng, KwaZulu Natal, the Eastern and Western Cape. Figure 2.4 indicates where in South Africa the BOP consumers are situated, thus outlining where the market potential is situated in South Africa. This figure shows that the majority of the BOP consumers are situated in Limpopo, North West, Gauteng and KwaZulu Natal. The conclusion which can be drawn from these two figures is that the areas in South Africa where the largest parts of the population are situated are also largely the location of the predominant BOP market sector in South Africa, if the population density of each province is taken into account.

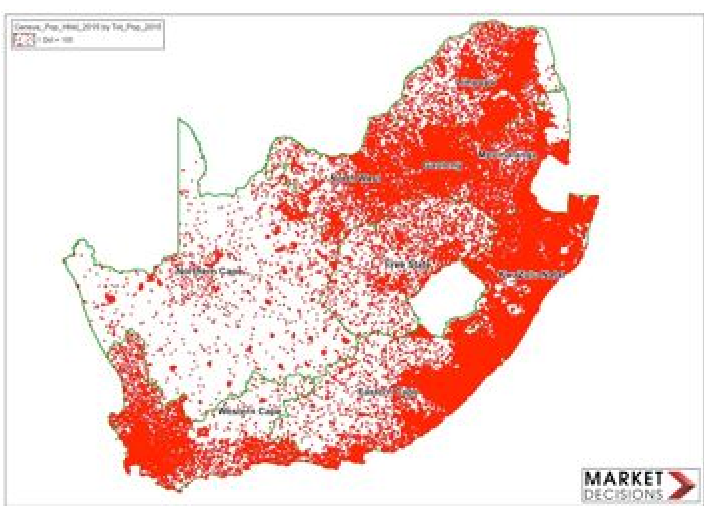

Figure 2.3: Population Density of South Africa (Market Decisions, c2016)

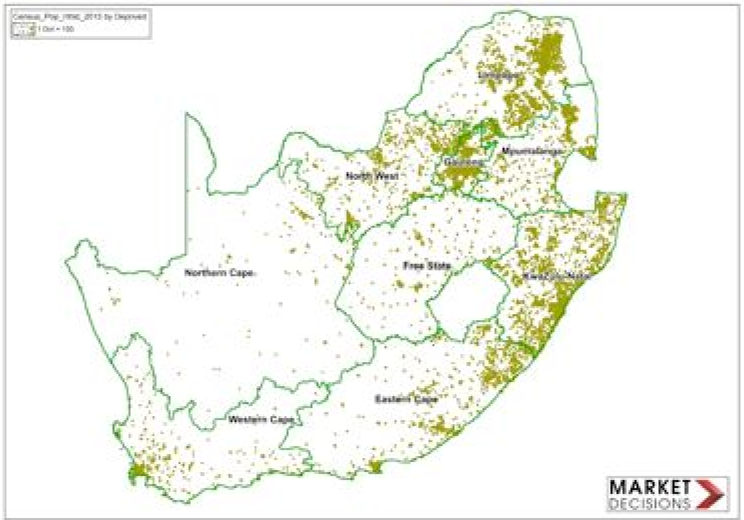

Figure 2.4: BOP Consumers in South Africa (Market Decisions, c2016)

Another aspect to take into consideration for the market evaluation is the structure of the BOP market. The BOP market in South Africa largely consists of informal retailers, such as spaza shops. The informal sector generates approximately R46 billion in annual sales. Over 9 million households shop at these stores, according to a report by consumer behaviour monitor, Nielsen South Africa. The informal sector experiences a continued increase in sales and shopper loyalty of 10% annually, which is 1% more than modern trade growth. Product purchases have increased by 7%, which is 3% higher than the modern trade sector (Mamphiswana, M., 2016).

South Africa has approximately 134 000 traditional trade stores, with 52 472 of them located in rural settlements and 81 587 located in urban settlements. Shoppers visit these traditional trade stores more than four times a week when compared to the modern trade retailers which are only visited once a week on average (Mamphiswana, M., 2016). This adds to the complexity of distribution to the BOP market segment, as more frequent drops (deliveries) to these stores would have to be made.

Targeting the BOP market segment could create a great value proposition and holds many benefits. According to DI International Business Development (2007), the business potential at the BOP market has five main advantages:

Vast market size: As mentioned previously the BOP market consists of four billion consumers. These consumers have a combined purchasing power of approximately \$5 trillion. Though the market is large, service and product delivery to this segment is neglected as companies fail to see the opportunities in the market. An important aspect which needs to be taken into consideration for companies aiming to enter the market is to expect low profit margins but high unit sales due to the profile and volume of the consumers constituting the BOP market segment, thus profits are driven by volume rather than high margins.

High growth rates: African countries are experiencing growth rates of 5%. Particularly, the South African population is growing by an annual rate of 1.6%, with the rural population growing at a rate of approximately 0.16642% annually (Trade Economics, c2017).

A less competitive environment: The majority of companies are focused at the consumers at the top end of the pyramid as it is an easier market to service due to the fact that the market is already established. This has caused the formation of a 'Red Ocean', as multiple companies are competing for the business of the same consumers. Targeting the BOP market means creating a 'Blue Ocean'.

The 'Blue Ocean' provides a number of business possibilities in an environment characterized by limited competition, as the entry barriers to the market is difficult to overcome.

Cost-saving opportunities: Cost structures in developing markets tend to be lower, thus using local suppliers, producers and distributors can lower production costs.

Opportunities for innovation: Meeting the demands and needs of the consumers in the BOP market requires new solutions as servicing the BOP markets are more complex due to a number of reasons such as lack of proper infrastructure. Companies need to be innovative in developing an approach to successfully service this market segment to create a 'Blue Ocean'.

Entering the BOP market could prove to be very challenging. The five main challenges in entering the BOP market are (DI International Business Development, 2007):

Cash poor consumers: The largest challenge for companies entering the BOP market is the limited purchasing power of the individuals comprising the market due to low individual incomes of the consumers constituting this market. Adding to the problem is the fact that the habits and taste vary across markets that may be geographically distant from one another. This emphasizes the fact that companies need to be innovative when developing an approach to service the bottom-end markets in order to reap the benefits.

Geographic, economic and cultural distance: Companies looking to expand their services to the BOP market need to take into consideration the economic and cultural differences between the saturated top segment of the pyramid and the consumers constituting the BOP.

Limited product awareness and understanding: Some of the basic products are unknown to local consumers which means that they are unaware of their needs for these products. Companies looking to enter the market need to educate their potential consumers on their product offering to ensure success.

Weak physical and institutional infrastructure: Due to the lack of proper infrastructure in most BOP environments companies have to reevaluate the entire value chain (and thus the value proposition).

Working with longer time frames: Companies need to work with a longer time frame for profitability in the BOP markets than they would normally do in developed markets because the BOP market rests on large volumes of products with only a small mark-up per unit.

2.2 Supply Chain Opportunities at the Bottom of the Pyramid

Numerous companies have tried to improve their profits and overcome the challenges in distributing to the BOP market by bridging the infrastructure gap. Companies have attempted this through selecting the appropriate technologies, and controlling costs through differential or layered distribution networks (Smith, N.C. et al., 2008). Some companies outsource the 'last mile' in order to reduce their cost to reach these market segments. Other innovations include taking advantage of shared distribution networks by adding additional products (scalability) at low incremental cost once the distribution channel is in place (Smith, N.C. et al., 2008).

An alternative approach is to engage and empower the BOP consumers through an inclusive business model, focussing on education, information and collaboration in an attempt to drive cost effective distribution.

Companies that have been successful (and profitable) in servicing the BOP market have experimented with several strategies and have through the experimentation of these strategies, developed a unique product and service offering to deliver to the BOP segment. Anderson and Billou (2007) have developed a framework to assess the application and success of innovation in the distribution channel called the 4A's model (acceptability, affordability, availability and awareness). According to Osborn, D. (2011) the model can be defined as:

Acceptability: what is the level to which the product or service offering is accepted by the BOP consumers?

Affordability: is the company able to deliver the product or service offering at a price which is affordable and acceptable to the poorest consumer constituting the bottom-end market?

Availability: how easy is it for a consumer to acquire and use a product or service? Does the company plan on exploring alternative methods to deliver their products or services to the BOP consumers situated in the most isolated, rural areas?

Awareness: to what extent have the stakeholders in the distribution chain been educated to ensure that the level to which consumers are made aware of product and service offerings and accessibility to these offerings are effective?

According to Sodhi, M.S. et al. (2016) there are two main reasons why traditional supply chain thinking may not suffice in the BOP market:

1. The poor can serve as upstream suppliers or downstream distributors which cause numerous transactions to take place. The added transaction costs require new and improved ways to design and operate logistics networks.
2. The BOP consumers lack market power. This means that new mechanisms for the BOP suppliers and distributors need to be developed in order to obtain an equitable share of the supply chain surplus. To successfully meet this challenge, supply chains would need to be built around 'social' business models that seek both profits and poverty alleviation to ensure success.

According to the work done by Mtshemla, N. (2014) there can be differentiated between two main distribution channels, which are:

1. Traditional distribution channels
2. Alternative distribution channels

These two distribution channels will be further discussed in the subsequent sections.

2.2.1 Traditional Distribution Channels

According to Mtshemla (2014) 'in a study performed by Chow, Kaynak and Yang (2011), they referred mainly to the retailer as the traditional distribution channel.' The study performed by these authors demonstrated the importance of manufacturers and distributors to retain their power over retailers by using more than one distribution channel.

The importance of large retailers can be expressed as an influence in the food choices of consumers in two significant ways; firstly by the decisions of retailers regarding their purchase decisions from suppliers and secondly, the decisions of retailers regarding the management of their selling processes to consumers. These two advantages have enabled retailers to gain even more control over their relationships with suppliers and consumers (Dawson, 2013).

According to PWC South Africa (2012), the township and rural retail sectors are more aligned with those in other poor economies. This is due to the fact that there is a presence of a far higher proportion of informal retail outlets where spending is focussed on food products and goods. It is claimed that the small informal retailers in townships and rural areas in South Africa are withering away due to the shift towards retail markets. The main reason for this occurrence is the price disadvantage of the smaller players in the informal sector as compared to the formal retail players that enjoy larger discounts.

Companies intending on exploring the BOP market need to be aware of the landscapes of the potential distribution channels. Adebayo (2013) suggests that most suppliers sell their products through large retailers, and in turn, the retailers sell their products in the BOP market to the BOP consumers. Thus leveraging and/or introducing alternative distribution channels may reduce dependency on large retailers and could possibly present both opportunities and complexities in terms of relationships in the alternative distribution channels.

There are numerous benefits to encourage suppliers to have more than one distribution channel. Penetrating the BOP market is an opportunity for companies to make a positive contribution to society, by integrating local communities in their value chain, thus building an inclusive business model. In doing so, brand preference and brand loyalty of the companies' products may be increased.

2.2.2 Alternative Distribution Channels

According to the work done by Mtshemla (2014), studies have indicated that many developing countries require the creation and development of more inclusive business models to ensure success. These business models should directly integrate the BOP consumers as entrepreneurs, suppliers, distributors, retailers and employees. The consumers constituting the BOP market should be viewed as resilient entrepreneurs and value-concious consumers rather than impoverished victims. South Africa presents such an opportunity due to the high unemployment rate. The available work force can be utilized as local agents, vendors, etc. and thereby significantly increase work opportunities, contributing to the economy of the country.

When alternative distribution channels are being considered the conditions in which the consumers reside must be taken into consideration to ensure that companies present viable alternatives to service the BOP market. To conclude; the alternative distribution channels entail inclusive business models through directly integrating the BOP consumers as entrepreneurs, suppliers, distributors, retailers and employees. Research completed by the World Bank and United Nations has indicated that 'the expansion of employment and entrepreneurial opportunities are the single most important pathways out of poverty'.

2.3 Literature Case Studies

Ernest and Young (2015) have noted in one of their studies that supply chains and logistics in Africa would be a challenge due to the fragmented nature of the market combined with underdeveloped infrastructure in Africa. 'However, probably the greatest operational challenge for most consumer product companies in most African countries are to gain control of the route to market and point of sale (Ernst and Young, 2015).'

Companies who perform well in African markets have a well-designed distribution network which combines efficiency and flexibility. Companies who cover multiple markets may have a combination of direct coverage and partnerships with third-party distributors, wholesalers and micro-entrepreneurs. A key consideration is the degree of control which is often achieved by teaming distribution partners with a directly employed sales force.

Companies who have successfully entered the BOP market are:

Clover: Clover has re-engineered their distribution model to a hub and spoke distribution model in order to reach the BOP market segment in 2012. This enabled them to reduce stock holding and improve stock planning and replenishment. It also provided them a sustainable competitive advantage as distribution network is a key enabling platform for any distribution company.

In the Clover distribution network, stores receive deliveries between two to five times per week, depending on the sales volumes.

Clover's distribution model services 9 801 stores in the informal sector, it has a recoded sales growth increase of 64% from 2015 and a forecasted sales growth of 55% for the next 12 months.

Clover also provides 3PL services to numerous food manufactures which provides one of Clover's most valuable revenue streams. A visual depiction of Clover's distribution centres can be seen in Figure 2.5.

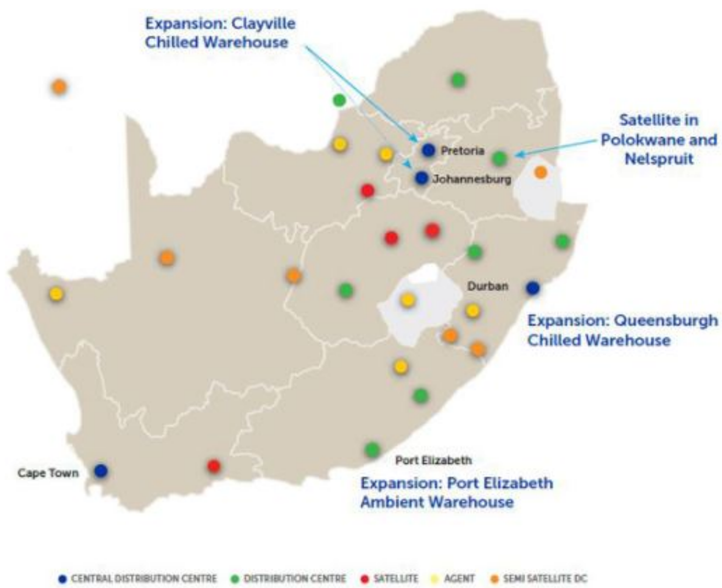

Figure 2.5: Clover Distribution Network (Clover, 2014)

Coca-Cola: Coca-Cola makes use of a micro-distribution model which enables an effective route to the consumer in informal market settings.

Coca-Cola Sabco (CCS) operates approximately 232 bottling plants and employs 9 500 people in seven African countries, which makes it one of Coca-Cola's largest bottlers in Africa.

The distribution model which has worked well for bottling CCS in parts of East Africa is known as the Official Coca-Cola Distributor (OCCD) approach. The approach is based on the following principle; local bottling factory partners with a number of 'micro-distributors', who are local entrepreneurs, of which each is given responsibility for a defined geographical area. This area is generally a 1 km radius in an urban environment, servicing at least 500 outlets. These OCCDs have become a central element in the core distribution of Coca-Cola Sabco's strategy in numerous countries in which they are situated. They are responsible for more than 70% of sales volume in countries such as Ethiopia, Kenya, Uganda and Tanzania.

Using the OCCD approach Coca-Cola Sabco has not only addressed their core route to consumer challenge, but they have also engaged with the community by creating countless economic opportunities for local entrepreneurs and their employees. CCS has adapted an approach in which they enrich communities.

Danone: The distribution and storage challenge which Danone faced were the high price together with a weak cold chain. In addressing this problem, Danone opted for setting up a distribution channel from scratch, rather than acting through the existing network, as servicing the BOP market has a lot more variable which need to be taken into consideration.

Danone has innovated their business model to successfully distribute to the BOP market. They chose to develop a door-to-door sale through a network of female members of the community, which were known as the Daniladies, thus engaging the community in their distribution ventures. These ladies were provided with equipment such as cooler boxes, carts and uniforms to ensure successful distribution.

Once the first phase were successful, the micro-finance concept was enhanced in 2007. A Danimama was introduced as a mentor, who acts as a main distributor in a specified area and serves as a rallying point for advice and coordination.

FanMilk: This is a Danish owned company which produces dairy products. FanMilk has several local production plants in West Africa. The aim of FanMilk is to provide consumers with high quality, nutritious products produced in high, hygienic standards.

An essential part of their distribution network is the use of cool boxes. The FanMilk cool box is also an essential part of the equipment made available for self employed private vendors distributing the FanMilk dairy products to ensure that the dairy product are distributed at the right temperatures. This enables locals to make a better living and serves as an initiative to provide many more jobs in the community.

Nestlé: Over 80% of Nestlé's business is situated in the traditional trade, which consists of small stores in the informal sector, thus consumer activation, branding and controlling the route to market is of high importance in this situation. Nestlé achieves success in this sector through a combination of its own sales force and outsourcing to trusted third party distributors.

An important element of Nestlé's distribution model in African countries is direct to consumer. They have been one of the leading companies in creating entrepreneurial opportunities for coffee and ice cream vendors. The latest development in the micro-partnerships is the 'My Own Business' initiative. This entails Nestlé providing the vendor with a portable coffee dispenser, which they strap onto their backs, enabling the vendors to sell individual cups of coffee at markets, events, etc., thus expanding the market. The initiative was launched in Nigeria in 2012 and has since been operational in Burkina Faso, Ghana, Cameroon, Kenya and Senegal. It is also being extended to Angola, DRC, Ethiopia and Mozambique.

Unilever: Consciously they have been embedding corporate responsibility in the development of their distribution model, which is a part of their broader Sustainable Living Plan. One key focus of Unilever has been to make their products available to the BOP consumers in Africa through innovations such as their 'small unit pack/low unit price' concept, whereby they sell small packages of salt, cooking oil, toothpaste, laundry detergent, shampoo, etc.

Unilever's distribution network has also been adapted in some markets for informal traders who have working capital constraints. One example of this is where the products are effectively given to street traders on a one week credit basis. Consequently, the payment is then collected a week later when the trader has accumulated some cash from his or her market in order or pay for their products.

They have introduced their direct-to-consumer distribution model to Africa (Shakti) that has been proven to be successful in India. The Shakti scheme consists of approximately 45 000 Indian women who sell Unilever products directly to three million households. Unilever aims to begin in Nigeria and Kenya, employing tens of thousands of vendors that would be selling directly to the consumers. To set up their business in foreign countries, Unilever provides micro-finance to their vendors and in the process provides livelihood for people who might struggle to find work otherwise.

2.3.1 Conclusion

To conclude the literature case studies it is important to note a few key principles to successfully service the BOP market segment. Operating successfully in the BOP market requires:

- imagination, flexibility and innovation to create sustainable business practices;
- research and development of alternative distribution channels; and
- development of inclusive business models.

Distribution companies who have successfully entered the BOP market make use of several distribution channels as can be seen from the literature case studies. The main distribution models/channels will be discussed in detail below together with a few alternative models not outlined in the literature case studies.

Micro-distribution

There are numerous variations on this type of distribution method. The main idea behind a micro-distribution model is the use of the community and local entrepreneurs to assist in the distribution of goods.

One of these methods are called the local door-to-door distribution method. A distributor who has successfully implemented this distribution model is Danone. This type of distribution model entails setting up a sales force to deliver products door-to-door. The door-to-door distribution method can help create brand recognition in new markets and bring additional value through home delivery that retail could not provide. The drawback of this model is the sustainability thereof. The door-to-door model requires that each sales person generates enough revenue locally to be able to cover their costs, thus sales needs to be recurring and the client density high enough. There is evidence that this model only works sustainably for consumer goods in dense urban areas which is rarely the case in the BOP market, as the market structure tends to be very fragmented and dispersed.

These types of distribution models also tend to be higher in the cost division due to the increased transportation costs, which are usually higher than in other distribution systems.

Companies such as Unilever, Fanmilk, Nestlé and Coca-Cola have innovated their last mile distribution to consumers through the use of micro-distribution models.

Hub and Spoke Distribution

Previously the transportation and logistics industry was guided by the principles of point-to-point or direct-route options. As technology developed more cost-effective ways of distributing to consumers were developed, which gave rise to the development of thee hub and spoke distribution model.

A hub and spoke model is a centralized, integrated logistics system which is typically designed with the aim of keeping logistics costs as low as possible. Hub and spoke distribution centres receive products from various origins. These products are then consolidated and sent directly to the destinations. Figure 2.6 visually depicts this network structure.

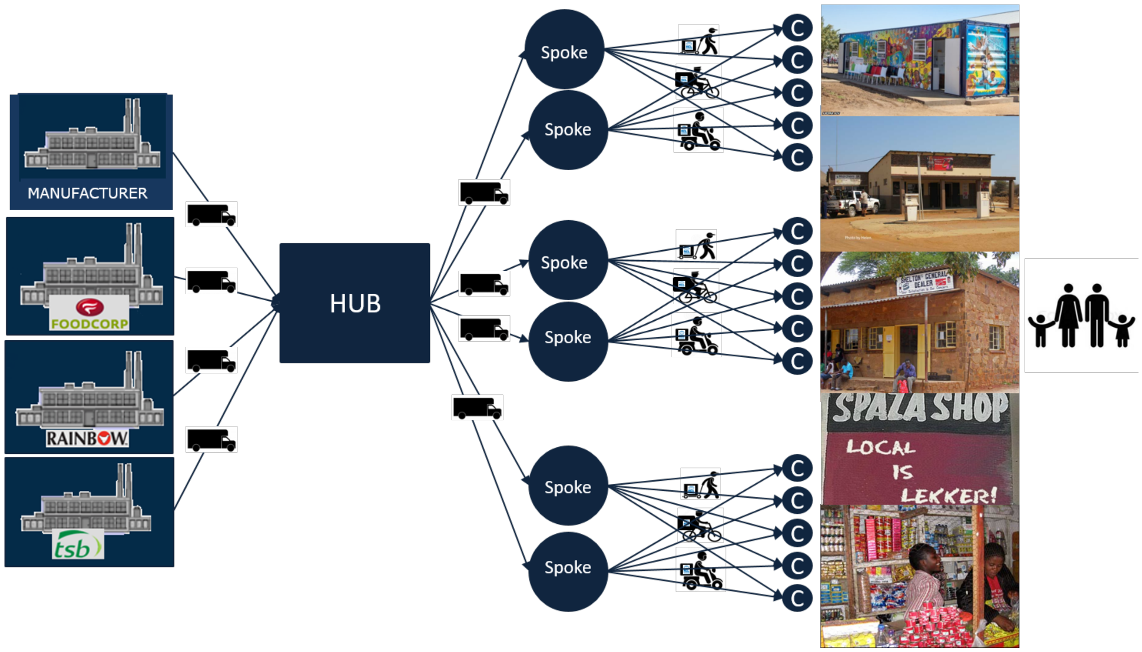

Figure 2.6: Hub and Spoke Model

One of the distribution companies who has recently adopted this strategy is Coca-Cola. They have created a three tier distribution structure. Under the hub and spoke distribution system, stock is transported from the bottling plant to hubs and then from the hubs, the stock is transported to the spokes which are situated in small towns. The spokes feed the retailers catering to the demand in rural areas.

In the development of a hub and spoke model it is of great essence for the hub and spokes to be located at the optimal or most ideal location. The hubs directly impact on the efficiency of transportation systems, since they directly affect the flow of goods. It is therefore very important to correctly position these hubs in order to achieve an increased efficiency and reduced transportation costs. The determination of the most ideal location to position the hub will assist in the expansion of economies of scale, increase competitive advantage and lead to better customer satisfaction through more efficient transport (dos Santos Vieira, C.L., Mendes Luna, M.M., 2016).

Advantages of the hub and spoke model are:

- products can be distributed in areas not easily accessible to distributors;
- new market development;
- market penetration ('Blue Ocean' strategy);
- cost effectiveness; and
- transport efficiency.

Syndicated Distribution

This type of distribution method is a viable approach to gain entry into the BOP market segment. Syndicated distribution entails two or more companies joining forces to form a syndicated trading organization.

This means that these companies jointly distributes a collective group of products in rural markets by sharing distribution costs.

It would be beneficial for small companies to tie up with larger companies which already has a presence in the respective market segment. It is important to note that the smaller company should not deal in the same products that the leading company sells.

According to research conducted by Osborn (2011), 67% of interviewed companies have opted for collaboration with other distribution parties. All of the respondents to the interviews highlighted the fact that companies aiming to enter the BOP market for the first time could not do it on their own. The respondents also emphasized that the correct (non-competing) partner should be chosen for syndicated distribution in order to be successful.

Wholesale Distribution

Wholesale distribution is a form of an indirect channel, i.e. intermediary parties are involved in the distribution of products to customers. Wholesalers are one of the most important middlemen in the distribution channel who deals with the products in large (bulk) quantities. The wholesalers then sell the products in relatively smaller quantities to retailers or in some instances they sell directly to consumers. Generally the wholesalers deal with a limited variety of items and also in a specific product line. The main characteristics of a wholesaler are:

- wholesalers purchase products directly from producers and manufacturers;
- they buy goods in large quantities and sell in relatively lower quantities;
- wholesalers sell different varieties of a specific line of product;
- they may employ a number of agents or workers for the distribution of products; and
- in a town or city they are usually located in one specific area of the market.

The use of a wholesale channel brings about the use of the term 'rebates'. A rebate is a return of a part of the purchase price by a seller (manufacturers or producers) to a buyer (wholesale customer), usually on purchase of a predefined quantity, or value of goods within a designated period. Unlike a discount, which is deducted in advance from the payment, a rebate is given after the payment of the full invoice amount. Rebates are used to price on 'real' rather than 'promised' purchases (Vendavo, c2017).

Rebates can be classified into two main categories based on business objective and customer type, which are:

1. Incentive rebates
2. Channel management rebates

Incentive rebates can be further broken down into the following elements (Vendovo, c2017):

Volume Rebates: This is the simplest type of rebate and is designed to limit customer gaming and over-promising. The price is quoted on a tiered pricing strategy where the invoice price is fixed, but the actual price varies with volume and the difference is granted by rebate.

Growth Rebate: A growth rebate is an uncomplicated variation of volume rebates. This type of rebate is designed to revenue or growth, and drives growth in a specific product family. Growth rebates are much like volume rebates, except that the rebate is paid on incremental volume rather than on all revenue or the total volume.

Retention Rebates: This rebate is paid to reward continued business or customer loyalty. Retention rebates can be of any form, volume, growth and mix, but are usually end of year or 'cliff' rebates, which is paid upon realization of a specified condition.

Mix Rebates: Mix rebates are a best practice, designed to help improve the customer and product mix of a supply relationship. A seller uses mix rebates to encourage a distributor to sell more volume of higher mix, or margin, products, or sell more to selected end consumers or end consumer segments. It should rarely be expressed as a percentage, which may run the risk of being interpreted as a discount, in essence which it is not. Mix rebates should definitely be used with distributors and buying groups.

Channel management rebates can be further broken down into the following elements (Vendovo, c2017):

Ship and Debit Rebate: This is a special use case in that they are rebates, i.e. it represents an off-invoice discount which disguises the actual price, but Ship and Debit rebates are associated with a sale made through a stocking distributor.

Indirect Customer Rebates: This is an effective tool for maintaining a strategic supply relationship with an end consumer, and driving mix and volume objectives, despite not having a billing relationship. In most instances this type of rebate takes the form of a check, as opposed to a credit memo, which would be the case if a billing relationship exists. The servicing of 'national accounts' often involves rebates of this kind.

Price Masking Rebate: One of the most common reasons for using a rebate is to keep the 'actual' price from being visible in the market. A rebate is by definition an off-invoice discount, thus the use thereof allows the supplier to issue an invoice at a price that is not the actual, or net, price which should be paid by the customer. Price Masking rebates are designed to allow invoicing at a price that is artificially high.

In order to ensure that the correct rebate strategy is deployed, goals should be set for each channel, customer or segment, i.e. 'what behaviour are you trying to achieve (Vendavo, c2017)?' For each type of behaviour, determine what type of rebate should be employed. Common customer objectives and rebate types are depicted in Table 2.3.

Customer Objective	**Rebate Type**
Increasing overall volume	Volume, Growth or Mix rebates
Adjusting mix with particular account	Mix rebates with conditions
Discouraging over-promising	Volume or Growth rebates
Price change hidden from competition	Price Masking rebates

Table 2.3: Customer Objectives and Rebate Types (Vendavo, c2017)

2.4 Distribution Network Modelling

Models for the design of distribution networks are generally more complex due to the great diversity and high degree of uncertainty related to the input data. The uncertainty of the input data can be traced to a few contributing factors, which are (Dujak, D., Mesaric, J., c2017):

- the number and variety of participants in the network;
- long planning horizon; and
- large number of possible distribution systems and strategies.

Various modelling techniques exist in order to construct and evaluate distribution options. The use of the appropriate modelling technique will facilitate a comparison of the functioning and cost/service effectiveness of the developed distribution network. Once the appropriate modelling technique has been selected it should be used to assist in identifying a distribution network that is in line with the objectives to successfully service the BOP market.

According to the work done by Coyle, Gibson, Langley and Novack (2013) there are three main modelling approaches:

- optimization models;
- simulation models; and
- heuristic models.

Each one of these models will be discussed in detail the subsequent sections.

2.4.1 Optimization Models

The optimization model is based on exact mathematical procedures that will determine the optimal solution given the mathematical definition of the problem at hand. Taking into consideration the relevant constraints to the problem, optimization approaches essentially select an optimal course of action from a number of feasible alternatives. There are several advantages to using this technique, such as:

- the optimal solution can be developed for a given set of assumptions, constraints and data;
- numerous complex models can be handled accurately;
- the analysis and evaluation of the alternatives result in a more efficient analysis; and
- cost and profit savings can be evaluated.

Various network optimization tools exist to facilitate the development of optimization models. According to work done by Jose, R. (2015) basic programs can be used for simple optimization models, such as Excel, but complex scenarios require software built for optimization and simulation. The aim of using optimization software is to allow businesses to examine and study various potential real-life scenarios and the effects that different factors may have on the distribution network.

LLamasoft: Supply Chain Guru

Supply Chain Guru is a supply chain analysis tool that facilitates network optimization. This tool enables the user to visualize, optimize, analyse and simulate the entire supply chain.

The program combines simulation and optimization tools into a single software. According to work done by Jose, R. (2015) the program also allows for constraint modelling which allows the model to be built and display real-life situations. One of the main advantages of this software package is that it allows multi-objective optimization which compares multiple scenarios against one another to obtain optimal answers. The software also makes use of the Geographical Information System (GIS) which enables the user to visualize the solution. This adds to the accuracy of the modelling routes, travel time and distance (LLamasoft Inc, 2015).

Operations Research Approach

Operations research makes use of a systematic approach and techniques to establish optimal solutions given a defined set of constraints. The process identifies the problem that needs to be solved. The problem is solved based on the data and objectives of the model. The model is formulated using various decision variables from which an objective function is constructed to solve the problem at hand. The model is subjected to numerous constraints which is also formulated based on the data and decision variables. A visual depiction of this method is shown in Figure 2.7.

The problem is formulated in mathematical software such as MATLAB or LINGO in order to determine the optimal values for the decision variables as well as for the objective function.

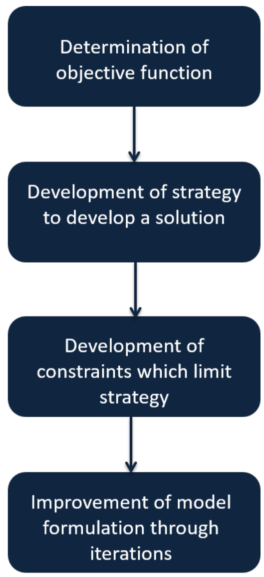

Figure 2.7: Operations Research Approach

2.4.2 Simulation Models

Simulation is the process of building a model based on a real system to conduct experiments for the purpose of either understanding the behaviour of the system and what influences the system or to evaluate various alternatives within the limits enforced by a set of criteria for the operation of the system. Simulation models are best used for dynamic models. Network simulation requires developing a computer illustration of the logistics network and observing the cost and service characteristics of the network being modelled.

Simulation does not guarantee an optimal solution as can be accomplished through optimization modelling. It simply evaluates the alternatives which are constructed and tested, thus selecting an 'optimal' solution based on the alternatives which were created and evaluated.

Simulation models are very capable in terms incorporating relatively comprehensive and detailed problem descriptions as several variables can be measured in a single model. In some instances an optimization approach is initially used to identify and evaluate feasible solutions and thereafter highly customized simulation models are used to focus on the exact logistics network that will best meet the desired objectives.

AnyLogic

AnyLogic is a simulation software which enables the user to build multiple simulation to depict real world problems. One of the most important advantages of using the software is that the user can visualize the system. A simulation model can is able capture more details than an analytical model which provides for increased accuracy. Uncertainty can also be built into the model to accommodate system variability.

In terms of using the software package for the purpose of developing a distribution network the strategic and tactical logistics plan can be identified and the feasibility and costs can be evaluated (Distribution Network Planning & Inventory Optimization Supported by Simulation – AnyLogic Simulation Software, c2017). AnyLogic is also able to assist in risk assessment and risk management in transportation logistics. One of the biggest drawbacks of the modelling technique is that an optimal solution will not be provided, the best solution may be accepted based on alternative scenarios developed and tested.

AnyLogistix (ALX)

AnyLogistix is an expansion of the AnyLogic simulation software for the exclusive use of modelling supply chains in dynamic environments. ALX is able to find suitable site locations and characteristics when the expansion of a supply chain to a new region is considered. ALX carries out network optimization, which takes into consideration various factors such as demand volume and seasonality, roads, product types, etc.

ALX enables the user to evaluate the efficiency of their current distribution network and assess whether it makes sense to reconfigure it.

ALX provides visibility into the supply chain actually works in dynamics. The change of parameters change over time which can be seen when simulation modelling is used to model a network. This enables the user to identify cause-and-effect dependencies in the network, which provides additional data points for analysis, which can be crucial in decision making (anyLogistix Supply Chain Optimization Software, c2017).

Again, as mentioned in Section 2.4.2 one of the pitfalls of simulation modelling is that an optimal solution will not be developed, the best solution may be accepted based on alternative scenarios developed and tested.

2.4.3 Heuristic Models

Heuristic models are able to assist in broad problem definitions, but as with simulation models, they are not able to determine the optimal solution. Heuristic models are used to reduce a problem to a manageable size and search automatically through various alternatives in an attempt to find a better solution. Numerous heuristics are based on mathematical optimization models and algorithms.

2.5 Facility Location Selection

Facility location refers to the choice of geographical location and the selection of a particular site for setting up facility. The main factors to consider in site selection are (Tompkins, J.A., White, J.A., Bozer, Y.A., Tanchoco, J.M.A., 2010):

- proximity to markets;

- supply of material;
- transportation;
- infrastructure;
- labour and wages;
- government policies;
- climate conditions;
- supporting industries and services;
- the acceptability of the local community; and
- environmental impact.

One of the main distribution strategies which was identified in Section 2.3 is the hub and spoke model. This model requires the identification of an optimal location to situate the 'hub' from which secondary distribution would be configured. There are many methods to determine the location to position the hub, which will be discussed in the subsequent sections.

2.5.1 Weighted Location Factor Rating Method

This location modelling technique is the most widely used technique as it considers numerous factors which impact on location selection (Study Stock, S.a.).

The weighted location factor rating method is a variation of the location factor rating method. The location factor rating method entails identifying the most important locational factors which would impact on your model. Each factor would then be rated based on its relative importance, the higher the rating, the more important the respective factor (factor rating). The next step in the process is to rate each location according to the merits of the location for each identified factor (location rating). Thereafter the rating for each location would be calculated by multiplying the factor rating with the location rating. The location with the highest score is selected as the best location.

The weighted location factor rating method combines qualitative and quantitative data. Each factor is assigned a weight based on its relative importance and a weightage score is assigned for each location by using a calculated preference matrix. The location with the highest score is selected as the best location.

2.5.2 Centre of Gravity Method

The centre of gravity method is a mathematical technique used to determine the location of a distribution centre that will minimize the distribution cost, i.e. this is a quantitative method for locating a facility at the centre of movement in a geographic area. This method takes various aspects into account such as the location of markets, the volume of goods shipped to the markets and the shipping cost (transportation cost). It is important to note that transportation costs are a function of distance, weight and time.

The centre of gravity method identifies a set of coordinates designating a central location on a map relative to all other locations.

The first step in this method is to place all the relevant locations on a coordinate system. The origin and scale of the coordinate system used is arbitrary. It is important that the relative distances are represented accurately.

The centre of gravity is determined using equations (2.1) and (2.2) respectively (Tompkins, J.A., et al, 2010).

$$x - coordinate = \frac{\sum_{i=1}^{n} x_i w_i}{\sum_{i=1}^{n} w_i} \tag{2.1}$$

$$y - coordinate = \frac{\sum_{i=1}^{n} y_i w_i}{\sum_{i=1}^{n} w_i} \tag{2.2}$$

where:
x, y = coordinates of the new facility at the centre of gravity
x_i, y_i = coordinates of the existing facility
w_i = annual weight shipped from facility i

This method is built on the assumption that cost is directly proportional to distance and the volume shipped. The ideal location is that which minimizes the weighted distance between the 'hub' and the secondary distribution locations, where the distance is weighted by the number of containers shipped.

It is important to take into consideration that the coordinates calculated through this method is based on straight line distances which is not representational of the actual roads, which may be more circular.

2.5.3 Load Distance Method

The load distance method is a variation of the centre of gravity method. It is a mathematical model used to evaluate locations based on proximity factors. During the execution of this method a single set of coordinates is not identified. Rather various locations are evaluated using a load distance value that is a measure of weight and distance. The objective is to select a location that minimizes the total weighted loads moving in and out of a facility, thus selecting the location which has the lowest load distance value. Alternatively time can be used rather than distance. The distance between two points is expressed by assigning the points to grid coordinates on a map.

The load distance value for a single potential location is calculated using equations (2.3) and (2.4) respectively (Tompkins, J.A., et al, 2010).

$$d_i = \sqrt{(x_i - X)^2 + (y_i - y)^2} \tag{2.3}$$

where:
x, y = coordinates of the proposed new location
x_i, y_i = coordinates of the existing facility i

$$LD = \sum_{i=1}^{n} l_i d_i \tag{2.4}$$

where:
l_i = the load expressed as a weight, number of trips or units being shipped from the proposed location i
d_i = the distance between the proposed location and location i

2.6 Conclusion

The problem investigation phase of the project proved and concluded that there is a market opportunity in South Africa to successfully service the BOP market segment, especially in the food manufacturing and distribution industry. The market would be more difficult to penetrate due to a few contributing factors as mentioned in Section 1.3. Consequently, the industrial engineering tools, in the form of distribution network design and evaluation will be used to develop an industry solution to successfully service the BOP market segment. The research based on literature case studies proved that it is possible for logistics providers to successfully enter the BOP market. Various distribution methods and channels do exist for companies to distribute to the BOP market.

From the literature review it is clear that alternative distribution channels would have to be considered for successful distribution to the BOP market segment. The following distribution models were identified from the literature case studies:

- micro-distribution;
- hub and spoke distribution;
- syndicated distribution; and
- wholesale distribution.

Each distribution model will be evaluated in relative detail based on the research conducted in the following chapter.

Chapter 3

Solution Development

The aim of the solution development phase is to determine the best way of ensuring that the problem statement is met and the objectives of the project are achieved. Based on the research conducted, a framework to evaluate the distribution models as discussed in Section 2.3 will be developed. The evaluation of these distribution models will aid in determining the most effective distribution model to service the BOP market segment.

3.1 Evaluation Framework

In order to effectively evaluate the different distribution models, a framework which is applicable to the operation in the BOP market segment would have to be developed. The research conducted in Chapter 2 together with the considerations outlined in Section 1.3 extensively discuss the challenges that logistics providers face when entering the BOP market. The framework is built based on those aspects together with a framework developed by Aithal and Vaswani (2005).

The evaluation framework will be divided into two main categories. These two categories each have their own evaluation criteria as can be seen in Figure 3.1.

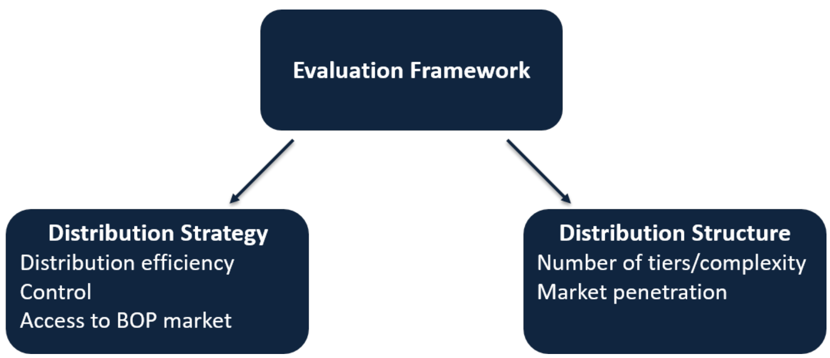

Figure 3.1: Evaluation Framework

A weighting factor will be assigned to each evaluation criteria based on importance. The assigning of the weight factors should adhere to equation (3.1).

$$MaxSum = \frac{(MaxWeight - MinWeight)(n)}{2} \tag{3.1}$$

Each distribution model will be evaluated based on the subjective value method. The procedure of the subjective value method begins with a judgement of the relative utility of each criterion on a rating scale (Kossiakoff, A., Sweet, W.N., Seymour, S.J., Biemer, S.M., 2003), thus assigning a score value to each distribution model based on the respective criteria. The score value will then be multiplied by the weight factor in order to determine the most appropriate concept. A simple rating scale of 1 to 5 has been created to evaluate each model. Table 3.1 explains the rating scale used.

Rating	Description
5	Exceptional
4	Good
3	Satisfactory
2	Fair
1	Poor

Table 3.1: 1 to 5 Rating Scale

Table 3.2 depicts the application of the evaluation framework. The classification of the distribution models are:

- Model A: micro-distribution;
- Model B: hub and spoke distribution;
- Model C: syndicated distribution/strategic partnerships; and
- Model D: wholesale distribution.

Criteria	Weight	Model A	Model B	Model C	Model D
Distribution Strategy					
Distribution efficiency	3	3	4	4	4
Control	1	4	4	3	2
Access	3	4	4	3	2
Distribution Structure					
Complexity/Number of tiers	1	4	3	2	2
Market penetration	2	4	4	3	2
Total	**10**	**37**	**39**	**32**	**28**

Table 3.2: Distribution Model Evaluation

Explaining the logic behind the ratings:

Distribution Efficiency: This relates to how effectively a logistics provider can service the BOP market segment.

Micro-distribution models may be affected by various external factors, thus scoring the lowest of all the models. The distribution efficiency for the hub and spoke model will be relatively good, depending on the effectiveness and research of the developed model. For syndicated distribution a partnership may be developed with companies who already have a market presence and established distribution channels,thus scoring a 4. The distribution efficiency to wholesalers are good due to the fact that large quantities are dropped at one single location which usually is easy to reach.

Control: This aspect evaluates the control which the distributor will have over their own distribution efforts, up until the products reach the retailers.

In micro-distribution and the hub and spoke model the distributor will have full control over what is sent to the consumers, thus scoring the highest. Through the use of a micro-distribution model (i.e. direct shipping/direct to consumer) intermediaries will be eliminated, thus the distributor will have more control over the distribution network/model used. For syndicated distribution the distributor will have relative control over the distribution to the BOP market, depending on the set out arrangement. Wholesale distribution entails the distributor simply distributing to the wholesaler and from there it is the responsibility of the wholesaler to distribute to the BOP market segment, thus scoring the lowest on control.

Access: This evaluates the direct access which the distributors will have to the BOP market, thus the greater the access to the market the better.

The micro-distribution and hub and spoke models' will have the greatest access to the market as the distributors will deal directly with the customers. The hub and spoke model also allows for a closer proximity to the market, which means that more customers may be serviced in a minimum amount of time. Syndicated distribution may also have great access to the market depending on the agreement between the partners and the distribution channels already in use by the 'mother company'. For wholesale distribution, the distributors will have limited access to the customers due to the model structure, thus scoring the lowest.

Number of Tiers: The number of tiers evaluate the amount of middlemen in the distribution structure, which may add to the complexity of distribution.

Micro-distribution usually has more than one tier, depending on the distribution structure used. Hub and spoke distribution generally has three tiers and usually simplifies the network routes. Syndicated distribution may have several tiers, again depending on the structure and model used by the partnering company. Wholesale distribution only has two tiers.

Market Penetration: The market penetration evaluates the degree to which a distributor will be able to establish a market presence in the BOP segment given successful market entry. This also relates to the market share which the distributor will gain in the BOP market.

Using the micro-distribution or hub and spoke model will establish great market presence, as the distributor itself will service the market segment. For syndicated distribution, it will be dependent on the structure and model used by the partnering company. Wholesale distribution will have limited market presence due to the fact that the distributor will only distribute to the wholesaler.

As can be seen from Table 3.2 Model B has scored the highest, thus according to the evaluation framework based on research, the hub and spoke model would be the best route to market.

In order to further evaluate the distribution models, technical and financial criteria need to be taken into consideration. The technical criteria refers to the technical suitability of a process, material or system to achieve the objective/s. The main objective of the project is to determine the best route to market. All four of the researched distribution models allow for market entry, the deciding factor will be based on the ease of the market penetration, the complexity thereof, the financial implications and the market share which the distributor will gain given successful market entry.

Technical Evaluation: The evaluation framework concluded that in terms of market penetration for a distributor, the best options would be through the use of a micro-distribution model, or alternatively the hub and spoke model. These two models allow for direct market entry, as the distributor would be associated with their distribution efforts to the BOP market segment. Through the use of the wholesale channel the distributor may only gain recognition up to the wholesale tier, thus not gaining direct market entry. According to Nestlé, who uses a wholesaler, they do not have a direct link to the BOP market segment. They have also indicated that wholesale distribution is a very passive channel in terms of distribution, thus new ways have to be considered to generate demand. Strategic partnerships may be beneficial to use and could potentially allow for great market penetration, depending on the agreement between the partnering companies.

The complexity of market penetration is high in the BOP market segment. The wholesale channel would probably be the least complex of the four models considered in this paper. SCL, a distribution consulting company, has noted that the wholesale distributors understand the local conditions better and they can negotiate much better lease terms with proprietors. Market penetration complexity would also be lower through the use of strategic partnerships, as the main idea of this model is to partner with companies who already have a footprint in the market. The most complex model, in terms of the setup, would most likely be the micro-distribution model, as a lot of effort has to go into ensuring the effectiveness of this model.

Financial Evaluation: In terms of setup cost, the wholesale channel, together with strategic partnerships would be the least expensive route to follow, however the use of rebates in the wholesale channel need to be taken into consideration. Rebates can, at the maximum level, be as high as 12% to 15%.

The use of a micro-distribution model could bring about a lot of added costs. The main reason for this is due to the low adoption rate of technology in the BOP market, thus provision has to be made for cash sales and credit options.

Alternatively through the use of a hub and spoke model, the transportation costs will be significantly lower, as more effective transporting could be conducted. According to a study performed by the Department of Logistics at Stellenbosch University, transportation costs are the largest contributor towards logistics costs, as can be seen from Figure 3.2. The total transport cost for the year of 2014 amounted to 57% of the total logistics costs. Economies of scale will result in cost savings.

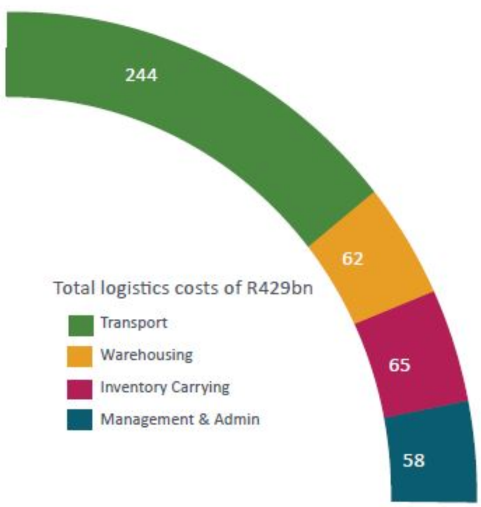

Figure 3.2: Logistics Cost Elements (Havenga, J.H. et al., 2016.)

The benefits for the use of a hub and spoke model far outweigh the drawbacks thereof, when compared to other distribution models. In order to gain more market share, it would be beneficial for companies to consider re-engineering their distribution model to one which they can service the BOP market themselves. This would include looking at the micro-distribution and hub and spoke models. The micro-distribution model has numerous drawbacks in terms of management, effort and time which need to be spent to ensure success, especially considering that the BOP market segment has a low adoption rate of technology, thus provision has to be made for cash sales which brings about the use of credit and finance. The hub and spoke model allows a distributor to develop their own distribution strategy in which they can modify it to their needs. Once the model is in place, it can be altered to a degree, in order to incorporate local entrepreneurs if required.

Based on the results as obtained through the evaluation phase, a hub and spoke model will be created and further discussed in the subsequent section.

3.2 Model Development

Based on the research conducted, together with the results obtained in Section 3.1, a hub and spoke model will be developed. The hub and spoke model is one of the most relevant distribution models in the modern era. To at least some degree the majority of the industry is driven by this model.

The literature study indicated that it is important that the hub and spokes are positioned at the most ideal/optimal location, as this will decrease transportation costs and account for more effective consolidation of orders. This will also lead to better customer satisfaction as deliveries can be completed more frequently, which will address the problem of limited on premises storage space. The most ideal location for the hub would be determined through the use of facility location selection models as discussed in Section 2.5. The location of the spokes within a designated area will also be selected using the facility location selection methods. The optimal number of spoke locations to be utilized in the distribution network will be determined by creating an optimization model as discussed in Section 2.4.1.

3.2.1 Data Analysis

In order to initiate the the solution development phase the data had to be analysed. The data analysed is for a single business unit (for one year) in South Africa, thus the fleet mix delivered to the BOP segment will not be taken into consideration for the solution development. The data consisted of:

- customer locations based on customer ID's;
- quantities ordered per customer ID; and
- ordering dates for each customer ID.

Thus from this data the following was determined:

- the number of customer ID's situated in a province; and
- the frequency of delivery for each customer ID in a province.

Due to the large quantity of data the data set had to be reduced to increase model effectiveness and decrease model run time. An important aspect in proving that an idea/methodology will work is to test it on a sample piece of data, if this works the probability that the concept can be replicated on a larger dataset is highly probable. The data was reduced in the following ways to create a predefined distribution area:

Province Selection: For the first step in data reduction a province was selected to focus on. In order to select the appropriate province the number of customer ID's and delivery frequency per province was taken into consideration. The visual depiction thereof can be seen in Figures 3.3 and 3.4 respectively.

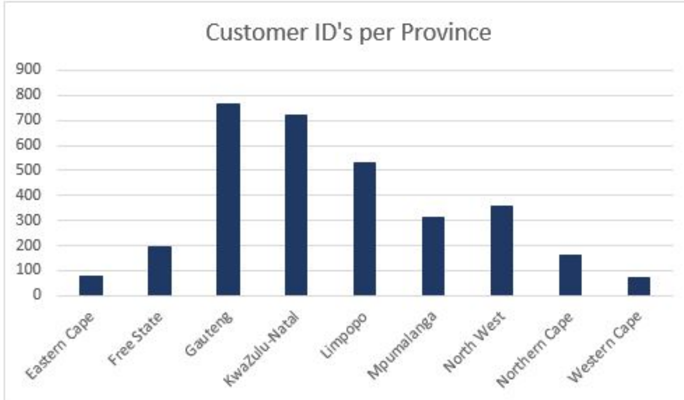

Figure 3.3: Customer ID's per Province

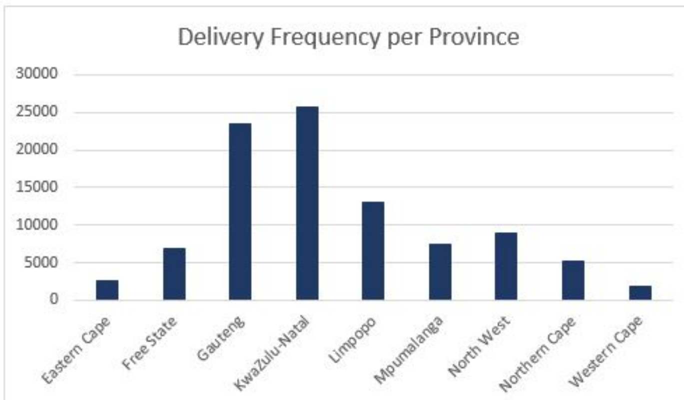

Figure 3.4: Delivery Frequency per Province

Three Sigma Range: After the province selection, the data set was further reduced by applying a three sigma range to the data to eliminate the outlying locations or locations which are rarely visited. This yielded a number of 103 customer ID's to be evaluated.

3.2.2 Hub Location

Once the data set was reduced the most ideal location for the hub was determined by using the centre of gravity method as discussed in Section 2.5.2. The main reasons for selecting the centre of gravity method are the similarity between the inputs described in the literature and the data available; and the fact that the model does not have to take 'human factor' which may lead to bias decision making, such as weight assigning to certain criteria (weighted location factor rating method), into consideration. The inputs to this model were:

- the longitude (x) and latitude (y) for each customer ID; and
- the amount of products distributed to each customer ID as the weight factor of the model.

The most ideal location for the hub was determined to be situated at the following points:

- longitude (x): 30.90611; and
- latitude (y): -29.445

A visual depiction of the hub location together with the customer locations can be seen in Figure 3.5. It is important to note that the visual depiction of the ideal hub location is based on the locations of the customer ID's and is in terms of longitude and latitude, thus the distances as shown in Figure 3.5 between the locations are not a real world representation of the actual geography.

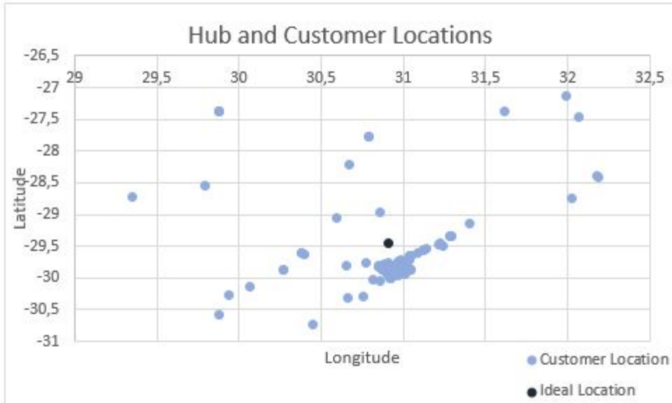

Figure 3.5: Ideal Hub Location

3.2.3 Spoke Locations

An optimization model was built, by using the Operations Research approach, in order to determine the optimal number of spoke locations to be used in the hub and spoke model for this study. In order to formulate the optimization model the following assumptions were made:

- a single spoke location cannot service more than 15 customer ID's per day;
- only clusters within a radius area of 70 km from a spoke location will be serviced by the respective spoke;
- the loads distributed are full capacity loads and to the requirements of an order;
- the amount of customer ID's per cluster is constant;
- the correct amount of products are always available for distribution; and
- the appropriate transportation mechanism is used (i.e. cold, refrigerated and room temperature distribution).

We let:

$$y_i \triangleq \begin{cases} 1 \text{ if spoke } i \text{ is used; where } i \ = \{1, 2, ..., 31\} \\ 0 \text{ otherwise} \end{cases}$$

$$x_{ij} \triangleq \begin{cases} 1 \text{ if cluster } j \text{ is serviced by spoke } i\text{; where } i; j \ = \{1, 2, ..., 31\} \\ 0 \text{ otherwise} \end{cases}$$

$c_{ij} \triangleq$ the number of customer ID's situated in cluster j being serviced by spoke location i, where $i, j = \{1, 2, ..., 31\}$

$d_{ij} \triangleq$ the given distance, in km, between spoke location i and cluster j, where $i, j = \{1, 2, ..., 31\}$

$a_j \triangleq$ the given number of customer ID's in cluster j, where $j = \{1, 2, ..., 31\}$

$$min\ z = \sum_{i=1}^{31} y_i \tag{3.2}$$

subject to:

$$\sum_{i=1}^{31} c_{ij} \geq a_j \qquad \forall j \in \{1, 2, ...31\} \tag{3.3a}$$

$$\sum_{j=1}^{31} c_{ij} \leq 15 y_i \qquad \forall i \in \{1, 2, ...31\} \tag{3.3b}$$

$$d_{ij} x_{ij} \leq 70 \qquad \forall i, j \in \{1, 2, ...31\} \tag{3.3c}$$

$$c_{ij} \leq M x_{ij} \qquad \forall i, j \in \{1, 2, ...31\} \tag{3.3d}$$

$$\sum_{j=1}^{31} x_{ij} \geq M y_i \qquad \forall i \in \{1, 2, ...31\} \tag{3.3e}$$

$$x_{ij} \in \{0; 1\} \qquad \forall i, j \in \{1, 2, ...31\} \tag{3.3f}$$

$$y_i \in \{0; 1\} \qquad \forall i \in \{1, 2, ...31\} \tag{3.3g}$$

$$c_{ij} \geq 0\ and\ integer \qquad \forall i, j \in \{1, 2, ...31\} \tag{3.3h}$$

In this formulation the objective function (3.2) minimizes the number of spoke locations (y_i) to be used in the hub and spoke model. Throughout the model development phase, the indices i and j refer to the spoke and cluster locations respectively, where i and j are each a set of 31 values as created by the test case. The objective is to determine which cluster location will be serviced by which spoke location.

The variables y_i and x_{ij} are both binary variables, thus these variables can only take a value of 1 if the statement is true or a value of 0 if the statement is not true. Consequently the decision variables of the model are y_i, x_{ij} and c_{ij}, which are used to determine whether a specific spoke location will service the respective cluster location, and if so, how many customer ID's in the specific cluster location (j) will be serviced by the respective spoke location (i). Variables d_{ij} and a_j are parameter values which serve as inputs to the model.

Constraint (3.3a) ensures that all the customer ID's in each cluster is serviced. The capacity of each spoke location is limited in constraint (3.3b), i.e. a single spoke location can only serve a limited number of customer ID's per day. Constraint (3.3c) ensures that only clusters within the required radius area are serviced by spoke locations. The different variables are linked in (3.3d) and (3.3e). Binary constraints are included in (3.3f) and (3.3g). Constraint (3.3h) ensures non-negativity and that c_{ij} is an integer value.

Chapter 4

Model Validation

In this chapter computational results for a test case, with the purpose of validating the model developed in Section 3.2.3, is presented. The test case was developed from the data used to create the proof of concept, as mentioned in Section 3.2.

4.1 Test Case

The test case incorporates 31 cluster and 31 spoke locations with corresponding distances between the respective locations together with the given number of customer ID's per cluster.

The customer ID's were clustered based on their locations, thus creating 31 clusters. The cluster location was determined by taking the average longitude (x) and latitude (y) of all the customer ID's situated in the cluster.

The ideal spoke location was determined for each cluster using the centre of gravity method as discussed in Section 2.5.2. A distance matrix was created based on each spoke location relative to each cluster location. The distances between the various locations were calculated by using the trigonometric formula used to calculate distance along the surface of a sphere which can be seen in equation (4.1).

$$Distance = \frac{\cos^{-1}(\sin(lat1) \times \sin(lat2) + \cos(lat1) \times \cos(lat2) \times \cos(long2 - long1))(180)(60)}{\Pi} \quad (4.1)$$

This formula calculates the answer in nautical miles, thus a conversion factor of 1 nm = 1.852 km was used to convert the distances to kilometres. The distance matrix can be seen in Table 4.1. The ideal spoke locations relative to the customer locations can be seen in Figure 4.1.

Figure 4.1: Ideal Customer and Spoke Locations

4.2 Results for the Test Case

For the test case, a distribution area was defined through the data analysis as conducted in Section 3.2.1, and a predefined number of possible spoke locations was determined as described in Section 3.2.3.

(i) \ (j)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	7.52	201.71	21.75	23.49	108.29	29.32	109.96	340.03	10.46	307.45	116.54	28.69	35.03	189.56	111.49	41.34	221.78	200.69	61.81	26.18	302.86	88.23	18.51	182.32	55.57	69.49	87.54	62.08	33.05	46.39	175.93
2	201.01	0.00	195.47	203.05	126.13	173.06	210.90	314.40	204.59	300.39	149.16	190.10	195.15	59.31	204.52	195.03	278.41	140.80	139.94	189.33	267.90	246.75	192.82	260.66	154.95	202.04	199.78	195.94	217.82	192.89	143.63
3	16.58	194.44	2.07	8.63	90.05	26.02	130.73	316.34	16.41	283.71	94.91	5.78	11.61	175.88	87.94	17.90	198.74	180.06	56.94	5.16	279.42	111.97	6.38	159.69	63.07	46.46	64.06	38.61	56.76	22.75	154.72
4	16.59	203.40	8.37	0.60	97.44	34.28	133.68	318.50	14.09	285.30	100.51	13.66	13.77	184.21	88.53	19.37	198.06	186.05	65.86	14.07	282.41	110.98	12.77	158.42	70.37	46.05	64.56	39.34	55.67	24.73	160.38
5	103.65	126.13	91.86	97.37	0.00	81.83	181.52	254.64	105.39	228.02	28.14	84.36	84.99	90.80	79.08	82.05	170.99	94.47	64.29	85.32	212.07	186.87	91.95	143.75	95.24	79.37	74.10	75.25	137.55	78.03	72.41
6	27.96	173.06	26.00	33.76	81.83	0.00	114.09	323.62	31.68	292.70	94.30	24.98	33.94	160.41	102.15	38.57	213.90	175.79	33.25	22.37	284.45	106.62	21.69	176.50	37.87	65.03	79.62	56.06	55.72	41.22	152.09
7	117.17	210.90	129.18	133.11	181.52	114.09	0.00	434.25	120.41	404.90	202.10	133.64	142.18	229.33	216.07	148.25	327.84	273.06	117.45	130.52	393.00	57.25	124.37	289.80	86.59	176.76	193.03	168.29	85.43	152.41	253.52
8	332.91	314.40	318.38	318.84	254.64	323.62	434.25	0.00	332.00	38.10	232.17	311.38	305.48	256.07	231.16	299.35	142.93	177.44	317.24	314.05	46.51	428.06	321.64	180.04	347.80	273.54	254.62	279.23	373.08	294.06	187.13
9	4.85	205.12	14.65	13.64	105.81	32.21	120.61	332.14	0.53	299.14	111.58	22.40	26.68	189.87	102.53	32.80	212.14	196.61	65.46	20.73	295.65	96.94	13.89	172.43	63.63	60.13	78.56	53.23	41.60	38.08	171.36
10	300.19	300.39	285.71	285.68	228.02	292.70	404.90	38.10	299.03	0.00	203.75	278.95	272.60	241.17	197.16	266.38	104.90	160.05	288.88	281.73	45.43	395.67	289.23	142.56	318.95	239.79	220.93	245.96	340.43	261.17	164.88
11	110.59	149.16	96.94	100.60	28.14	94.30	202.10	232.17	111.26	203.75	0.00	89.18	86.87	106.07	56.14	82.25	142.89	85.71	85.21	91.02	191.25	200.91	98.50	116.00	115.63	69.79	58.45	68.89	148.36	77.24	59.87
12	21.86	190.10	7.77	13.43	84.36	24.98	133.64	311.38	22.09	278.95	89.18	0.00	9.14	170.59	83.80	14.71	195.01	174.29	53.85	3.13	274.19	116.75	10.28	156.31	62.77	43.13	60.07	34.82	61.73	18.84	148.97
13	27.64	195.15	13.42	13.95	84.99	33.94	142.18	305.48	26.53	272.60	86.87	9.14	0.00	173.10	76.47	6.32	187.13	172.48	61.18	12.16	269.01	123.18	17.87	148.09	71.80	34.85	52.54	27.07	67.85	11.43	146.72
14	130.30	72.27	123.76	131.22	60.39	102.58	165.02	294.35	133.65	272.57	87.49	118.12	122.93	64.86	138.92	122.76	228.23	118.72	70.31	117.49	249.04	188.75	121.40	203.45	91.58	130.90	130.59	124.33	151.68	120.66	107.77
15	104.05	204.52	89.85	88.94	79.08	102.15	216.07	231.16	102.47	197.16	56.14	83.80	76.47	161.89	0.00	70.15	111.77	125.80	111.22	86.79	197.47	199.46	93.89	74.96	135.79	42.66	23.98	49.41	144.10	65.20	99.51
16	34.67	194.58	20.42	20.45	81.35	38.82	148.80	298.57	33.44	265.62	81.44	15.20	7.03	170.49	69.44	0.83	180.20	167.15	63.44	18.33	262.26	130.20	24.70	141.27	76.59	28.02	45.52	20.06	74.86	4.55	141.19
17	214.27	278.40	200.54	198.54	170.99	213.90	327.84	142.92	212.16	104.89	142.89	195.02	187.14	222.62	111.77	180.84	0.01	149.57	219.92	198.08	127.22	308.52	204.89	41.11	246.58	152.34	135.00	160.22	253.55	176.21	136.56
18	195.22	140.80	182.05	186.12	94.47	175.79	273.06	177.44	196.26	160.05	85.71	174.29	172.48	81.50	125.80	167.95	149.58	0.00	157.66	175.90	131.37	281.33	183.18	145.61	188.20	153.46	138.67	153.86	231.29	162.95	26.74
19	61.86	139.25	58.08	65.96	63.69	33.91	118.00	316.74	65.58	288.44	84.75	54.33	61.60	130.17	111.13	63.92	219.69	156.99	0.77	52.73	275.05	126.16	54.65	185.65	31.55	83.49	92.57	74.72	83.02	64.14	136.03
20	20.05	188.97	7.07	14.10	84.87	22.26	130.71	313.70	20.81	281.40	90.59	3.00	12.10	170.37	6.52	17.70	197.83	175.46	51.94	0.45	276.32	114.38	8.07	159.20	59.96	46.05	62.86	37.68	59.51	21.72	150.29
21	295.98	267.90	281.48	282.70	212.07	284.45	393.00	46.51	295.47	45.43	191.25	274.19	269.01	209.56	197.47	263.06	127.24	131.37	275.59	276.70	0.00	390.19	284.36	157.94	306.41	238.81	220.00	243.62	335.82	257.71	142.62
22	95.54	246.75	109.98	110.56	186.87	106.62	57.25	428.06	96.99	395.67	200.91	116.75	123.18	253.13	199.46	129.46	308.52	281.33	125.43	114.03	390.19	0.00	106.47	268.31	97.72	157.03	175.48	150.10	55.36	134.59	258.36
23	11.83	193.07	5.12	12.07	92.23	21.88	124.29	321.84	13.17	289.42	98.76	10.47	17.97	176.49	94.04	24.20	205.02	183.44	54.28	7.90	284.58	106.28	0.28	166.05	57.79	52.81	70.22	44.82	51.28	28.87	158.38
24	174.80	260.66	161.41	158.91	143.75	176.50	289.80	180.04	172.47	142.56	116.00	156.31	148.09	208.73	74.96	141.86	41.10	145.61	185.79	159.41	157.94	268.31	165.94	0.00	210.74	113.25	96.90	121.54	213.59	137.47	126.43
25	58.77	154.97	62.60	69.79	95.25	37.87	86.58	347.81	63.13	318.96	115.64	62.77	71.79	155.53	135.80	76.38	246.59	188.21	30.97	60.02	306.42	97.71	57.68	210.74	0.02	101.85	114.73	92.77	63.12	78.70	167.56
26	61.99	202.04	48.22	46.49	79.37	65.03	176.76	273.54	60.10	239.79	69.79	43.13	34.85	170.05	42.66	28.61	152.34	153.46	83.33	46.25	238.81	157.03	52.70	113.25	101.84	0.00	18.93	9.08	101.72	24.38	126.80
27	80.07	199.75	65.92	64.95	74.08	79.59	193.00	254.64	78.47	220.95	58.44	60.05	52.52	162.93	24.00	46.19	135.03	138.67	92.52	63.08	220.01	175.46	70.05	96.93	114.70	18.91	0.03	25.44	120.10	41.32	111.92
28	59.87	196.69	45.73	44.86	74.53	60.88	173.42	274.21	58.33	240.84	66.27	40.02	32.32	165.30	44.19	25.99	155.00	150.69	78.07	43.10	238.81	155.30	49.93	116.39	97.27	5.55	20.23	5.24	99.94	21.21	124.11
29	39.31	218.36	53.83	54.16	137.26	55.46	86.91	372.20	40.60	339.49	147.80	60.89	66.89	213.32	143.07	73.14	252.39	230.91	82.43	58.34	335.04	56.40	50.68	212.40	63.80	100.65	119.09	93.72	1.49	78.32	206.70
30	39.05	192.87	24.68	25.01	78.01	41.20	152.40	294.06	37.94	261.17	77.23	18.83	11.43	167.61	65.20	5.37	176.21	162.94	63.81	21.93	257.71	134.59	28.73	137.48	78.69	24.39	41.36	15.99	79.27	0.02	136.92
31	168.35	143.17	154.88	158.63	70.60	150.23	251.76	188.58	169.17	166.11	58.03	147.11	144.88	86.07	98.05	140.18	136.63	28.43	134.84	148.86	144.16	256.51	156.26	125.93	165.76	125.06	110.27	125.61	205.30	135.10	1.87

Table 4.1: Distance Matrix

The results for the test case, as determined through the optimization model formulated in Section 3.2.3 can be seen in Table 4.2, which indicates that the optimal number of spoke locations to be used in the distribution network is 11. The respective spoke locations which will be utilised are 2, 3, 6, 7, 10, 11, 18, 20, 24, 27, 29.

Table 4.2 also indicates which cluster (j) will be serviced by which spoke location (i), and the number of customers in each cluster (j) to be serviced by the respective spoke location (i). The results from the optimization model, as formulated in Lingo, demonstrate the model's ability to satisfy the capacity constraints as formulated in Section 3.2.3. Thus, each spoke location, (i), only services selected clusters (j) within a radius area of lower than 70 km from the respective spoke location, satisfying constraint (3.3c) as formulated in the optimization model. Each spoke location, (i), also does not service more than 15 customers in a cluster (j), thus satisfying constraint (3.3b) in the formulated optimization model.

The proposed distribution network, based on the ideal hub location and optimization model results, can be seen in Figure 4.2. Primary distribution would be from the manufacturing facility in truck loads to the hub location, thus large quantities are delivered to the hub locations. From the hubs, the customer orders are consolidated based on the cluster requirements. Secondary distribution is established by sending the cluster requirements to the relevant spoke locations, in smaller quantities, from were individual customer orders are consolidated. The final mile of distribution is from the spoke location, to the specified customer location. Thus the distribution model developed is in essence a three tier distribution model.

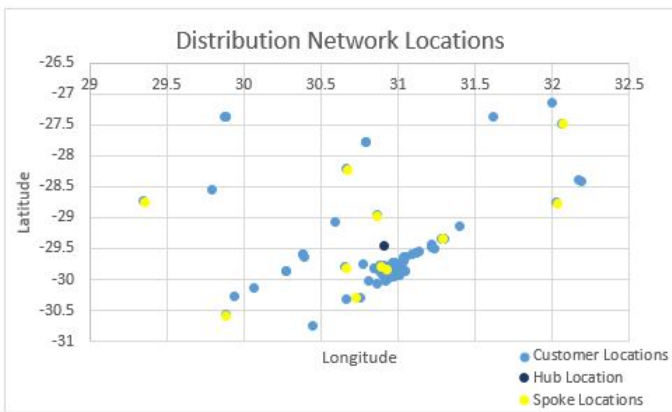

Figure 4.2: Distribution Network Locations

4.3 Sensitivity Analysis

A sensitivity analysis was created in order to determine how the uncertainty in the output of the model can be assigned to different sources of uncertainty in its inputs. It is important to ensure that the model responds as expected when the inputs/constraints are varied.

For the purpose of validating the optimization model, the model was run for a number of iterations. The constraints based on the assumptions as mentioned in Section 3.2 were varied in accordance to a percentage change from the base case values in order to determine whether the model would behave as expected. The two assumptions which were changed are:

- the radius distance from which a spoke can service a cluster location; and
- the amount of customers within a cluster, which each spoke location can service.

Table 4.3 depicts the values used to conduct the sensitivity analysis. The percentage change is the

(i)															(j)																
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	14	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	6	0	0	3
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	1	0	0	2	0	0	0	1	0	0	0	0	0	3	2	0	0	4	0	2	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	4	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	4	0	4	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**4**	**1**	**4**	**33**	**1**	**1**	**1**	**1**	**6**	**1**	**1**	**1**	**1**	**6**	**1**	**2**	**2**	**1**	**3**	**2**	**1**	**1**	**4**	**1**	**2**	**1**	**4**	**6**	**2**	**4**	**3**

Table 4.2: Optimization Model Results

variation from the base case values as used in the model formulation. The radius distance values were altered (from 70 km to each respective value in the table) while the number of customers serviced were kept constant. The number of spokes for each scenario were recorded, as the output given by the Lingo model. Furthermore the number of customers each spoke can service was changed from the base case value of 15 customers (with a percentage from the base case as seen in Table 4.3), keeping the distance radius constant at 70 km, and the output (number of spokes) generated by the Lingo model was recorded. A visual depiction of the results for the sensitivity analysis can be seen in Figure 4.3.

Percentage Change	**Distance (km)**	**Spokes**	**Capacity**	**Spokes**
-0.30	49.00		10.50	13
-0.25	52.50		11.25	13
-0.20	56.00		12	12
-0.15	59.50	11	12.75	12
-0.10	63.00	11	13.50	11
-0.05	66.50	11	14.25	11
0.00	70.00	11	15	11
0.05	73.50	11	15.75	11
0.10	77.00	10	16.50	10
0.15	80.50	10	18	10
0.20	84.00	10	18	10
0.25	87.50	9	18.75	10
0.30	91.00	9	19.5	10
0.35	94.50	9	20.25	9
0.40	98.00	9	21	9
0.45	101.50	9	21.75	9
0.50	105.00	8	22.50	9
0.55	108.50	8	23.25	9
0.60	112.00	8	24	9
0.65	115.50	8	24.75	9
0.70	119.00	8	25.50	9
0.75	122.50	8	26.25	9
0.80	126.00	8	27	8
0.85	129.50	8	27.75	8
0.90	133.00	8	28.50	8
0.95	136.50	8	29.25	8
1.00	140.00	8	30	8

Table 4.3: Sensitivity Analysis Values

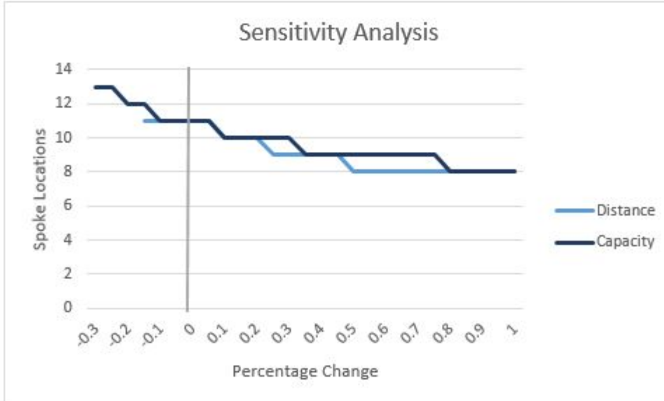

Figure 4.3: Sensitivity Analysis

The results show that for a distance variation of -0.30 to -0.20 from the base case value, no feasible solution was found. This is due to spoke and cluster location 13. As can be seen from the distance matrix in Table 4.1 the smallest distance between a spoke location (i) and cluster location (j) is 59.31 km. Consequently the model only starts yielding results once the distance variation reaches a value of -0.15 from the base case value (59.50 km), which indicates that the model behaves as expected.

Furthermore with a variation in the distance radius serviced, the model yields a larger number of spoke locations to be utilised for the reduction in distance. As the distance radius serviced is increased from the base case value, the number of spoke locations to be utilised decrease. In both instances the model behaves as expected.

As the amount of customers to be serviced by each spoke location is decreased, the number of spoke locations to be utilised increases. Consequently the number of spoke locations to be utilised in the instance of an increase in the amount of customers to be serviced by each spoke location, decreases.

The conclusion which can be drawn from the sensitivity analysis is that the model behaves as expected when the assumption values are varied, which serves as model validation.

Chapter 5

Conclusion and Recommendations

The aim of the project was to determine whether a market opportunity exists to service the BOP market segment in South Africa. Based on the results from the market evaluation phase, various distributors who have successfully entered the BOP market were researched in order to determine what the best route to market solution would be.

The literature review in Chapter 2 successfully addressed the problem statement and aim of the project. The analysis of the BOP market segment globally and locally validated that there is a market opportunity for companies to enter this segment. Various distributors who have successfully entered the BOP market segment were researched to evaluate their approaches to service this segment. Based on the findings from the literature case studies in Section 2.3, the distribution models used were further researched to ensure a clear understanding of the working thereof. Several modelling techniques were researched in this project in order to make an effective recommendation based on the findings in the literature review.

An evaluation framework was developed in order to determine the most effective route to market based on key criteria. The evaluation framework determined that the best route to market for established distribution companies is to develop a hub and spoke distribution model. Consequently the selected distribution method had to be modelled in order to make an informed recommendation.

The data set provided was reduced in order to create a proof of concept for the model formulation phase of the project. The data was reduced by firstly selecting a province on which to focus, based on analyses, and secondly by applying a three sigma range to the data set. The hub and spoke model was formulated based on the reduced data set.

The ideal location for the hub was determined by using the centre of gravity method as discussed in Section 2.5.2. The cluster locations were determined by clustering the data based on the customer ID locations. The location for each spoke was determined by again applying the centre of gravity method. A distance matrix was created in order to use as an input into the spoke location model.

An optimization model was created in order to determine the optimal number of spoke locations to be used in the distribution network. The optimization model was built on a few key assumptions as mentioned in Section 3.2.3.

The model was validated by applying it to a test case to create the proof of concept as mentioned previously. The main objective of the model was to minimize the number of spoke locations to be used in the distribution model. The input locations into the model was a 31×31 distance matrix. After the formulation of the model in Lingo, the model calculated that the optimal number of spoke locations to be used in the distribution network is 11, thus satisfying the objective function of minimization. The test case results were also evaluated to determine whether it satisfied all the constraints, especially the capacity constraints, in which it did, which added to the validation of the model. Together with the test case created, a sensitivity analysis was performed to evaluate whether the model behaved as expected, which it did, thus proving that the model is valid.

Thus the recommended distribution strategy to service the BOP market segment would be the implementation of a hub and spoke model. The research conducted in this project mentioned a few logistics providers who have successfully adapted their distribution structure to a hub and spoke model. The main benefit of using this structure is the 'reach' in terms of customers and markets, as the distributor is closer to the customer. The main goal is to supply a maximum amount of customers a minimum amount of time. The hub and spoke model allows for the goal to be reached.

The economies of scale is another advantage of using the hub and spoke distribution model. Furthermore the consolidation of smaller order quantities for deliveries may be achieved, thus addressing the problem of more frequent deliveries due to limited on premises storage space as mentioned in Section 1.3. Theoretically costs will also be reduced as transportation mechanisms can be interchanged at the hub and spoke locations as required, i.e. switching between larger and smaller transport modes. The hub and spoke model also allows for simplified network routes, which decreases the complexity of distribution.

5.1 Recommendations

Further research should be conducted into the possible backbone structures used in the hub and spoke model in order to further optimize the recommended solution. The various backbone structures can be seen in Figure 5.1. The most appropriate delivery methods should also be determined, i.e. smaller vans, bicycles, etc. The possibility and benefits of including the local community in the distribution network should also be evaluated, as this was a key success factor for other distribution companies.

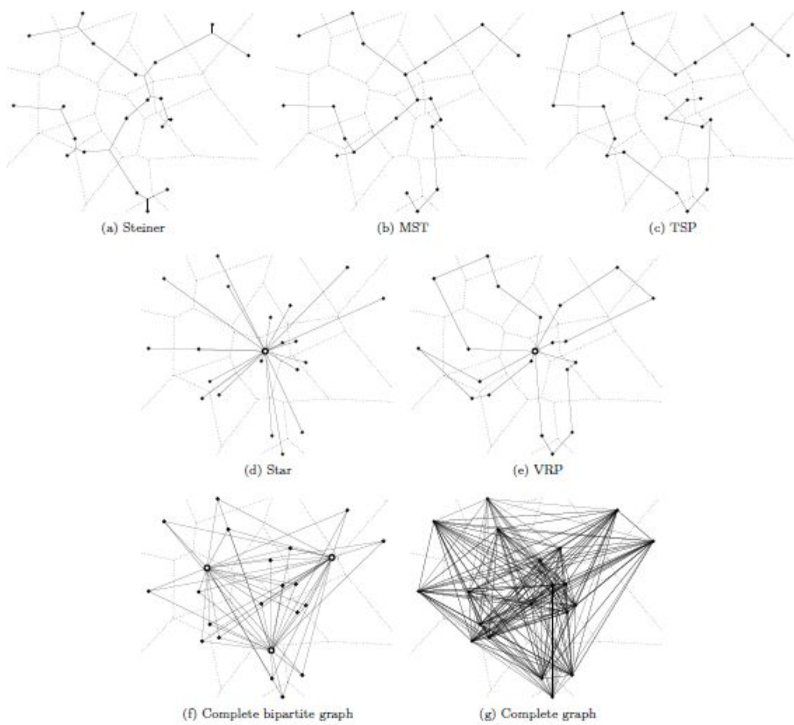

Figure 5.1: Backbone Network Structures (Gunnar, J., Jia, F., 2013)

The model was built on the assumption that the appropriate product mix is delivered to the customers. Research may be conducted into methods to determine what the optimal fleet mix would be to deliver to the BOP customer segment based on the frequency of delivery and distribution method and model used.

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Appendix A

Industry Sponsorship Form

Department of Industrial & Systems Engineering
Final Year Projects
Identification and Responsibility of Project Sponsors

All Final Year Projects are published by the University of Pretoria on *UPSpace* and thus freely available on the Internet. These publications portray the quality of education at the University and have the potential of exposing sensitive company information. It is important that both students and company representatives or sponsors are aware of such implications.

Key responsibilities of Project Sponsors:

A project sponsor is the key contact person within the company. This person should thus be able to provide the best guidance to the student on the project. The sponsor is also very likely to gain from the success of the project. The project sponsor has the following important responsibilities:

1. Confirm his/her role as project sponsor, duly authorised by the company. Multiple sponsors can be appointed, but this is not advised. The duly completed form will considered as acceptance of sponsor role.
2. Review and approve the Project Proposal, ensuring that it clearly defines the problem to be investigated by the student and that the project aim, scope, deliverables and approach is acceptable from the company's perspective.
3. Review the Final Project Report (delivered during the second semester), ensuring that information is accurate and that the solution addresses the problems and/or design requirements of the defined project.
4. Acknowledges the intended publication of the Project Report on UP Space.
5. Ensures that any sensitive, confidential information or intellectual property of the company is not disclosed in the Final Project Report.

Project Sponsor Details:

Company:	RCL Foods (Vector Logistics)
Project Description:	Determining the optimal fleet mix & size for servicing the "bottom of the pyramid" given multi-temperature products
Student Name:	Riandré Prinsloo
Student number:	13055675
Student Signature:	Prinsloo
Sponsor Name:	Ashleigh Jacobs
Designation:	Supply Chain Solutions Architect
E-mail:	ashleighj@vectorlog.com
Tel No:	087 362 8451
Cell No:	084 245 0325
Fax No:	-
Sponsor Signature:	Jacobs

Appendix B

Lingo Model Formulation

```
Model:

Title: Determining the optimal number of spoke locations;

sets:
      location/1..31/:
            a, ! given number of customers in cluster j;
            y; ! 1 if spoke location i is used;
               ! 0 otherwise.;
      assign(location,location):
            d, ! given distance between i and j;
            c, ! number of customers in cluster j serviced by spoke location i;
            x; ! 1 if cluster j is serviced by spoke location i
                ! 0 otherwise.;
endsets

data:
      d = 7.52    201.71 21.75 23.49 108.29 29.32 109.96 340.03 10.46 307.45 116.54 28.69 35.03 189.56 111.49 41.34 221.78 200.69 61.81 26.18 302.86 88.23 18.51 182.32 55.57 69.49 87.54 62.08 33.05 46.39 175.93
          201.01  0.00 195.47 203.05 126.13 173.06 210.90 314.40 204.59 300.39 149.16 190.10 195.15 59.31 204.52 195.03 278.41 140.80 139.94 189.33 267.90 246.75 192.82 260.66 154.95 202.04 199.78 195.94 217.82 192.89 143.63
          16.58   194.44 2.07 8.63 90.05 26.02 130.73 316.34 16.41 283.71 94.91 5.78 11.61 175.88 87.94 17.90 198.74 180.06 56.94 5.16 279.42 111.97 6.38 159.69 63.07 46.46 64.06 38.61 56.76 22.75 154.72
          16.59   203.40 8.37 0.60 97.44 34.28 133.68 318.50 14.09 285.30 100.51 13.66 13.77 184.21 88.53 19.37 198.06 186.05 65.86 14.07 282.41 110.98 12.77 158.42 70.37 46.05 64.56 39.34 55.67 24.73 160.38
          103.65  126.13 91.86 97.37 0.00 81.83 181.52 254.64 105.39 228.02 28.14 84.36 84.99 90.80 79.08 82.05 170.99 94.47 64.29 85.32 212.07 186.87 91.95 143.75 95.24 79.37 74.10 75.25 137.55 78.03 72.41
          27.96   173.06 26.00 33.76 81.83 0.00 114.09 323.62 31.68 292.70 94.30 24.98 33.94 160.41 102.15 38.57 213.90 175.79 33.25 22.37 284.45 106.62 21.69 176.50 37.87 65.03 79.62 56.06 55.72 41.22 152.09
          117.17  210.90 129.18 133.11 181.52 114.09 0.00 434.25 120.41 404.90 202.10 133.64 142.18 229.33 216.07 148.25 327.84 273.06 117.45 130.52 393.00 57.25 124.37 289.80 86.59 176.76 193.03 168.29 85.43 152.41 253.52
          332.91  314.40 318.38 318.84 254.64 323.62 434.25 0.00 332.00 38.10 232.17 311.38 305.48 256.07 231.16 299.35 142.93 177.44 317.24 314.05 46.51 428.06 321.64 180.04 347.80 273.54 254.62 279.23 373.08 294.06 187.13
          4.85    205.12 14.65 13.64 105.81 32.21 120.61 332.14 0.53 299.14 111.58 22.40 26.68 189.87 102.53 32.80 212.14 196.61 65.46 20.73 295.65 96.94 13.89 172.43 63.63 60.13 78.56 53.23 41.60 38.08 171.36
          300.19  300.39 285.71 285.68 228.02 292.70 404.90 38.10 299.03 0.00 203.75 278.95 272.60 241.17 197.16 266.38 104.90 160.05 288.88 281.73 45.43 395.67 289.23 142.56 318.95 239.79 220.93 245.96 340.43 261.17 164.88
          110.59  149.16 96.94 100.60 28.14 94.30 202.10 232.17 111.26 203.75 0.00 89.18 86.87 106.07 56.14 82.25 142.89 85.71 85.21 91.02 191.25 200.91 98.50 116.00 115.63 69.79 58.45 68.89 148.36 77.24 59.87
          21.86   190.10 7.77 13.43 84.36 24.98 133.64 311.38 22.09 278.95 89.18 0.00 9.14 170.59 83.80 14.71 195.01 174.29 53.85 3.13 274.19 116.75 10.28 156.31 62.77 43.13 60.07 34.82 61.73 18.84 148.97
          27.64   195.15 13.42 13.95 84.99 33.94 142.18 305.48 26.53 272.60 86.87 9.14 0.00 173.10 76.47 6.32 187.13 172.48 61.18 12.16 269.01 123.18 17.87 148.09 71.80 34.85 52.54 27.07 67.85 11.43 146.72
          130.30  72.27 123.76 131.22 60.39 102.58 165.02 294.35 133.65 272.57 87.49 118.12 122.93 64.86 138.92 122.76 228.23 118.72 70.31 117.49 249.04 188.75 121.40 203.45 91.58 130.90 130.59 124.33 151.68 120.66 107.77
          104.05  204.52 89.85 88.94 79.08 102.15 216.07 231.16 102.47 197.16 56.14 83.80 76.47 161.89 0.00 70.15 111.77 125.80 111.22 86.79 197.47 199.46 93.89 74.96 135.79 42.66 23.98 49.41 144.10 65.20 99.51
          34.67   194.58 20.42 20.45 81.35 38.82 148.80 298.57 33.44 265.62 81.44 15.20 7.03 170.49 69.44 0.83 180.20 167.15 63.44 18.33 262.26 130.20 24.70 141.27 76.59 28.02 45.52 20.06 74.86 4.55 141.19
          214.27  278.40 200.54 198.54 170.99 213.90 327.84 142.92 212.16 104.89 142.89 195.02 187.14 222.62 111.77 180.84 0.01 149.57 219.92 198.08 127.22 308.52 204.89 41.11 246.58 152.34 135.00 160.22 253.55 176.21 136.56

          195.22  140.80 182.05 186.12 94.47 175.79 273.06 177.44 196.26 160.05 85.71 174.29 172.48 81.50 125.80 167.95 149.58 0.00 157.66 175.90 131.37 281.33 183.18 145.61 188.20 153.46 138.67 153.86 231.29 162.95 26.74
          61.86   139.25 58.08 65.96 63.69 33.91 118.00 316.74 65.58 288.44 84.75 54.33 61.60 130.17 111.13 63.92 219.69 156.99 0.77 52.73 275.05 126.16 54.65 185.65 31.55 83.49 92.57 74.72 83.02 64.14 136.03
          20.05   188.97 7.07 14.10 84.87 22.26 130.71 313.70 20.81 281.40 90.59 3.00 12.10 170.37 86.52 17.70 197.83 175.46 51.94 0.45 276.32 114.38 8.07 159.20 59.96 46.05 62.86 37.68 59.51 21.72 150.29
          295.98  267.90 281.48 282.70 212.07 284.45 393.00 46.51 295.47 45.43 191.25 274.19 269.01 209.56 197.47 263.06 127.24 131.37 275.59 276.70 0.00 390.19 284.36 157.94 306.41 238.81 220.00 243.62 335.82 257.71 142.62
          95.54   246.75 109.98 110.56 186.87 106.62 57.25 428.06 96.99 395.67 200.91 116.75 123.18 253.13 199.46 129.46 308.52 281.33 125.43 114.03 390.19 0.00 106.47 268.31 97.72 157.03 175.48 150.10 55.36 134.59 258.36
          11.83   193.07 5.12 12.07 92.23 21.88 124.29 321.84 13.17 289.42 98.76 10.47 17.97 176.49 94.04 24.20 205.02 183.44 54.28 7.90 284.58 106.28 0.28 166.05 57.79 52.81 70.22 44.82 51.28 28.87 158.38
          174.80  260.66 161.41 158.91 143.75 176.50 289.80 180.04 172.47 142.56 116.00 156.31 148.09 208.73 74.96 141.86 41.10 145.61 185.79 159.41 157.94 268.31 165.94 0.00 210.74 113.25 96.90 121.54 213.59 137.47 126.43
          58.77   154.97 62.60 69.79 95.25 37.87 86.58 347.81 63.13 318.96 115.64 62.77 71.79 155.53 135.80 76.38 246.59 188.21 30.97 60.02 306.42 97.71 57.68 210.74 0.02 101.85 114.73 92.77 63.12 78.70 167.56
          61.99   202.04 48.22 46.49 79.37 65.03 176.76 273.54 60.10 239.79 69.79 43.13 34.85 170.05 42.66 28.61 152.34 153.46 83.33 46.25 238.81 157.03 52.70 113.25 101.84 0.00 18.93 9.08 101.72 24.38 126.80
          80.07   199.75 65.92 64.95 74.08 79.59 193.00 254.64 78.47 220.95 58.44 60.05 52.52 162.93 24.00 46.19 135.03 138.67 92.52 63.08 220.01 175.46 70.05 96.93 114.70 18.91 0.03 25.44 120.10 41.32 111.92
          59.87   196.69 45.73 44.86 74.53 60.88 173.42 274.21 58.33 240.84 66.27 40.02 32.32 165.30 44.19 25.99 155.00 150.69 78.07 43.10 238.81 155.30 49.93 116.39 97.27 5.55 20.23 5.24 99.94 21.21 124.11
          39.31   218.36 53.83 54.16 137.26 55.46 86.91 372.20 40.60 339.49 147.80 60.89 66.89 213.32 143.07 73.14 252.39 230.91 82.43 58.34 335.04 56.40 50.68 212.40 63.80 100.65 119.09 93.72 1.49 78.32 206.70
          39.05   192.87 24.68 25.01 78.01 41.20 152.40 294.06 37.94 261.17 77.23 18.83 11.43 167.61 65.20 5.37 176.21 162.94 63.81 21.93 257.71 134.59 28.73 137.48 78.69 24.39 41.36 15.99 79.27 0.02 136.92
          168.35  143.17 154.88 158.63 70.60 150.23 251.76 188.58 169.17 166.11 58.03 147.11 144.88 86.07 98.05 140.18 136.63 28.43 134.84 148.86 144.16 256.51 156.26 125.93 165.76 125.06 110.27 125.61 205.30 135.10 1.87;

      a = 4 1 4 33 1 1 1 1 6 1 1 1 1 6 1 2 2 1 3 2 1 1 4 1 2 1 4 6 2 4 3;
      BigM = 1000000;
enddata

! Minimize the number of spoke locations;
[Objective] Min = @Sum(location(j): y(j));

! Limit distance;
@For(assign(i,j):
      d(i,j)*x(i,j) <= 70;
);

! All customers in cluster is serviced;
@For(location(j):
      @Sum(location(i): c(i,j)) >= a(j);
);
```

```
! Spoke capacity limit;
@For(location(i):
      @Sum(location(j): c(i,j)) <= 15 * y(i);
);

! Linking variables;
@For(assign(i,j):
      c(i,j) <= BigM * (x(i,j));
);

! Linking variables;
@For(location(i):
      @Sum(location(j): x(i,j)) <= BigM * (y(i));
);

! Binary and integer values;
@For(assign:
      @Bin(x);
);
@For(location:
      @Bin(y)
);

End
```