CHAPTER 1

1.0 Introduction

In the 80's and the early 90's people were seen buying food in leaves and using cups to sell water. This kind of living brought about many illness and diseases. Then people found out that the use plastic was a safe and hygienic way of transporting food, water, drugs and other items and it was also cheap. This came with a price to Ghana and that is the waste. One of the major problems in Ghana is the amount of plastic littering the streets. There is no proper way of collecting plastic bag waste and people are not educated as to the problems associated with plastic waste. It is in this light that some private companies have seen the revenue that can be generated in this waste.

The greatest resource of recycling companies is the items they produce, which is their main sources of income. Recycling companies have to select items that will maximize revenue to produce as they have the option of producing a lot of items. Almost every organization faces the problem of allocating limited resources (capital and other scarce resources including time, people) across projects or other type of investments. There is therefore the need to allocate these resources to maximize the returns from a given investment. The goal is to select the particular subsets of items, which can be funded within a budget constraint. Packing is the action of putting things together, especially of putting clothes into a suitcase for a journey or surround with something crammed tightly. Packing problems form integral part in a man's life and cannot be ignored outright. Almost everyone is involved in packing. When it is done efficiently, at least to its optimal level, space and time are saved These problems are generally called knapsack problems, since they recall the situation of a traveler having to fill up his knapsack by selecting from among various possible objects those which will give him the maximum comfort.

1.1 Background of the study

Plastic has become one of the most successful products in recent times. It has gain popularity due to the fact that they are lightweight, strong, and cheap and is a hygienic way of transporting foods and goods.

It is estimated that currently between five hundred (500) billion and one trillion plastic are used globally each year. As much as consumed, 75% of what is consumed end up as waste soon after use. Because of the cheap nature of plastics, they are gotten freely and therefore they are discarded anyhow making it difficult to control the environment and also to adapt better ways of handling them (Food production daily, 2005).

There are a lot of plastic manufacturing companies in Accra and Kumasi. Also these two cities are heavily populated due to rural-urban migration. There is heavy influx of people from rural areas in search for 'white color jobs'.

Plastic bag waste is a continually growing problem at global and regional as well as at local levels. Plastic wastes arise from human and animal activities that are normally discarded as useless or unwanted. In other words, plastic wastes may be defined as the organic and inorganic materials produced by various activities of man, and which have lost their value to the first user.

As a result of rapid increase in production and consumption, urban society rejects and generates plastic bag waste regularly, which leads to considerable increase in the volume of plastic bag waste generated from several sources such as, domestic plastic wastes, commercial plastic wastes, institutional plastic wastes and industrial plastic wastes of most various categories.

Management of plastic bag waste may be defined as that discipline associated with the control of generation, storage, collection, transfer and transport, processing, and disposal in a manner that is in accord with the best principles of public health, economics, conservation, aesthetics, and other environmental considerations. In its scope, waste management includes all administrative, financial, legal, planning, and engineering functions involved in the whole spectrum of solutions to problems of wastes thrust upon the community by its inhabitants (Tchobanaglous et al., 1997).

Plastic wastes have the potential to pollute all the vital components of living environment (i.e., air, land and water) at local and at global levels. The problem is compounded by trends in consumption and production patterns and by continuing urbanization of the world. The problem is more acute in developing countries than in developed countries as economic growth as well as urbanization is more rapid.

Governments in developing countries for some time now, have included private organizations in providing this public service. New methods of storage, collection, transportation, processing and disposal are being implemented. It is necessary to improve upon the current process at this stage to understand if the methods being implemented are suitable for the Ghanaian scenario and to identify the gap in the methods being adopted.

Numerous options are available in plastic bag waste management, among developed countries. Replicating the same in low-income countries is inappropriate. The success of plastic bag waste disposal practices depends largely on overcoming the following constraints:

(i) municipal capacity: The scale of task is enormous and regulatory authorities are able to collect only 20-40% of total plastic bag waste generated, so treatment and disposal inevitably receives less attention. Attempts are being made in a few instances to overcome this lack of capacity by privatizing this operation.

(ii) political commitments: plastic bag waste management is much more than a technical issues; it has implications for local taxation, employment, and regulation of public and managing authorities. Any change needs political support to be effective. However, it is rarely a priority for political concerns unless there is strong and active public interest. This is viewed as a cost to the "public" without apparent returns.

(iii) finance, cost recovery and resource constraints: Deployment of a proper management system represents a major investment and it may be difficult to give it priority over other resource demands. Most of the waste management authorities are severely constrained by the lack of resource to finance their services. Since the collection and transport itself usually dominate waste management costs in developing countries, safe disposal invariably receives less attention where as in all other developed countries concentrate on all aspects of management.

(iv) technical guidelines: Standards of planning and implementation in high-income countries may not be appropriate in low-income countries due to difference in climate, resource, institutions, attitude priorities, etc. However, relatively little appropriate guidance is available for low-income countries. Arising from this uncertainty, officials find themselves ill equipped to plan management strategies, which are both achievable and avoid unacceptable environmental hazards.

(v) Inadequate legal provisions: In most countries there are no laws and regulations on plastic bag waste management and in countries where they have, they are outmoded and uneven and hence are inadequate to deal effectively with the modern complications of managing plastic wastes in large cities. Most of the laws deal with the general tidiness of the city streets, waste collection and their disposal at places away from settlements. Even these inadequate laws are not fully enforced. This aggravates the situation further.

There are two types of plastic waste that are generated in Ghana, which are primary and secondary plastic waste. Primary plastic wastes are generated within the plastic producing and goods manufacturing industries. A characteristic of primary plastic bag waste is that the quantity of plastic recovered for processing is almost as high as that of virgin plastics. The plastic bag waste is pure and suitable for reprocessing with standard equipment into the same kind of products manufactured from virgin materials. The processing of primary plastic bag waste into products with characteristics similar to those of original products is called primary recycling (Ehrig, 1992). Primary plastic bag waste is usually homogeneous and therefore its recycling is comparatively economical and easier.

'Secondary plastic waste' refers to plastic bag waste from sources other than the industrial plastic waste. This type of plastic bag waste is many in Ghana due to the consumption and littering habits of inhabitance. These plastic wastes are impure, that is they may be contaminated and often consist of mixture of various types of plastics. The direct reprocessing of such mixed plastics/supplies is called secondary recycling and results in products with poor mechanical properties because of the different characteristics of the plastic they contain. The potential for marketing these materials is relatively low.

As regards their persistence, currently used plastic bags are known to take between 20 and 1000 years to decompose or break down in the environment (Parliament of New South Wales, 2004). Their ecological and visual litter impact include plastic bag waste resources in the form of useful materials locked up in landfills, aesthetic deterioration of landscapes and water ways, treats to wildlife and toxic gas emissions through open burning (zero plastic waste, new Zealand, 2002)

The impact of plastic bag waste in the marine is also a matter of concern to all, as aquatic life can easily be affected through entanglement, suffocation and ingestion (National Plastic Bags Working Group, 2002).

1.2 Statement of the problem

From practically zero consumption in the beginning of the 20th century, human kind consumes more than two hundred (200) million tons of plastic per year. Plastic has now come to replace leave, paper, and metal. Plastics have shown to be durable and flexible, light weight, hygienic, safe, good resistance to chemicals and water and it is also cheap.

Rank	Country	1998 MMT	country	2000 MMT	country	2010 MMT	2010/ 2000
1	USA	16.6	USA	27.3	USA	38.9	3.6%
2	Germany	6.4	china	14.4	china	31.3	8.1%
3	Japan	4.3	Japan	9.1	India	12.5	14%
4	China	3.7	Germany	6.4	Japan	11.5	2.3%
5	Italy	3.1	Korea	4.7	Germany	9.4	3.9%
6	CIS	2.4	Italy	4.7	Korea	7.4	4.8%
7	France	2.4	France	4.1	Italy	6.8	3.8%
8	UK	2.2	UK	3.5	Brazil	6.7	7.0%
9	Taiwan	1.9	India	3.4	CIS	6.2	9.1%
10	Korea	1.8	Brazil	3.4	France	6.1	4.1%

Table 1.1 The global consumption of plastic for the first ten countries (Girish Luthra (2010))

From Table 1.1, it is clear that, plastic consumption has been increasing from year to year.

Over the last few decades there has been a steady increase in the use of plastic products resulting in a proportionate rise in plastic bag waste in the municipal solid waste streams in large cities in sub-Sahara Africa (World Bank, 1996; Yankson, 1998). Kreith (1994) suggested that the factors that tend to increase the per-capita and total amount of waste as well as their constituents in waste stream include increase population, increase levels of affluence, changes in life style, changes in work patterns, new products, redesign of products, material substitution and changes in food processing and packaging methods.

Again, because of the heat in the country we require regular intake of water during working hours or anytime we fill like it at any places. So it is very common to see people (young and old) selling iced water in basins, trays or ice-chest on their head in streets and public places in towns and cities.

Sellers of cooked foods used to use leaves and papers to sell their products but nowadays they have also turn to the use of plastic bags as that is the most safe, portable, convenience and hygienic way to transport food to other places. It is even common to see people eating from plastic bags. The food is sold to passers-by who will usually accept the food in plastics/leaves (Yankson, 1998).

The packaging materials are most often dumped anywhere at the convenience of the trekking population since there is usually no mechanism that allows proper disposal of these materials after consumption. This gives rise to indiscriminate dumping of various types of plastic bags.

It is very common in many West African countries to have places where food and drinking water are sold to the public cited in open spaces. This is normally anywhere near offices, market places, public schools, churches and in any available open space and in places where people can easily see it. The most common of this kind of trade is that practiced by vendors of drinking water and food who use walkways and pavements as the premises of their businesses to market their products to people in moving vehicles.

In the 80's, it became apparent that easy spread of such food and water bring diseases as typhoid, cholera and dysentery, in event of epidemics were intricately associated with these cultural practices in the food and water industry. This discovery imposed a safety requirement on street vendors to institute new ways of food and water handling that would be safe and healthy so as to minimize the risk of disease episodes associated with the marketing of cooked foods and drinking water. the growing awareness in safe and proper modes of food packaging as well as increase need for more hygienic methods of handling drinking water to safeguard public health started off a decade of remarkable increase in the use of plastic products in west Africa.

This has addressed the health issues relating food and water packaging, but it has also created the problem of plastic bag waste in the country. Potential hazards of plastic wastes are numerous to the living community when it is improperly managed. Plastic wastes have the potential to pollute all the vital components of living environment (i.e., air, land and water). Some of the hazards caused by plastic wastes are listed below;

(i) Uncollected plastic wastes often end up in drains, causing blockages that result in flooding and unsanitary conditions.
(ii) Cattle that graze on the waste from bins end up eating the plastic along with the vegetable matter, which proves to be fatal for them. The milk obtained from the cattle that feed on waste can be contaminated and can prove to be unsafe for human health.
(iii) Mosquitoes breed in blocked drains and in rainwater that is retained in discarded plastic bags, tire and other objects. Mosquitoes spread disease, including malaria.
(iv) The open burning of plastic bag waste causes air pollution; the products of combustion include dioxins that are particularly hazardous.
(v) Uncollected plastic bag waste degrades the urban environment, discouraging efforts to keep streets and open spaces in a clean and hygienic condition. Plastic bags are in particular an aesthetic nuisance.
(vi) Plastic bag waste items that are reused without being cleaned effectively or sterilized can transmit infection to later users.
(vii) Plastic waste that is treated or disposed of in unsatisfactory ways can cause a severe aesthetic nuisance in terms of smell and appearance.

In Ghana, streets in cities are choked with trash and littered with plastic bag waste that blocks gutters and clogs storm drains. Drinking water comes in sachets that cost a few pesewas. Cheap and convenient, they are sold in shops and by street hawkers. But once they have been drunk they are often simply dropped on the ground.

Plastic dumped in the streets ends up blocking drains, which can cause seasonal flooding. Others make it into the sea via drains and sewage pipes, with unsightly tangles of plastic bags washing up on the beaches,

One of the problems in Ghana is the amount of plastic littering the streets. There is not a proper way of collecting plastic bag waste and people are not educated as to the problems of plastic waste.

The pure-water sachet is ubiquitous. When anyone wants water they cannot drink tap water so they buy these sachets, even for their home.

Once they have drunk the water they drop it in the street. People are seen dropping them from their cars.

In Ghana, the per capital generation of plastic bag waste stands at 0.016-0.035 kg/person/day and plastic make up between 8-9% of the component materials in the waste stream (Fobil, 2000).

Figure 1.1 gives the current waste generation in Accra;

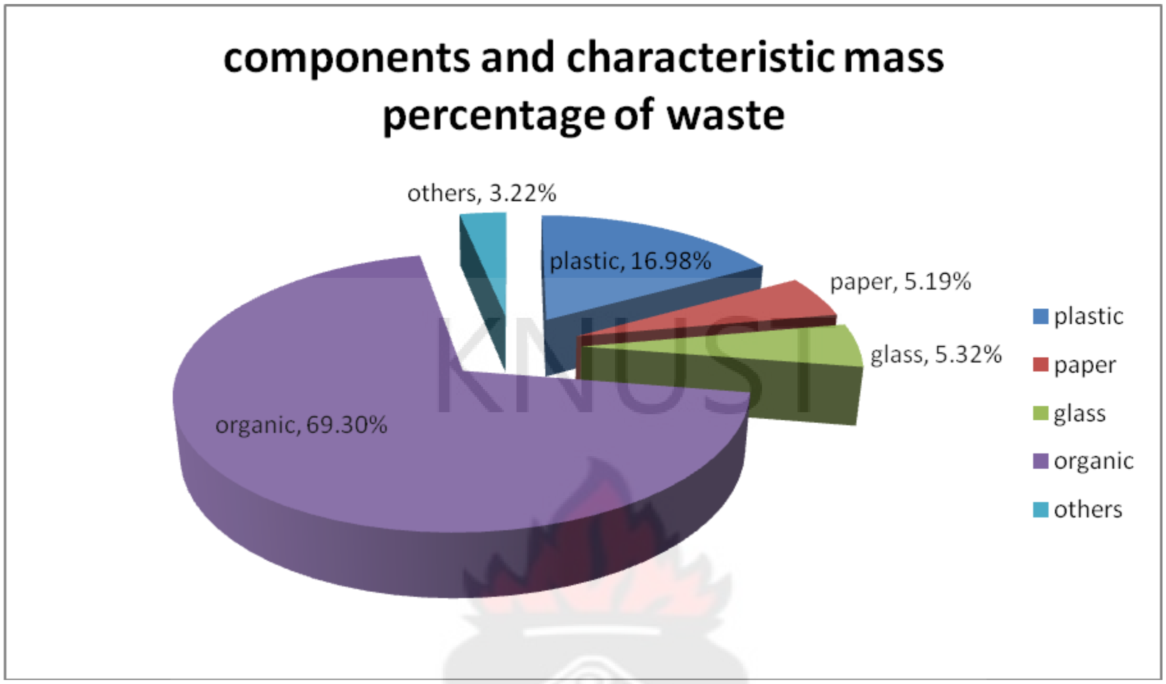


Fig 1.1 The percentage of waste component as at June 2010 in Accra metropolis. Source Zoomlion Ghana Ltd

From the above chart it shows that plastic is now the second highest waste in the country. But what is worrying is that, the highest component, which is organic is able to decompose where as plastic cannot.

This problem has now received the attention by international, national policy making bodies and citizens. In the international level the awareness regarding plastic bag waste began in 1992 with the Rio Conference, here plastic bag waste was made one of the priorities of Agenda 21. Here specific attention was given to the environmentally sound management of plastic wastes.

The Johannesburg World Summit on Sustainable development in 2002 focused on initiatives to accelerate the shift to sustainable consumption and production, and the reduction of resource degradation, pollution, and waste. The priority was given to waste minimization, recycle, and reuse followed by the safe disposal of waste to minimize pollution.

Plastic bag waste has become a major environmental issue in many developing countries particularly, their cities. This has become the concern of many Africans that the first African Expects Meeting on the Ten Year Framework Program on Sustainable Consumption and Production, with the intent of developing a response to the problem. UNEP then helped the establishment of a Regional Taskforce on plastic under the auspices of the African Roundtable on Sustainable Consumption and Production (UNEP, 2004).

Options for manage plastic bag waste are combustion, landfill and recycling. But the first two are not sustainable and environmental friendly since combustion produces carbon dioxide which helps in global warming and plastic are non degradable therefore landfilling is also not the best. The best is recycling, which is a sustainable way of managing plastics it is therefore in the good direction if we are able to help those who are doing the recycling to improve upon their revenue in order to keep them in business.

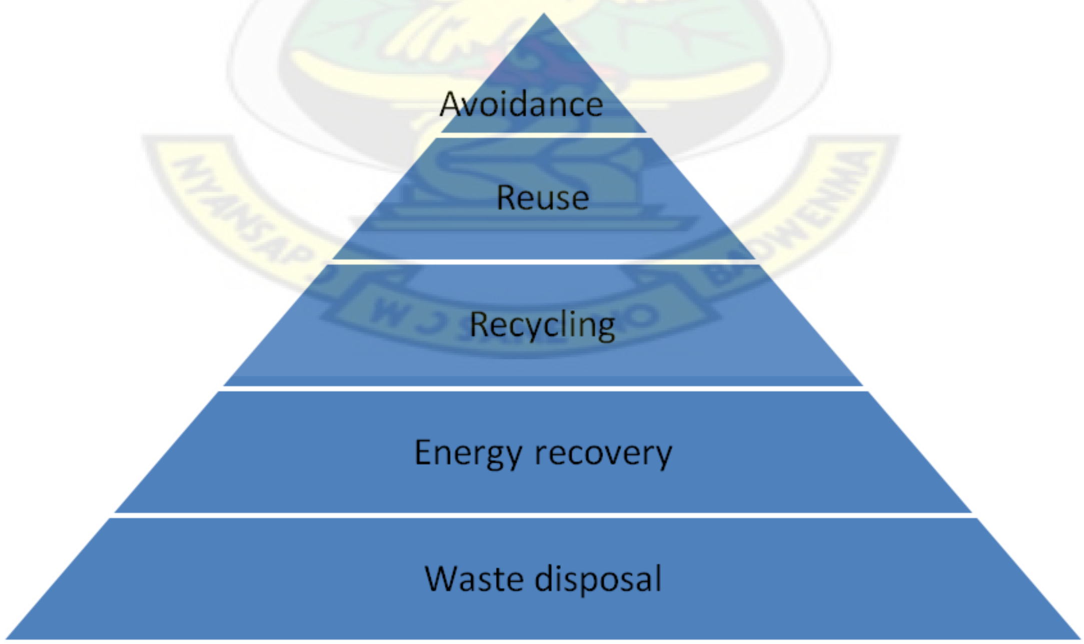


Figure 1.2 : Current waste hierarchy

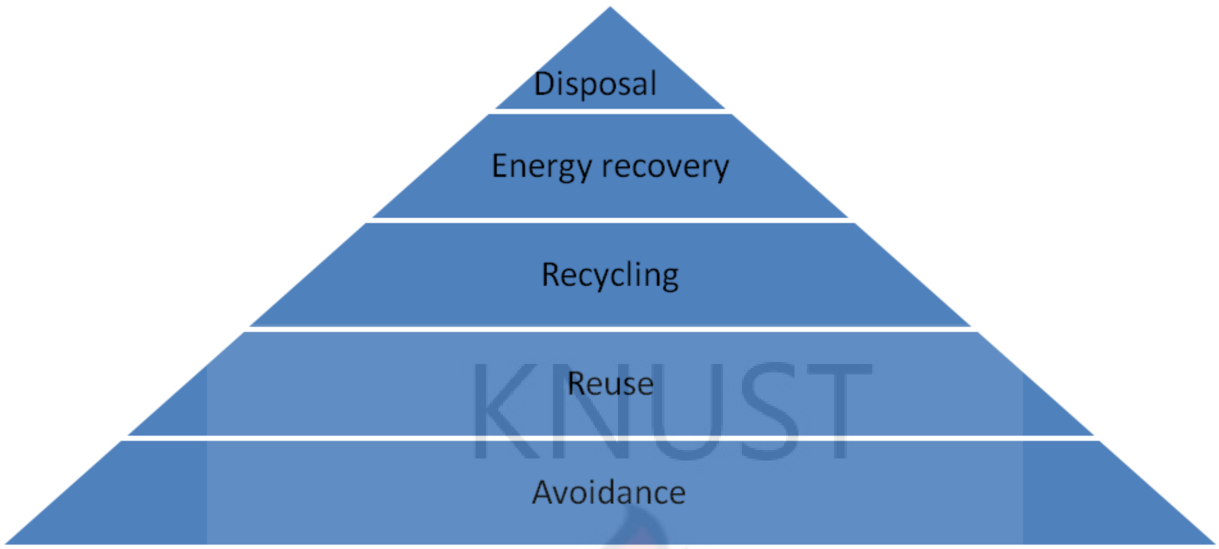


Figure 1.3: Recommended waste hierarchy

Figures 1.2 and 1.3 are the proposed waste management hierarchy by GCCC (GCC, 2002).

1.3 Objective of the study

This study is aimed at using the basic knapsack model for the optimal operations of plastic bag waste recycling facilities. The model is to assist in selecting the best materials to produce in order to maximize revenue so as to collect more waste from people.

During this research it was found out that, the recycling companies do not go round with their trucks looking for waste bags but it is rather people who bring it to their facilities and sometimes the companies even stop them from bringing it for sometime because they want to produce what they have gotten first. This means that they do not have problem with the raw materials but things to produce more in other to get more revenue.

This thesis therefore uses heuristics (that is knapsack) to help obtain the best maximum production.

1.4 Purpose of the study

This study uses the knapsack model for the optimal operations of plastic bag waste facilities. The purpose of the model is to maximize revenue for plastic bag waste recycling companies as a means of managing plastic waste. This is because if they are able to make much revenue; they will stay in the business and will like to get more plastic bag waste which is a menace to the country.

The model is to assist in selecting the best products to produce so as to avoid waste that in effect minimizes the cost of production.

Recycling facilities represent an increasingly popular plastic bag waste management option as communities look for ways to divert part of the local plastic bag waste stream from landfills.

1.5 Methodology

This study uses the knapsack model which is made up of an objective function taking into accounts the cost of items produced and the number of items that can be produced for a particular product, the objective function will be maximize subject to a physical constrain which is the cost of producing a particular item and the number that can be produced. Data used in the study are secondary and was obtained from waste management companies and recycling companies. The data was used as inputs to test the model and the results will be used to analyze the situation.

1.6 Justification

This research is to contribute to the ongoing concern of plastic bag waste as menace in Ghana. The problem is more worrying when you think of the number of years it takes for plastic to be decomposed. It is therefore very important if it can be recycled rather than disposing it in landfills where it will take years for it to decompose.

The vice president of Ghana, John Dramani Mahama, is reported to have said (on 23rd September 2009 in Accra) "Indeed it is believed that Ghana's plastic bag waste have been found in the Mediterranean Sea. Plastic bag waste in Ghana has taken central stage and government is seriously considering a legislation to ban its usage completely. The nation would be better off not to suffer this any longer." GNA (2009). This show how worried government is when it comes to the problems created by plastic waste.

GNA(2010) reported that the Government of Ghana in July 2009 constituted a Committee , chaired by Lieutenant Colonel (retired) J. H. Blood-Dzraku to recommend ways to bring the plastic bag waste situation under control, and advice on the modalities to eliminate plastics in general and plastic bags in particular as well as improve their manufacturing and usage in Ghana.

The committee finished its work and submitted their findings and recommendations of plastic bag waste management in Ghana expected to better fight the plastic menace on 8th February 2010, to the Government. A copy of the background to the plastic situation in Ghana given to the Ghana News Agency indicated that the plastic subsector offers direct employment to one hundred and forty seven thousand, four hundred and ten (147,410) people and generates annual tax revenue of GH59.57 million to government.
It says today there are about eight hundred and ninety five (895) plastic manufacturing companies and sachet water manufacturers producing about two thousand six hundred(26,000) metric tons of assorted plastic products annually in the country GNA (2010).

From this, it is clear that we cannot do away with plastic as a country since it provide jobs for us and also generate income for the country. It is therefore right if we recycle it for the plastic bag waste to be more beneficial to us.

Also people have now realized that if all plastic bag waste is sent to landfill due to urbanization a time will come when it will be difficult for us to manage plastic bag waste since landfills also have life span. It is against this background that people are realize that if part of the plastic bag waste generated could be recycled it would be better for us.

1.7 Knapsack algorithm

The knapsack problem is a problem in combinatorial_optimization. It derives its name from the following maximization problem of the best choice of essentials that can fit into one bag to be carried on a trip. Given a set of items, each with a weight and a value, determine the number of each item to include in a collection so that the total weight is less than a given limit and the total value is as large as possible.

The decision problem_form of the knapsack problem is the question "can a value of at least *A* be achieved without exceeding the weight *a*?"

1.8 Limitations

The major limitation in this study is that, the model was tested with only one recycling company in a city in Ghana. It could have been use to test more companies in all cities in Ghana this would have been very good to know the weak and strength of the model to make informed decision about it and more universal for all cities. Also due to insufficient funds and time the researcher could not travel to various cities and towns for information and data. Again since this is a bit new in the country it was also difficult to get information from authorities since there is not much research on it in the country. But all the same it was a successful study with all the limitations notwithstanding.

1.9 Organization of the Thesis

This thesis is organized in five chapters. Chapter one presents the introductory aspect of the study. It deals with the essence of the study, why plastic bag waste and the way it can be managed. It also talks about the effect of uncollected plastic waste. In chapter two, we shall review pertinent literature on existing models, which will be useful in the study, they are plastic bag waste management models, models on recycling, production -planning models, environmental models and waste management models. In chapter three we shall put forward the methodology.

Chapter four deals with data collection and analysis. Chapter five presents the conclusions and recommendations of the study.

CHAPTER 2

LITERATURE REVIEW

The plastic waste menace has been with us for a long time and a lot has been done by various governments to calm the situation. This chapter focuses on the review of important literature on the core aspects of the topic under study. Some of the areas are:

(i) Plastic bag waste management models
(ii) production –planning models
(iii) recycling models
(iv) environmental models
(v) waste management models and
(vi) knapsack problems

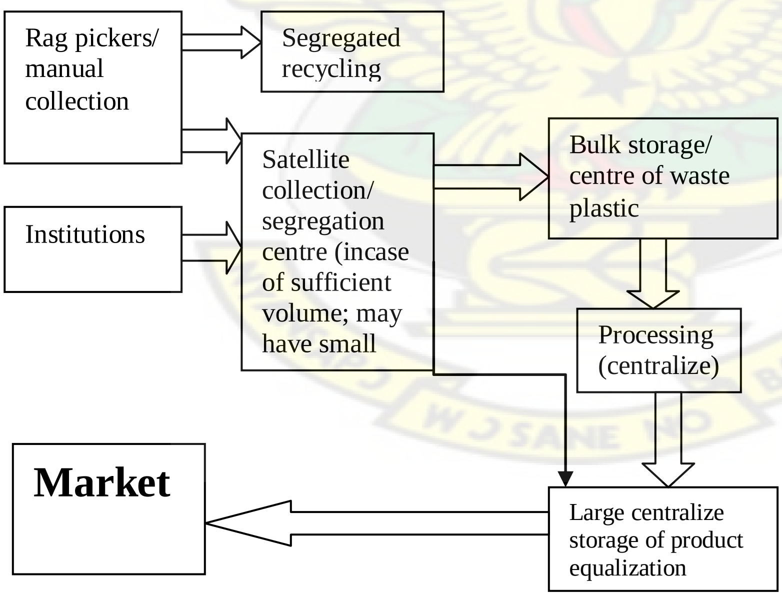
The chapter presents existing models on the problem under review to help as a basis for the study.

2.1 Plastic wastes management models

Haque et al., (2000) developed a model to capture the complex plastic recycling and landfilling scenarios in Bangladesh. The model was based on the assumption of a linear virgin plastic import pattern. The recovery (i.e. 40% in the first year and 55% in the second year) and landfilling (i.e. 2% in the first year and 3% in the second year) strategies based on the field survey contribute the main parameters of the model. If these strategies change at any time in the future, the model parameters can easily be updated. The scenarios presented in their work did not account for the presence of any recyclable or landfilled material before 1990 as there were no official import data available for virgin plastic. Although the results are presented at 'one year intervals (calculation year)', the model is capable of predicting recovery and landfilling scenarios over much shorter or longer time intervals. The model could be used in future decision making processes within the plastic recycling arena of countries concerned to achieve an environmental sound and cost effective waste management option.

Vujic et al., (2010) developed a model of the flow of plastic in the republic of Serbia. The model provided the basic framework, assumptions and results of the analysis of plastic material flows based on the material flow analysis (MFA) method. The model constructed in their study encompasses the production, import, stocks in economy, export, and amount of plastic materials that represent waste that are disposed in landfills. The obtained results served as the basis for modeling the flows of plastic materials for the period 2000-2020, with the aim to point out that the increasing stocks of plastic materials in the market lead to increase accumulation of these materials in economy, which will have a significant influence on the waste management system, bearing in mind that the majority of plastic goods that are in use will become waste.

Luthral (2010) developed a business model for conversion of waste plastic to fuel for India. The model uses plastic bag waste as its raw material. Below is a schemes representation of the model;



Negpal et al., (1999) suggested plastic recycling in India would be improved by establishing deposit centers for post-consumer plastic waste. Over the past two decades, detailed models have been adopted regarding economics of materials recovery resulting from municipal solid waste, and their environmental burdens. Bousted (1992) also broader methods including cost, public acceptance and ease of operation and maintenance.

Tucker, et al., (1999) developed a model to deal with the complexity involved in organizing the collection chain. So they distinguished four main model routes under this model for organizing PVC waste management which are;

(i) bring systems for mixed plastic bag waste (PVC recycled as part of municipal plastic waste)
(ii) separation of municipal plastic bag waste from integral solid waste, particularly municipal solid waste (PVC recycled as part of municipal plastic waste)
(iii) bring systems for specific end-of-life PVC products
(iv) separation of plastics/PVC from complex waste streams (eg end-of-life products, or other integral waste streams)

These models helped when one wants to recycle PVC from different sources.

Wongthatsanekom Wuthichai (2009) developed a model to help make multi-objective recycling problem easier, the plastic reverse logistics network design was formulated as a mixed integer goal programming. The model was based on the work by Wongthatsanekom et al., (2007). That formulation was able to capture inter-relationship among different goals for the network design problem at the strategic level. The model used the following assumptions;

(i) all parameters are deterministic
(ii) costs functions are linear functions and
(iii) the location of all possible sites are predetermined.

The continuous variables in the model represent the flows of materials and the integer variables in the model represent the existence of the potential infrastructure. There are also five entities in the model which are;

(i) initial source of plastic waste
(ii) collection sites

(iii) processing sites

(iv) landfills and

(v) customer's site

The model was to help the management of solid waste collection and processing systems by aiming to raise the percentage of plastic recycle economically and as a result see less plastic bag waste in the environment and raise the quality of life of people.

2.2 Models on recycling

Reverse logistics models was generated to analyses how products can be collected effectively and efficiently, in other to be reuse in future, remanufacture, or recycling. Fleischmann et al., (1997) presented an overview of existing recovery models and found that 'nearly all the models proposed so far are one-product, one –component models'.

Lund (1990) proposed a model that utilizes recycling as an instrument to determine the level of annual landfill deposit. This in turn determines the life of the landfill, and therefore the time when a new landfill must be started. The greater the amount of recycling, the smaller the amount of waste that will be transported to landfills. The life span of the landfill is therefore extended since recycling postpones the time when an existing landfill must be placed. Hence the cost of future landfill operations is postponed. The optimum recycling and replacement strategy is one that minimizes the cost of recycling and landfill operations over the life of the initial site, plus the terminal cost of future waste operations beyond its life. The model uses a linear programming approach to determine an optimum recycling strategy for a given life of the landfill site. This is repeated for every possible lifespan of the landfill site, and the present value of the cost of all waste operations is recorded. In the second stage, these cost plus terminal cost are compared, and the optimum lifespan is selected. The model allows for different types of waste recycling, each with a different unit cost, and each diverting a given share of the total waste from landfill. Even a maximum recycling effort, however, will not eliminate all waste. Hence, there is a maximum life for the landfill site, say $T_{max,}$ beyond which life cannot be extended, even if all recycling options are utilized all the time. There is also a minimum life for landfill, say $T_{min.}$ This is the life that the landfill will have if recycling is never used. Hence, the model examines the recycling strategy for each life span T, $T_{min} < T < T_{max}$.

Realff et al., (2004) modeled the economic implementations of operating a used carpet recovery system within US using a list of potential collection and processing site locations. This model has more than one component, but relates to only one single -material.

Fleischmann et al., (2000) compared general characteristics of product recovery network with traditional logistic structure and moreover derive a classification scheme for recovery networks.
Some models has also focused on a variety of different approaches, from manual disassembly to mechanical separation, examining which processes approach and relate operating parameters should be used.

Boon et al., (2003) modeled the revenue ability of recycling car bodies as a function of car materials composition and the processors choice of how many parts are manually disassembled before shredding.
There also works that investigated the cost of complex durable goods recycling more comprehensively, focusing on facilities or systems operating in a particular environment or operational context. Example is Kang and Schoenung (2006) who uses a technical cost model to examine the cost and revenue associated with the operation of electronics plastic bag waste recycling in California.

Caudill et al., (2003) examined an electronics recycling system in the Seattle-Tacoma urban are in Washington state which they analyses the effectiveness of various collection approaches example is collection at a central drop-off facility versus collection at 20 ‘big box’ stores.

Bohr (2007) proposed a recovery of WEEE in Europe model with economic models approximating a central European system

2.3 Production-Planning models

Holt et al., (1960) developed a production-planning model for Pittshurgh Paint Company. They assumed a single aggregate product and then defined three decision variables;

(i) Production of the aggregate item during time period t
(ii) Inventory of the aggregate item at end of time period t
(iii) Workforce level in time period t

The authors assumed that the cost function in each period has four components which are the regular payroll costs, the hiring and layoff cost, the overtime and idle time costs and the final one is inventory and backorder costs.

Their objective was to minimize the sum of the expected costs over a fixed horizon, subject to an inventory balance constraint.

Hegseth (1984) considered a production process in series with uncertainty. He used a formula that implies production factors for different stages of the operation. The bill of materials is modified using the yield factors and the material planning is carried out after this modifications.

New and Mapes (1984) addressed uncertain production losses. He considered processes with high looses and variability in losses. They proposed a model that relates the quantities of inputs and outputs for a random yield factor. They also study different approaches based on safety stocks, safety times and hedging to treat such losses.

Caridi and Cigolini (2000) provided a new methodology for dimensioning an overall buffer against uncertainty in demand in Material requirement planning environment. Because of this, a set of recommendations guidelines is reported to dimension position safety and strategic stocks within products bills of materials and manufacturing pipelines.

Das and Abdel-Malek (2003) proposed a method for estimating the level of supply chain flexibility as a function of varying demand quantities and varying supply lead times. The model provide estimates of the annual procurement cost in a given buyer-supplier relationship.

Gfrerer and Zapfel (1995) presented a multi-period hierarchical production-planning model with two planning levels, that is aggregate and detailed, and with uncertain demand.
Meybodi and Foote (1995) developed a multi-period hierarchical production-planning model and scheduling but theirs was with random demand and production failure.

Hatchuel et al., (1997) developed a model, referred to as dynamic anticipation approach, based on a classical hierarchical two-stage decomposition of the planning and scheduling process. The planning stage uses a combined PERT/material requirement planning approach, whereas job shop control uses a dynamic scheduling rule.

Buchel (1983) considered a planning procedure based on stochastic use ratios for optimal parts when their demand is stochastic. The "use ratio" for a specific is the ratio between the component demand and the total demand for all final products. Small ratios (and/or a small number of customer orders) cause considerable demand variations that require high safety stocks. He also demonstrated how the use ratio could be included in material requirement planning to reduce the uncertainty in demand.

Wacker (1985) developed a statistical model that estimates the average and variance of the outputs of final products and components due to uncertainties. He used a safety stock approach. In a make-to-order environment, the safety stocks of final products do not alleviate the uncertainty in demand. The model uses a standard 'forecast error' for components as an estimate of safety stocks. He comments that a material requirement planning system should not imply sophisticated control measures to monitor environmental and system uncertainties, but it should incorporate these variations in the same system.

2.4 Environmental Models

White et al., (1995) published a book including a spreadsheet model that is the integrated waste management for calculating the life cycle inventory for waste management systems. But the model was not user-friendly. So McDouall et al., (2001) updated the model to a more user-friendly version in a new book in 2001.

A Swedish model, the ORWARE model (Organic waste Research) has special focus on evaluating different strategies for organic waste from households and industry. The model works with a set of functional units that all have to be obtained for all comparing scenarios (Bjorklund and Bjuggren, 1998; Eriksson et al., 2002)

The Environmental Protection Agency in the USA developed the Integrated Solid waste Management Decision –Support-Tool which main aim was to optimize the waste system in respect to one of the given functions while the system comply with a set of restrictions. The model has a higher focus on the optimization module (Harrison et al., 2001)

Nielsen and Hauschild (1998) developed a spreadsheet model which was especially for estimation of emission from landfills to be used in environmental assessment. The model considers the components in the waste individually and emission estimates are calculated on the basis of input quantity and type of components.

Najm et al., (2002) Presented a model meant to serve as a solid waste decision support system for municipal solid waste management taking into accounts both socio-economic and environmental considerations. The model accounts for solid waste generation rates, composition, collection, treatment, disposal as well as potential environmental impacts of various municipal solid waste management techniques. The model follows a linear programming formulation with the framework of dynamic optimization. The model was used as a tool to evaluate various municipal solid waste management alternatives and obtain the optimal combination of technologies for handling, treatment and disposal of municipal solid waste in an economic and environmental sustainable way. The sensitivity of various waste management policies was also addressed. The work was presented in a series of two papers:

(i) Model formulation and
(ii) Model application and sensitivity analysis.

Zhao et al., (2009) with the purpose of assessing the environmental impacts and benefits of current municipal solid waste management system, a life-cycle model, was used to evaluate the waste system of Hangzhou city in china. An integrated model was established, including waste generation, collection, transportation, treatment, and disposal and accompanying external processes. The results shown that CH_4 released from land filling was the primary pollutant contributing to global warming, and HCl and NH_3 from incineration contributed most to acidification. Material recycling and incineration with energy recovery were important because of the induced savings in material production based on virgin materials and in energy production based on coal combustion. A modified system in which waste is transported to the nearest incinerators was found to be cost effective due to the decrease in pollution from landfill waste and the increase in energy production from waste avoiding energy production by traditional power plants. A ban on free plastic bags for shopping was shown to reduce most environmental impacts due to saved oil resource and other materials used in producing the plastic bags. Sensitivity analysis confirmed the robustness of the results.

Chang (1996) developed a model which was different from his earlier work. Here he considered environmental impacts such as air pollution from incinerators and leachate in landfill facilities. The model not only determines the location and capacity of solid waste facilities, but also the level of facility operations over time. Sub models evaluate leachate impact and air pollution, forecast waste generation, and determines the residual value of facilities at the end of the planning period.

The EASEWASTE model is a model for environmental systems analysis of solid waste management systems using the methodology of life cycle assessment. System analysis is a systematic assessment of a given system including all processes and interrelated connections (Bjorklund, 2000). The system for assessment by EASEWASTE is real or potential future solid waste system for a given area with a certain population. Many processes in the model depend on the waste composition, defined both by material fractions and physical and chemical properties, enabling the model to calculate consequences of a changed waste composition. The model is able to assess the environmental exchanges and potential environmental impacts associated with a waste management system for municipal solid waste. The model is also able to identify waste fractions, substances and treatment options that contribute to a set of environmental impacts.

Solano et al., (2002) presented an integrated solid waste management model to assist in identifying alternative solid waste management strategies that meet cost, energy, and environmental emissions objectives. A solid waste management system consisting of over forty (40) units processes for collection, transfer, separation, treatment for example, combustion, composting, and disposal of waste as well as remanufacturing facilities for processing recycled material is defined. Waste is categorized into forty-eight (48) items and their generation rates were define for three types of sectors: single-family dwelling, multifamily dwelling, and commercial. The mass flow of each item through all possible combinations of unit processes was represented in a linear programming model using a unique modeling approach. Two objective functions were developed; the first one for cost minimization and the second one for minimization of energy consumption, and environmental emission associated with waste processing at each unit process are computed in a set of specially implemented unit models. A life-cycle approach was used to compute energy consumption and emissions of carbon monoxide (CO), fossil and biomass-derived carbon dioxide (CO_2), oxides of nitrogen, sulphide oxide, particulate matter, and greenhouse gases. The model is flexible to allow representation of site-specific issues, including waste diversion targets, mass flow representations and requirements, and targets for the values of cost, energy, and each emission.

The waste Integrated Systems Assessment for Recovery and Disposal tool was also develop by (now Price water House Coopers) for the Environment Agency in United Kingdom and is one of the most complex models giving the user the opportunity to choose any treatment methods and technologies. The model was criticized for usability, lack of transparency and lack of guidance for interpretation of results (Environment Agency).

2.5 Waste management models

WHO in 1989 published the working document “management and control of the environment” (WHO, 1989), this was the review version of the Rapid Assessment of Sources of Air, Water and Land Pollution (WHO, 1984). The reviewed version includes a working table for the calculation of solid and hazardous waste. This model uses waste/production relationships to estimate waste quantities for various industrial activities in a worksheet set up. The quantity of plastic bag waste predicted for each industrial group in this model is much smaller than in other models.

INVENT is also another waste prediction model that uses employment data to provide the user with a first estimate of the volume, nature and composition of industrial waste Barnard (1991). This model is a computer program developed to predict industrial waste generation within an area with the minimum of data collection; it is based mainly on the number of employees per industrial category.

Liebman (1975) also distinguish five groups of waste management models based on a survey of the literature of the 1960s and1970s. They are:

(i) waste generation prediction,
(ii) fixed facilities ,
(iii) vehicles routing ,
(iv) manpower assignment and
(v) overall system

models.

The first deals with the forecasting of waste generation in specific areas based on such variables as population growth, population density and income. The second category focuses on site selection, capacity expansion and facility operations. The third deals with such issues as timing of vehicles replacement and the routing of vehicles to provide a required level of service at minimum cost. The manpower model deals with the crew assignment in waste management operations. Finally system models deals with the overall operations of the waste collection system.

Bruvoll and Ibreholt (1997) model waste generation in the manufacturing sector based on the sector's use of raw material and intermediate inputs. The authors expected waste generation to be proportional to either the level of production or the amount of material input, but found that the growth of waste is better explained by the growth of inputs than by the growth of production.

Folz (1999) investigated the changes in performance of municipal recycling with curbside collections between 1986 and 1996 across 127 cities (25 states) in the U.S. Panel data was collected through mail survey in 1990 and 1997. He focuses on recycling costs and the factors that affect these costs over time, relating the unit recycling cost to the amount of waste recycled, the recycling participation rate, the participation type (mandatory or voluntary), the presence of yard waste composting, same day collection with other waste types, and multifamily households. All estimates are statistically significant, except for multifamily households.

Rao et al., (1971) developed the simplest waste generation model, distinguishing between residential, commercial, and industrial customers, measured respectively in terms of number of housing units, establishments and employment. The amount of waste from each group is then the product of sector size and generation rate. Generation rates are obtained from regional data averaged over a year and assumed constant over time. Hence the model dose not account for changes in generation rates as a result of changes in income or prices. Economic growth is considered in a descriptive manner, by projecting population, employment and establishment changes over time.

Chang (1991) put forward a waste generation sub-model as part of a large waste management model. The model uses econometric analysis to forecast the amount of waste generated over a planning period of 20 years, dividing the total area into n generation districts and projecting the waste of each as a linear function of dwelling units, per capita income, and population. The improvement in this model is the consideration of income as a determinant of waste generation. However, Chang dose not differentiate waste by sector, as in Rao's model.

Daskalopoulos et al., (1998) developed two models, one to estimate total waste generation, and the other to estimate waste composition, at country level, using aggregate observations on the municipal solid waste of industrialized countries.

Total waste generated (in tons) was found to be a non-linear function of population size and living standard (represented by GDP per capita). The composition of waste was modeled by dividing waste into six categories;
plastic, paper, glass, metal, organic and others.
The share of each waste category is then shown to be a non-linear function of the pattern of consumption as represented by six major product groups which are;

(i) food and drink
(ii) clothing and footwear
(iii) furniture and
(iv) books and magazines

Hocket et al., (1995) used a linear regression model to identify and measure the variables that influence per capita municipal solid waste generation. His study was conducted using county data in the Southeastern United States. The variables include;

(i) disposal fee
(ii) per capita retail sales
(iii) per capita construction cost
(iv) per capita sales of eateries
(v) merchandise
(vi) food store
(vii) apparel stores
(viii) per capita income and
(ix) urban population (as a percentage of the county population).

Their study shown that, disposal fees and retail sales have the greatest impact on waste generation. The higher the disposal fee, the lower the waste generation, and the higher the retail sales, the higher the waste generation.

Gottinger (1986) developed a model where potential management facilities are given. The model minimizes the total cost, which includes fixed and variable facility cost, and transportation cost. Given a set of potential management facilities, the model uses a branch-and- algorithm to determine which one to build, how to route the waste and how to process and dispose of this waste.

2.6 Knapsack problems

Benisch et al., (2005) examined the problem of choosing discriminatory prices for customers with probabilistic valuations and a seller with indistinguishable copies of a good. They showed that under certain assumptions this problem can be reduced to the continuous knapsack problem (CKP). They presented a new fast epsilon-optimal algorithm for solving CKP instances with asymmetric concave reward functions. They also showed that their algorithm can be extended beyond the CKP setting to handle pricing problems with overlapping goods (e.g. goods with common components or common resource requirements), rather than indistinguishable goods.

They provided a framework for learning distributions over customer valuations from historical data that are accurate and compatible with their CKP algorithm, and validated their techniques with experiments on pricing instances derived from the Trading Agent Competition in Supply Chain Management (TAC SCM). Their results confirmed that their algorithm converges to an epsilon-optimal solution more quickly in practice than an adaptation of a previously proposed greedy heuristic.

Mastrolilli (2006) addressed the classical knapsack problem and a variant in which an upper bound is imposed on the number of items that can be selected. They showed that appropriate combinations of rounding techniques yield novel and powerful ways of rounding. As an application of these techniques, they presented a faster polynomial time approximation schemes that computes an approximate solution of any fixed accuracy in linear time. This linear complexity bounds gave a substantial improvement of the best previously known polynomial bounds.

Transportation programming, a process of selecting projects for funding given budget and other constraints, is becoming more complex. Zhong and Young (2009) described the use of an integer programming tool, Multiple Choice Knapsack Problem (MCKP), to provide optimal solutions to transportation programming problems in cases where alternative versions of projects are under consideration. Optimization methods for use in the transportation programming process were compared and then the process of building and solving the optimization problems discussed. The concepts about the use of MCKP were presented and a real-world transportation programming example at various budget levels were provided. They illustrated how the use of MCKP addresses the modern complexities and provides timely solutions in transportation programming practice.

The knapsack container loading problem is the problem of loading a subset of rectangular boxes into a rectangular container of fixed dimensions such that the volume of the packed boxes is maximized. A new heuristic based on the wall-building approach was proposed earlier. That heuristic divides the problem into a number of layers and the packing of layers is done using a randomized heuristic.

Martello and Toth (1998) presented a new algorithm for the optimal solution of the 0-1 Knapsack problem, which is particularly effective for large-size problems. The algorithm is based on determination of an appropriate small subset of items and the solution of the corresponding "core problem": from this they derived a heuristic solution for the original problem which, with high probability, can be proved to be optimal. The algorithm incorporates a new method of computation of upper bounds and efficient implementations of reduction procedures. They also reported computational experiments on small-size and large-size random problems, comparing the proposed code with all those available in the literature

Glickman and Allison, (1973) considered the problem of choosing among the technologies available for irrigation by tubewells to obtain an investment plan which maximizes the net agricultural benefits from a proposed project in a developing country. Cost and benefit relationships were derived and incorporated into a mathematical model which is solved using a modification of the dynamic programming procedure for solving the knapsack problem. The optimal schedule was seen to favor small capacity wells, drilled by indigenous methods, with supplementary water distribution systems.

Akinc (2006) addressed the formulation and solution of a variation of the classical binary knapsack problem. The variation that was addressed is termed the “fixed-charge knapsack problem”, in which sub-sets of variables (activities) are associated with fixed costs. These costs may represent certain set-ups and/or preparations required for the associated sub-set of activities to be scheduled. Several potential real-world applications as well as problem extensions/generalizations were discussed. The efficient solution of the problem is facilitated by a standard branch-and-bound algorithm based on (1) a non-iterative, polynomial algorithm to solve the LP relaxation, (2) various heuristic procedures to obtain good candidate solutions by adjusting the LP solution, and (3) powerful rules to peg the variables. Computational experience shows that the suggested branch-and-bound algorithm shows excellent potential in the solution of a wide variety of large fixed-charge knapsack problems.

The Bounded Knapsack Problem (BKP) is a generalization of the 0-1 Knapsack Problem where abounded amount of each item type is available. Currently, the most efficient algorithm for BKP transforms the data instance to an equivalent 0-1 Knapsack Problem, which is solved efficiently through a specialized algorithm. Pisinger (2005) proposed a specialized algorithm that solves an expanding core problem through dynamic programming such that the number of enumerated item types is minimal. Sorting and reduction is done by need, resulting in very little effort for the preprocessing. Compared to other algorithms for BKP, the presented algorithm uses tighter reductions and enumerates considerably less item types. Computational experiments are presented, showing that the presented algorithm outperforms all previously published algorithms for BKP.

Several types of large-sized 0-1 Knapsack Problems (KP) may be easily solved, but in such cases most of the computational effort is used for sorting and reduction. In order to avoid this problem it has been proposed to solve the so-called core of the problem: a Knapsack Problem defined on a small subset of the variables. The exact core cannot, however, be identified before KP is solved to optimality, thus, previous algorithms had to rely on approximate core sizes. Pisinger (1997) presented an algorithm for KP where the enumerated core size is minimal, and the computational effort for sorting and reduction also is limited according to a hierarchy. The algorithm is based on a dynamic programming approach, where the core size is extended by need, and the sorting and reduction is performed in a similar "lazy" way. Computational experiments were presented for several commonly occurring types of data instances. Experience from these tests indicated that the presented approach outperforms any known algorithm for KP, having very stable solution times.

The multidimensional 0–1 knapsack problem, defined as a knapsack with multiple resource constraints, is well known to be much more difficult than the single constraint version. Freville and Plateau (2004) designed an efficient preprocessing procedure for large-scale instances. The algorithm provides sharp lower and upper bounds on the optimal value, and also a tighter equivalent representation by reducing the continuous feasible set and by eliminating constraints and variables. This scheme was shown to be very effective through a lot of computational experiments with test problems of the literature and large-scale randomly generated instances.

The binary quadratic knapsack problem maximizes a quadratic objective function subject to a linear capacity constraint. Due to its simple structure and challenging difficulty it has been studied intensively during the last two decades. Pisinger (2007) gave a survey of upper bounds presented in the literature, and showed the relative tightness of several of the bounds. Techniques for deriving the bounds include relaxation from upper planes, linearization, reformulation, Lagrangian relaxation, Lagrangian decomposition, and semi definite programming. A short overview of heuristics, reduction techniques, branch-and-bound algorithms and approximation results is given, followed by an overview of valid inequalities for the quadratic knapsack polytope. They concluded by an experimental study where the upper bounds presented are compared with respect to strength and computational effort.

Amponsah et al., (2011) developed a model which solves the ambulance location problem in urban areas by using a Genetic Algorithms (GA) that employs random key coding as proposed in Aytug and Saydam (2003), however, they introduced a formula for renormalization of the random key codes. They were able to solve the ambulance location problem using a reformulation of the Non-Linear Maximum Expected Covering Location Problem (MEXCLP) by Saydam and McKnew (1985), modeled with a random-key genetic algorithm implementation. It was seen from their results that 99.9999% of the total demand was covered. The ambulance locations were finely distributed based on the model and the demand generated at the various nodes. Four ambulances were being assigned to a location that was surrounded by high concentration of sub-urban centers which could facilitate easy reach. It was also complemented by the other two locations which were on either side of it. Using their algorithm the requirements of ten (10) minutes response time set by the US (1973) Federal EMS was tested on their data. They obtained solutions that exceeded the coverage stipulated for the EMS Act. The minimum percentage coverage encountered was 98% which still exceeds what the act stipulates. The percentage of total demand covered in both cases were far above the standard set by the US (1973) Federal EMS Act and this clearly demonstrates how the model used could be efficient.

CHAPTER 3

METHODOLOGY

In this chapter, we shall present the advantages of heuristic methods over exact methods; explain the basic model for the knapsack Problem and then use an example to find the maximum revenue for a company who has the option of producing a number of products but has a limit of producing a number of quantities.

3.1 Exact Versus Heuristic Methods

In this section we shall give a brief discussion of some exact and heuristic search methods commonly used in Operational Research (OR)/Management Science (MS).

Real-world problems are difficult to solve for the following reasons:

(i) The size of the search space: The number of possible solutions in the search space is so large as to forbid as exhaustive search for the best answer. For example, a 10-city Traveling Salesman's Problem (TSP) has about 181,000 possible solutions, a 20-city TSP has about 10^{16} possible solutions and a 50-city TSP has about 10^{62} possible solutions (Michalewicz, and Fogel, 2000).

(ii) Modeling the problem: Whenever a problem is solved, we realize that we are in reality finding the solution to a model of the problem. Most models could represent a specification of a real-world problem; otherwise they would be as complex and unwieldy as the natural setting itself. The process of problem solving consists of two separate general steps: (a) creating the model of the problem, and (b) using that model to generate a solution. The "solution" is only a solution in terms of the model. If our model has a high degree of fidelity, we can have more confidence that our solution will be meaningful. In contrast, if the model has too many unfulfilled assumptions and rough approximations, the solution may be meaningless. In this case to get any solution, we have to introduce simplifications that make the problem tractable (Amponsah, 2003).

(iii) Change over time: Real-world problems often do change over time. Some may change before modeling, or while the solution is being derived, or after the execution of the solution. We need to be sure that the model reflects current knowledge about the problem.

(iv) Almost all real-world problems pose constraints and if we violate the constraints we cannot implement our solution. There are usually two types of constraint: namely hard constraints (these are impossible to violate, as the solution becomes redundant) and soft constraints (desirable but could be violated). After putting down the right constraints for a problem, we are then left with the problem of searching for the best assignment: - that is the solution that is feasible and minimizes our evaluation function for the soft constraints. Suppose we have found a feasible solution which does not do well with regards to the soft constraints, we apply some variation operators to this solution with respect to the soft constraints, but in so doing, we generate a solution that violates at least one hard constraint. We must choose to discard the solution since it is infeasible, or we might see if we can repair it to generate a feasible solution that still handles the soft constraints as well. Either way, it is typically a difficult job (Michalewicz, Z. and Fogel, D. B, 2000).

3.2 Exact Methods

There are many classic algorithms that are designed to search spaces for an optimum solution.

The classic methods of optimization fall into two disjoint classes:

(i) Algorithms that only evaluate complete solutions.

(ii) Algorithms that require the evaluation of partially constructed or approximate solutions.

Whenever an algorithm treats complete solutions, we can stop it at any time and will always have at least one potential answer that we can try. In contrast, if we interrupt an algorithm that works with partial solutions, we might not be able to use any of the results at all. We can often decompose the original problem into a set of smaller and simpler problems. The hope is that in solving each of these easier problems, we can eventually combine the partial solutions to get an answer for the original problem. This is the concept used in dynamic programming.

In the next sections we present some of the exact methods like exhaustive search, integer programming (cutting plane, Branch-and-Bound) and dynamic programming.

3.2.1 Exhaustive Search

Exhaustive Search checks each and every solution in the search space until the best solution has been found. That means if we do not know the value that corresponds to the evaluated worth of the best solution, there is no way to be sure that we have found the best solution using the exhaustive search unless we examine every solution. Note that the size of the search space of real-world problems of even modest size can be too large to deal with. But exhaustive algorithms are interesting in some respect. At the very least, they are simple; the only requirement is to generate every possible solution to the problem systematically (Amponsah, 2003).

3.2.2 Integer Programming-Based Techniques

Problems in which the decision variables are discrete-where the solution is a set or sequence of integers or other discrete objects are known as combinatorial problems (Osei et al., 2006). Examples are the assignment problem, 0-1 knapsack problem, the set covering problem and the vehicle routing problem. Combinatorial problems have close links with Linear Programming (LP) and most of the early attempts to solve them used developments of LP methods.

Integer programming deals with the solution of mathematical programming problems in which some or all the variables can assume non-negative integer values only. An integer program is called mixed or pure depending on whether some or all the decision variables are restricted to integer values (Salhi, 1998). Integer programming is quite similar to LP except for the restriction that variables take on only integer values. One might therefore wrongly suppose that such an integer program could be solved by simply ignoring the integrating requirement, solving the Linear Program and rounding off any non-integer solution component to the nearest integers. The Linear Program that results from ignoring the integer constraint is called the linear programming relaxation (continuous) of the integer program. The linear programming solution provides a lower bound on the optional objective value for the integer problem (Ecker, and Kupferschmid, 1988). Several algorithms have been developed for the integer problem, but none of these methods are uniformly efficient from the computational perspective, particularly as the size of the problem increases (Salhi, 1998).

Many integer programming problems that arise in practical settings have the special property that some or all of their variables are restricted to take on only values 0 or 1. Such variables are called 0-1 variables; they often arise naturally in the formation of problems that involve yes-or-no decisions (Ecker, and Kupferschmid, 1988).

3.2.3 Cutting Plane Algorithm

One of the methods used in solving integer programming problems is the cutting plane method. This method, which is developed primarily for integer linear problems, starts with the continuous optimum. By systematically adding special “secondary” constraints, which essentially represent necessary conditions for integrality, the continuous solution space is gradually reduced until its associated continuous optimum extreme point satisfies the integer conditions. This method cuts (eliminates) certain parts of the solution space that do not contain the feasible integer solutions of the original problem (Salhi, 1998).

The idea of the cutting plane algorithm is to change the convex set of the solution space so that the appropriate extreme point becomes all integers. Such changes in the boundaries of the solution space should result still in a convex set. If a cutting plane algorithm fails to solve a given instance, we are left with several options. One option is to use the solution cost of the final LP relaxation, which is a (typically good) lower bound on the optimal value, to assess the quality of a known feasible solution found by any heuristic method. Another option is to feed the final (typically strong) linear relaxation into a classical Branch-and-Bound algorithm for integer problems (Amponsah, 2003) and (Benavent et al, 2000), which is described in the next sub-section.

3.2.4 Branch-and-Bound

The Branch-and-Bound method solves the integer problem by considering its continuous version. This method applies directly to both the pure and the mixed problems. In general, the idea of the method is first to solve problem as a continuous model (Linear Program). Supposed that x_r is an integer constrained variable whose optimum continuous value x_r^* is fractional, it can be shown that the range $(x_r^*) < x_r < (x_r^*) + 1$ cannot include any feasible integer solution. Consequently, a feasible integer value of x_r must satisfy one of the following conditions: $x_r \leq (x_r^*)$ or $x_r \geq (x_r^*) + 1$. These two conditions when applied to the continuous model result in two mutually exclusive LP problems. In this case it is said that the original problem is branched into two sub-problems. Actually the branching process deletes parts of the continuous space that do not include integer points by enforcing necessary conditions for integrality. Each sub-problem may be solved as linear program (using the same objective function of the original problem). If its optimum is feasible with respect to the integer problem, its solution is recorded as the best one so far available. In this case it will be unnecessary to further "branch" this sub-problem since it cannot yield a better solution. Otherwise, the sub-problem must be partitioned into sub-problems by again imposing the integer conditions on one of its integer variables that currently has a fractional optimal value. Naturally, when a better integer feasible solution is found for the sub-problem, it should replace the one at hand. This process of branching continues, where applicable, until each sub-problem terminates; either as an integer solution or there is evidence that it cannot yield a better solution. In this case the feasible solution at hand, if any, is the optimum. The efficiency of the computations can be enhanced by introducing the concept of bounding. This concept indicates that if the continuous optimum solution of the sub-problem yields a worse objective value than the one associated with the best available integer solution, it does not pay to explore the sub-problem any further. In this case the sub-problem is said to be fathomed and may henceforth be deleted. The importance of acquiring a good bound at the early stages of the calculations cannot be overemphasized (Amponsah, 2003).

3.3 Heuristics

Heuristics is derived from the Greek word "heuriskein" meaning to find or discover. A heuristic is a technique which seeks (near optimal) solutions at a reasonable computational cost without being able to guarantee either feasibility, or even in many cases to state how close to optimality a particular feasible solution is (Paulison, David, 2005).

A naïve approach to solving an instance of a combinatorial problem is simply to list all feasible solutions of a given problem, evaluate their objective functions and pick the best. This approach of complete enumeration is likely to be grossly inefficient.

It is possible in principle to solve any problem in this way but in practice it is not because of the vast number of possible solutions to any problem of a reasonable size.

In the early days of Operation Research, the emphasis was mostly on finding the optimal solution to a problem, or rather, to a model of a problem which occurred in the real world. Various exact algorithms were devised which would find the optimal solution to a problem much more efficiently than complete enumeration. One of the famous methods is the Simplex Algorithm for LP problems. Such exact algorithms may not be able to find optimal solution to larger NP-hard problems in a reasonable amount of computing time.

When approaching complex real life problems, four commonly applied methodologies exist. However, this list is not exhaustive as combinations do always exist but are usually difficult to explicitly define:

(i) an exact method to the exact (true) problem;
(ii) a heuristic method to the exact problem;
(iii) an exact method to the (approximate) modified problem;
(iv) a heuristic method to the approximation problem.

These rules are put in a priority ordering, however, the degree of modification of the problem is a crucial point when dealing with practical problems. The idea is to keep the characteristics of the problem as close as possible to the true problem and try to implement (i) or (ii) (Paulison, 2005).

3.3.1 Need for Heuristic

Heuristics are used only when exact methods, which guarantee optimal solutions, are intractable due to (i) either the excessive computational effort (ii) or the risk of being trapped at a local optimum. For such reasons heuristics become the only way to help a company to find reasonably acceptable solutions. The reasons for accepting and promoting heuristics include:

- They can be the way forward to producing concrete solutions to large combinatorial problems.
- Heuristics can be supported by a graphical interface to help the user in assessing the results more easily.

- Management and less specialized users find them reasonably easy to understand and therefore are able to comment and interact with the system.
- These are not difficult to write, validate and implement.
- Management can introduce some unquantifiable measures indirectly to see their effect as solutions can be generated reasonably fast.
- These methods are suitable for producing several solutions, and not only a single one, from which the user feels more relaxed to choose one or two solutions for further investigation.
- The design of heuristics can be considered as an art since a proper insight of a problem is fully required (Amponsah, 2003).

3.3.2 Performance of Heuristics

The main criteria for evaluating the performance of a new heuristic can be classified as (i) the quality of the solution provided and (ii) the computational effort, measured by CPU time usage on a given machine. Other criteria such as simplicity, flexibility, ease of control, interaction and friendliness can be of interest.

3.3.3 Solution Quality

Five approaches used in testing a given heuristic are:

(i) Empirical testing: This can be based on the best solutions of some existing heuristic when tested on a set of published (secondary) data. We can then produce an average deviation, worse deviation, the best solution etc. This measure, which is one of the most useful approaches in practice, is simple to use and is effective when secondary data exist.

(ii) Worst case analysis: a pathological example needs to be generated. This is represented purposely to show the weakness of the algorithm. It is usually very hard to find such an example especially if the problem is complex. One disadvantage of such analysis, though theoretically strong, is that in practice the problem under study rarely resembles the worst case example.

(iii) Probabilistic analysis; the density function of the problem data needs to be determined, and statistical measures derived, such as average and worst behavior.

(iv) Lower bound: one way is to solve the relaxed problem where at least one of the difficult constraints is removed (LP relaxation), or the transformed problem which falls into a nice class of easy problems. The main difficulty is that the lower bound solutions obtained need to be rather tight to tell the quality of the heuristic solution, otherwise misleading conclusions can be drawn.

(v) Benchmark: in some practical situations where a benchmark solution already exists, one can see how the heuristic solution compares with the benchmark solution (Reeves, and Beasley, 1993).

3.3.4 Computational Effort

The concept of large computer time is relative to both the nature of the problem and the availability of the computing resources. The computing time, and especially in real life, the total usage computer time which includes both the CPU time and the time for introducing input data as well as time for output is an important element in the decision process (Amponsah, 2003) and (Paulison, 2005).

3.4 The knapsack Problem

The concept of the knapsack problem here has to do with maximizing total production by choosing the best or valuable items to produce in other to attain the maximum number required.

The knapsack model is used for plastic bag waste recycling companies to be solved numerically. The model is based on the sale of recycled materials and the constrain is on the cost of recycling which includes the cost of plastic bag waste collection, processing and marketing. Hence it depends on market conditions and may be negative if sales revenue does not exceed collection, processing and marketing cost.

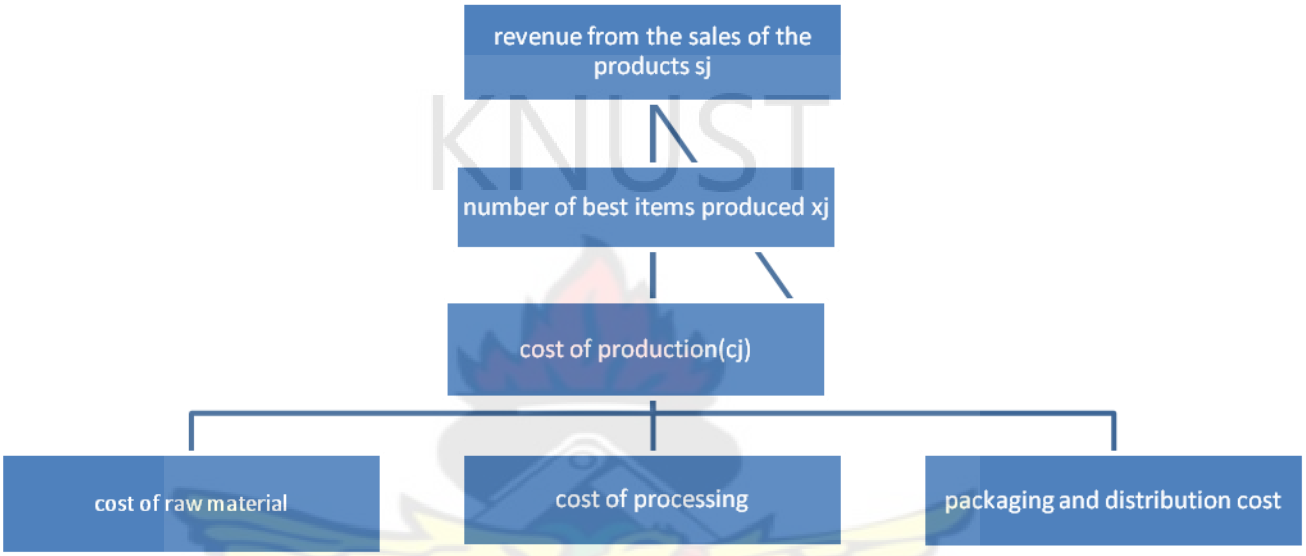


Figure 3.1 a raw representation of the process.

The Knapsack problem is the classic integer linear programming problem with a single constraint. The 0-1 Knapsack Problem (KP) is a problem of choosing a subset of the *n* items such that the corresponding revenue sum is maximized without having the weight sum to exceed the capacity *a*. This may be formulated as follows:

3.4.1 Objective function

$$Max revenue \equiv \sum_{j=1}^{n} S_j X_j$$

Subject to:

$$\sum_{j=1}^{n} C_j x_j \leq a$$

3.4.2 Decision variable

$x_j =$ quantity of products that can be produced

Subscript

j=total number of products (items) that can be produced; j=1,2,3,…,n

3.4.3 Other Variables

$S_j =$ selling price

$C_j =$ cost of production of the products

a= amount of money available for production

The objective function of the model is to maximize total revenue over the planning horizon. The objective function has one term. The term captures the revenue gained from the sales of the products.

The constraint ensures that the total cost of producing these items is less than or equal to the maximum number of items that is to be produced.
The only decision variable is the quantity of products that can be produced and this involves the individual quantity of each item. This is because our aim is to maximize revenue so if this is known, it will help us know the number to produce for each or some in other to attain our aim.

The kp depends on the number of items to be produced it is therefore important to have a require number of items that can be produced in other to work within that range.

3.4.4 Cost description

The cost of finished products is the price that the firm receives from the retailer during price negotiations for all products. This price is cedis per product.

The cost of production involves the cost of

(i) plastic bag waste collection (or cost of raw material) is the price that the company must pay to the plastic bag waste collectors to acquire the amount of plastic bag waste needed for production to take place. This cost is pesewas per kilo.

(ii) The packaging and distribution cost is the money spent on packaging the product and distributing them to the retail customers. The packaging cost includes the cost of the materials (e.g. boxes, stickers) and the cost of labor and transportation. This cost is cedis per finished case.

(iii) The cost of processing is the amount of money the firm spends on producing the products from the raw material to the finish product. This cost is cedis per case.

3.4.5 Illustration of the proposed model

The following data provides information regarding a plastic bag waste recycling company with a type of product to produce, number of product that can be produced by each, cost of production and selling price for each type of item. The aim is to find the number of items that can be produced so as to get maximum total value and maximum revenue.

3.4.6 Input data

The table below gives the input data where the company has the option of producing four different items (products)

Product type	Number of products (xj)	Cost of production (cj)	Selling price of products (sj)
1	4	2	4
2	3	3	7
3	4	2	5
4	5	5	8

Table 3.1list of products to be produced with weight and value

Let x_j ={0,1} be set of piece of product being included in the knapsack where x_j =1 if product x_j is included and 0 if not. The model will be used to test for a=10, 20 and 30.

From the table j=1, 2, 3,…,16

Objective function

$$Maxrevenue \equiv \sum_{j=1}^{n} S_j x_j$$

$$=4(x_1+x_2+x_3+x_4)+7(x_5+x_6+x_7)+5(x_8+x_9+x_{10}+x_{11})+8(x_{12}+x_{13}+x_{14}+x_{15}+x_{16})$$

Subject to:

$$\sum_{j=1}^{n} C_j x_j \leq a$$

$$2(x_1+x_2+x_3+x_4)+3(x_5+x_6+x_7)+2(x_8+x_9+x_{10}+x_{11})+5(x_{12}+x_{13}+x_{14}+x_{15}+x_{16}) \leq a$$

For a=10

i. $2(x_1+x_2+x_3+x_4)+3(x_5+x_6+x_7)+2(x_8+x_9+x_{10}+x_{11})+5(x_{12}+x_{13}+x_{14}+x_{15}+x_{16}) \leq 10$

2(1 +1 +1 +1) +3(0 +0 +0) +2(0 +0+0+0) +5(0 +0 +0 +0 +0)≤10

2(4) +3(0) +2(0) +5(0) ≤10

Then

maxrevenue= 4(1 +1 +1 +1) +7(0 +0 +0) +5(0 +0+0+0) +8(0 +0 +0 +0 +0)

$=4(4)+7(0)+5(0)+8(0)=16$

Or

ii. $2(x_1+x_2+x_3+x_4)+3(x_5+x_6+x_7)+2(x_8+x_9+x_{10}+x_{11})+5(x_{12}+x_{13}+x_{14}+x_{15}+x_{16})\leq 10$

$2(1+0+0+0)+3(0+0+0)+2(1+1+1+1)+5(0+0+0+0+0)\leq 10$

$2(1)+3(0)+2(4)+5(0)\leq 10$

Then

Maxrevenue$=4(1+0+0+0)+7(0+0+0)+5(1+1+1+1)+8(0+0+0+0+0)$

$=4(1)+7(0)+5(4)+8(0)=24$

Or

iii. $2(x_1+x_2+x_3+x_4)+3(x_5+x_6+x_7)+2(x_8+x_9+x_{10}+x_{11})+5(x_{12}+x_{13}+x_{14}+x_{15}+x_{16})\leq 10$

$2(0+0+0+1)+3(0+0+1)+2(0+0+0+0)+5(1+0+0+0+0)\leq 10$

$2(1)+3(1)+2(0)+5(1)\leq 10$

Then

Maxrevenue$=4(0+0+0+1)+7(0+0+1)+5(0+0+0+0)+8(1+0+0+0+0)$

$=4(1)+7(1)+5(0)+8(1)=19$

For a=20

i. $2(x_1+x_2+x_3+x_4)+3(x_5+x_6+x_7)+2(x_8+x_9+x_{10}+x_{11})+5(x_{12}+x_{13}+x_{14}+x_{15}+x_{16})\leq 20$

$2(1+1+0+0)+3(1+1+1)+2(1+0+0+0)+5(1+0+0+0+0)\leq 10$

$2(2)+3(3)+2(1)+5(1)\leq 20$

Then

maxrevenue$=4(1+1+0+0)+7(1+1+1)+5(1+0+0+0)+8(1+0+0+0+0)$

$=4(2)+7(3)+5(1)+8(1)=42$

Or

ii. $2(x_1+x_2+x_3+x_4)+3(x_5+x_6+x_7)+2(x_8+x_9+x_{10}+x_{11})+5(x_{12}+x_{13}+x_{14}+x_{15}+x_{16})\leq 20$

$2(1+1+0+0)+3(1+1+0+2(0+0+0+0)+5(1+1+0+0+0)\leq 10$

$2(2) + 3(2) + 2(0) + 5(2) \leq 20$

Then

Maxrevenue $= 4(1+1+0+0) + 7(1+1+0) + 5(0+0+0+0) + 8(1+1+0+0+0)$

$= 4(2) + 7(2) + 5(0) + 8(2) = 38$

Or

iii. $2(x_1 + x_2 + x_3 + x_4) + 3(x_5 + x_6 + x_7) + 2(x_8 + x_9 + x_{10} + x_{11}) + 5(x_{12} + x_{13} + x_{14} + x_{15} + x_{16}) \leq 20$

$2(0+0+0+0) + 3(1+1+1) + 2(1+1+1+1) + 5(0+0+0+0+0) \leq 20$

$2(1) + 3(3) + 2(4) + 5(0) \leq 20$

Then

Maxrevenue $= 4(0+0+0+0) + 7(1+1+1) + 5(1+1+1+1) + 8(0+0+0+0+0)$

$= 4(1) + 7(3) + 5(4) + 8(0) = 45$

For a=30

i. $2(x_1 + x_2 + x_3 + x_4) + 3(x_5 + x_6 + x_7) + 2(x_8 + x_9 + x_{10} + x_{11}) + 5(x_{12} + x_{13} + x_{14} + x_{15} + x_{16}) \leq 30$

$2(1+1+1+1) + 3(1+1+0) + 2(1+1+1+0) + 5(1+1+0+0+0) \leq 30$

$2(4) + 3(2) + 2(3) + 5(2) \leq 30$

Then

maxrevenue $= 4(1+1+1+1) + 7(1+1+0) + 5(1+1+1+0) + 8(1+1+0+0+0)$

$= 4(4) + 7(2) + 5(3) + 8(2) = 61$

Or

ii. $2(x_1 + x_2 + x_3 + x_4) + 3(x_5 + x_6 + x_7) + 2(x_8 + x_9 + x_{10} + x_{11}) + 5(x_{12} + x_{13} + x_{14} + x_{15} + x_{16}) \leq 30$

$2(1+1+0+0) + 3(1+1+1) + 2(1+0+0+0) + 5(1+1+1+0+0) \leq 30$

$2(2) + 3(3) + 2(1) + 5(3) \leq 30$

Then

Maxrevenue $= 4(1+1+0+0) + 7(1+1+1) + 5(1+0+0+0) + 8(1+1+1+0+0)$

$= 4(2) + 7(3) + 5(1) + 8(3) = 58$

Or

iii. $2(x_1 + x_2 + x_3 + x_4) + 3(x_5 + x_6 + x_7) + 2(x_8 + x_9 + x_{10} + x_{11}) + 5(x_{12} + x_{13} + x_{14} + x_{15} + x_{16}) \leq 30$

$2(0 + 0 + 0 + 1) + 3(1 + 1 + 1) + 2(0 + 0 + 0 + 0) + 5(1 + 1 + 1 + 1 + 0) \leq 30$

$2(0) + 3(3) + 2(0) + 5(4) \leq 30$

Then

Maxrevenue $= 4(0 + 0 + 0 + 0) + 7(1 + 1 + 1) + 5(0 + 0 + 0 + 0) + 8(1 + 1 + 1 + 1 + 0)$

$= 4(0) + 7(3) + 5(0) + 8(4) = 53$

From the above, the calculations can be shown on the table as below

(i) For a≥10, Maxrevenue=24.00

Product type	Number of products to be produced for each type (xj)	Number that can be produced to obtain maximum revenue
1	4	1
2	3	0
3	4	4
4	5	0

Table 3.2 when maxrevenue is GHC24.00

(ii) For a≥20, Maxrevenue=45.00

Product type	Number of products to be produced for each type (xj)	Number that can be produced to obtain maximum revenue
1	4	1
2	3	3
3	4	4
4	5	0

Table 3.3 when maxrevenue is GHC45.00

(iii) For a≥30, Maxrevenue=61.00

Product type	Number of products to be produced for each type (xj)	Number that can be produced to obtain maximum revenue
1	4	4
2	3	2
3	4	3
4	5	2

Table 3.4 when maxrevenue is GHC61.00

From the tables 3.2, 3.3 and 3.4 it shows that to obtain maximum revenue does not mean to produce all items but it depends on the maximum you are allowed to produced, the cost of producing it and also the revenue that can be gotten from it.

CHAPTER FOUR

DATA COLLECTION AND ANALYSIS

4.0 Introduction

In this chapter we shall present how the data was collected and how it was analyzed.

4.1 Case study

Trashy bags is used as the case study used in this study. This is because their way of managing the plastic bag waste is very welcoming. They do not apply heat to the waste, but recycle them in their raw nature (reuse)

Trashy Bags idea was to collect discarded sachets, clean them up and stitch them together to make brightly colored, fashionable bags wallets and raincoats.

And crucially, its network of collectors has gathered some 15 million plastic sachets that might otherwise be on the streets of Accra.

This study will use data from trashy bags to determine the quantity of items to produce so as to get maximum total value and maximum revenue.

4.2 Input data and Assumptions

The data for this model is from management at Trashy bags. The data is transformed for reasons of confidentiality.

Table 4.1 gives the input data where the company has the option of producing thirteen different items (products)

Table 4.1 list of products

Product type	Number of products (x_j)	Cost of production (c_j)	Selling price of products (s_j)
Briefcase	1	17	21
Laptop bag	1	18	24
Trashy shopper	4	9	12

Wallet	3	7	9
Purser	5	6	10
Water bottle holder	2	8	10
Lunch box	1	14	17
Pencil case	1	2	3
Sponge bag	2	12	16
Tobishe(hats)	3	12	15
Sankofa	2	13	16
Obaapa	1	7	9
Fish bag	1	10	13

Let $x_j=\{0,1\}$ be set of piece of product being included in the knapsack where $x_j=1$ if product x_j is included and 0 if not. The model will be used to test for a=100, 135 and 150.

From the table j=1, 2, 3,…, 27

Objective function

$$Max revenue \equiv \sum_{j=1}^{n} S_j x_j$$

$=21(x_1)+24(x_2)+12(x_3+x_4+x_5+x_6)+9(x_7+x_8+x_9)+10(x_{10}+x_{11}+x_{12}+x_{13}+x_{14})+10(x_{15}+x_{16})+17(x_{17})+3(x_{18})+16(x_{19}+x_{20})+15(x_{21}+x_{22}+x_{23})+16(x_{24}+x_{25})+9(x_{26})+13(x_{27})$

Subject to:

$$\sum_{j=1}^{n} C_j x_j \le a$$

$=17(x_1)+18(x_2)+9(x_3+x_4+x_5+x_6)+7(x_7+x_8+x_9)+6(x_{10}+x_{11}+x_{12}+x_{13}+x_{14})+8(x_{15}+x_{16})+14(x_{17})+2(x_{18})+12(x_{19}+x_{20})+12(x_{21}+x_{22}+x_{23})+13(x_{24}+x_{25})+7(x_{26})+10(x_{27})\le a$

For a=100

(i) $17(x_1) +18(x_2) +9(x_3 +x_4 +x_5 +x_6) +7(x_7+x_8 +x_9)+6(x_{10} +x_{11} +x_{12} +x_{13} +x_{14})+8(x_{15} +x_{16})+14(x_{17})+2(x_{18})+12(x_{19} +x_{20})+12(x_{21} +x_{22} +x_{23})+13(x_{24} +x_{25})+7(x_{26})+10(x_{27})\leq 100$

$17(1)+18(0) +9(0) +7(3)+6(1)+8(2)+14(1)+2(1)+12(0)+12(2)+13(0)+7(0)+10(0) \leq 100$

$17+21+6+16+14+2+24 \leq 100$

Then

maxrevenue$=21(1)+24(0)+12(0)+9(3)+10(1)+10(2)+17(1)+3(1)+16(0)+15(2)+16(0)+9(0)+13(0)$

$=21 +27+10+20+17+3+30 =128$

Or

(ii) $17(x_1) +18(x_2) +9(x_3 +x_4 +x_5 +x_6) +7(x_7+x_8 +x_9)+6(x_{10} +x_{11} +x_{12} +x_{13} +x_{14})+8(x_{15} +x_{16})+14(x_{17})+2(x_{18})+12(x_{19} +x_{20})+12(x_{21} +x_{22} +x_{23})+13(x_{24} +x_{25})+7(x_{26})+10(x_{27})\leq 100$

$17(1)+18(1) +9(1) +7(0)+6(5)+8(0)+14(0)+2(1)+12(2)+12(0)+13(0)+7(0)+10(0) \leq 100$

$17+18+9+30+2+24 \leq 100$

Then

maxrevenue$=21(1)+24(1)+12(1)+9(0)+10(5)+10(0)+17(0)+3(1)+16(2)+15(0)+16(0)+9(0)+13(0)$

$=21+24+12+50+3+32 =142$

For a=135

(i) $17(1)+18(1)+9(1)+7(1)+6(1)+8(1)+14(1)+2(1)+12(1)+12(1)+13(1)+7(1)+10(1)\leq 135$

$=17+18+9+7+6+8+14+2+12+12+13+7+10\leq 135$

Then

maxrevenue=21(1)+24(1)+12(1)+9(1)+10(1)+10(1)+17(1)+3(1)+16(1)+15(1)+16(1)+9(1)+13(1)

=21+24+12+9+10+10+17+3+16+15+16+9+13

=175

Or

(ii) 17(0)+18(1)+9(4)+7(0)+6(5)+8(0)+14(1)+2(1)+12(2)+12(0)+13(0)+7(0)+10(1)≤135

18+36+30+14+2+24+10 ≤135

Then

maxrevenue=21(0)+24(1)+12(4)+9(0)+10(5)+10(0)+17(1)+3(1)+16(2)+15(0)+16(0)+9(0)+13(1)

=24+48+50+17+3+32+13

=187

For a=150

(i) 17(1)+18(1)+9(1)+7(2)+6(1)+8(2)+14(1)+2(1)+12(1)+12(1)+13(1)+7(1)+10(1)≤150

=17+18+9+7+6+8+14+2+12+12+13+7+10≤135

Then

maxrevenue=21(1)+24(1)+12(1)+9(2)+10(1)+10(2)+17(1)+3(1)+16(1)+15(1)+16(1)+9(1)+13(1)

=21+24+12+18+10+20+17+3+16+15+16+9+13

=194

Or

(i) 17(1)+18(1)+9(4)+7(0)+6(5)+8(0)+14(0)+2(1)+12(2)+12(0)+13(1)+7(0)+10(1)≤150

17+18+36+30+2+24+13+10 ≤150

Then

maxrevenue=21(1)+24(1)+12(4)+9(0)+10(5)+10(0)+17(0)+3(1)+16(2)+15(0)+16(1)+9(0)+13(1)

=21+24+48+50+3+32+16+13

=207

Table 4.2 shows the distribution of products which gives maximum revenue compared with minimum revenue given the same value of a.

Table 4.2 The type of items that can be produced with their respective revenues when a=100

Product type	Number of products (x_j)	Revenue(127)	Revenue(142)
Briefcase	1	1	1
Laptop bag	1	0	1
Trashy shopper	4	0	1
Wallet	3	2	0
Purser	5	1	5
Water bottle holder	2	2	0
Lunch box	1	1	0
Pencil case	1	1	1
Sponge bag	2	0	2
Tobishe(hats)	3	2	0
Sankofa	2	0	0
Obaapa	1	1	0
Fish bag	1	0	0

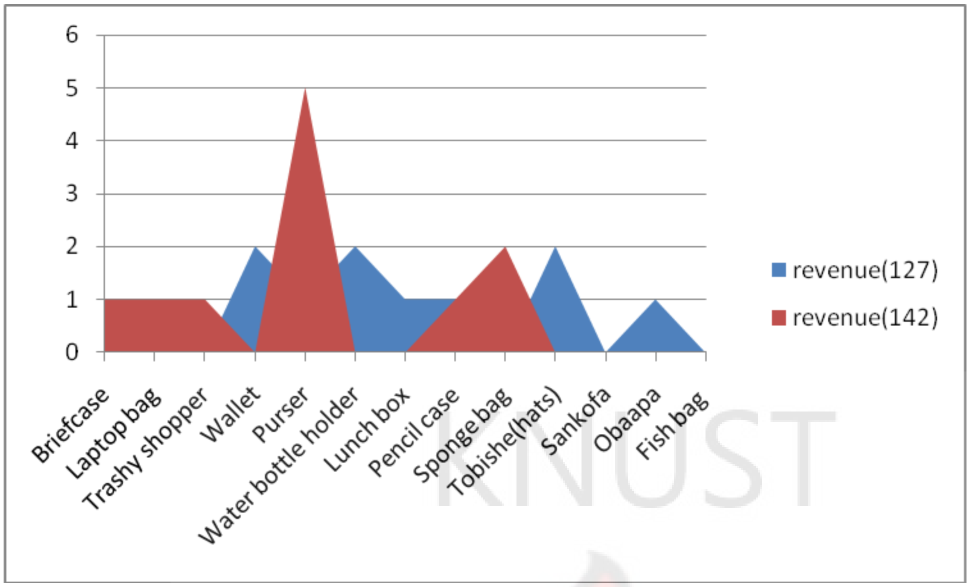


Figure 4.1 graph representing what can be produced when given GHC100.00

Table 4.3 The type of items that can be produced with their respective revenues when a=135

Product type	Number of products (x_j)	Revenue(175)	Revenue(187)
Briefcase	1	1	0
Laptop bag	1	1	1
Trashy shopper	4	1	4
Wallet	3	1	0
Purser	5	1	5
Water bottle holder	2	1	0
Lunch box	1	1	1
Pencil case	1	1	1
Sponge bag	2	1	2
Tobishe(hats)	3	1	0
Sankofa	2	1	0
Obaapa	1	1	0
Fish bag	1	1	1

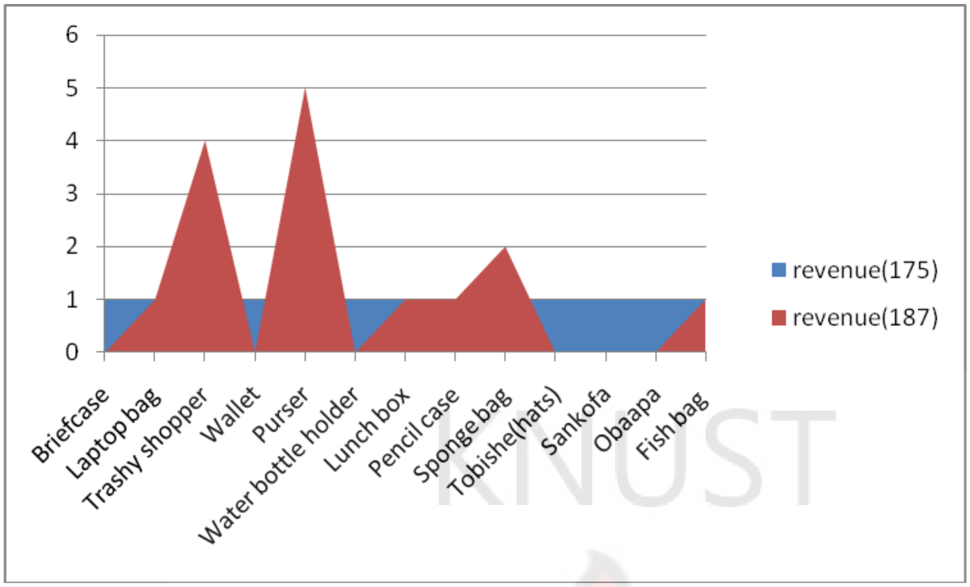


Figure 4.2 graph representing what can be produced when given GHC135.00

Table 4.4 The type of items that can be produced with their respective revenues when a=150

Product type	Number of products (x_j)	Revenue(194)	Revenue(207)
Briefcase	1	1	1
Laptop bag	1	1	1
Trashy shopper	4	1	4
Wallet	3	2	0
Purser	5	1	5
Water bottle holder	2	2	0
Lunch box	1	1	0
Pencil case	1	1	1
Sponge bag	2	1	2
Tobishe(hats)	3	1	0
Sankofa	2	1	1
Obaapa	1	1	0
Fish bag	1	1	1

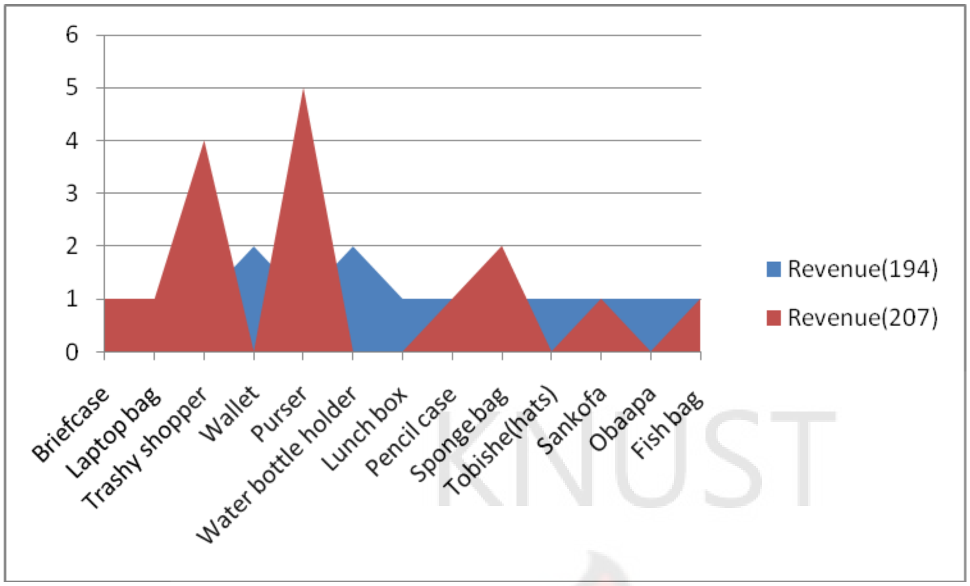


Figure 4.3 graph representing what can be produced when given GHC150.00

4.3 Discussion of Results

The result of the model from the three tables and figures shows that we need not produce all items to get maximum revenue. This is because from the results, non of the maximum revenue were obtain be producing all items. This shows that the company can produce just a few items and gets maximum revenue.

It can also be seen that as the amount of money for production increases, the number of products to be made also increases as well as the revenue from the sales of items.

The amount required to meet the minimum production is 2 GHS but from the results it is not always that this item was made neither was the most expensive ones made always. This shows that items was made in other to get maximum revenue but not on how they are on the table.

This also shows that the company can put down their budget for future production since they know what to produce with 0-1 knapsack algorithm and this can give managers better information around the expected revenue of profitability for a given production plan, allowing them to make better budget decisions.

CHAPTER FIVE

5.1 Conclusions and Recommendations

Inadequate revenue at most recycling companies are a typical case of a Knapsack optimization problem. Given a 0–1 knapsack optimization problem, we used two heuristic procedures to solve the problem of selecting which items are to be made given a limited amount of money.

Among the major areas of our research was the use of the Knapsack problem for selecting items in a critical situation with limited amount of money. Previously, items were produced randomly or based on their selling price. But now an effective, efficient and more scientific means can be used. Piling up of items is reduced significantly since more of them are made based on proper selection.

This however can be applied to any situation where given a set of items, each with a weight and a value, and we are to determine the number of each item to include in a collection so that the total weight is less than a given limit and the total value is as large as possible. Examples of such situations are capital investment, cargo handling, banking among others. Since Trashy Bags is owned by a private firm, in an event where management may have to include certain items for public interest, we suggest that total cost for such item(s) should be deducted from cost available before selecting the others to compete for the remaining cost. The two heuristic procedures used are among the few heuristic procedures that can be used to solve the selection problem.

5.2 Recommendations

We recommend to Trashy Bags to use the 0–1 knapsack optimization in selecting items to be produced. There are situations where too many items will reduce revenue. In this case, the company should consider the rate at which items are bought by customers as more than one constraint (i.e. both money limit and selling limit, where the cost of production and limited selling rate are not related), we get the multiple-constrained knapsack problem. We recommend that in future such a situation should be considered. We also recommended that in future it will be less time consuming if the company can use software based on 0–1 knapsack optimization for the selection.

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APPENDIX A: Some products of Trashy Bags