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Plastic Bags Waste Management Using the Knapsack Model, Case Study; Trashy Bags Accra

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ABSTRACT- Plastic waste is a big issue in Ghana, but the amount of recycled plastic in Ghana is still low due to the high investment and operating cost. Hence, the rest of plastic waste are burnt, sent to the landfills or left on the streets. In order to be financially viable, recycling companies need to use effective and efficient ways in selecting items to be produced from a lot of items given a fix or limited amount of money to achieve optimal use of the money. The knapsack problem is a problem in combinatorial optimization, which derives its name from the maximization problem of the best choice of essentials that can fit into a 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 or equal to a given limit with a maximum value. The problem often arises in resource allocation with constraints. The practice of selecting items to be produced from a lot of items to generate the maximum revenue given a fixed amount of money is a clear case of Knapsack Problem. In this study, we shall explore ways of effectively and efficiently selecting items to be produced from a lot of items given a fix or limited amount of money to achieve optimal use of the money in order to maximize revenue in Ghana, using the classical 0-1 knapsack problem with a single constraint. This work will also serve as reference material in the libraries and the internet for students who wish to undertake research into the piled-up problems of items to be made.

Key words- combinatorial optimization, Knapsack Model, maximization problem, piled-up problems, Plastic Bags waste, recycled plastic, Waste Management,

1 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 of 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.

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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.

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.

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.

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).

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.

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.

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;

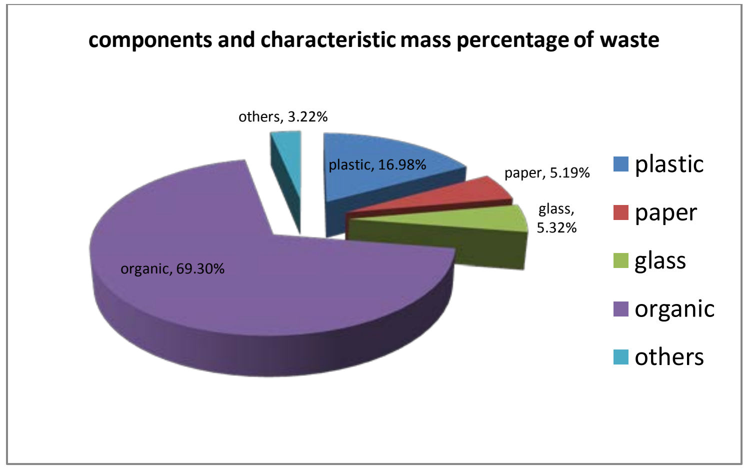

Fig 1.1 The percentage of waste component as at June 2010 in Accra metropolis. Source Zoomlion Ghana Ltd

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.

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.

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

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.

2 RELATED WORKS

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.

3 METHODOLOGY

3.1The 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.

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:

3.2.1 Objective function

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

Subject to:

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

3.2.2 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

3.2.3 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.

3.3 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.

4 DATA COLLECTION AND ANALYSIS

4.1 Case study

Trashy Bags is used as the case study in this study. This is because their way of managing the plastic bag waste is very

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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 uses 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

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

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

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

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) ≤100

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

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) ≤100

17+18+9+30+2+24 ≤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)≤135

=17+18+9+7+6+8+14+2+12+12+13+7+10≤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

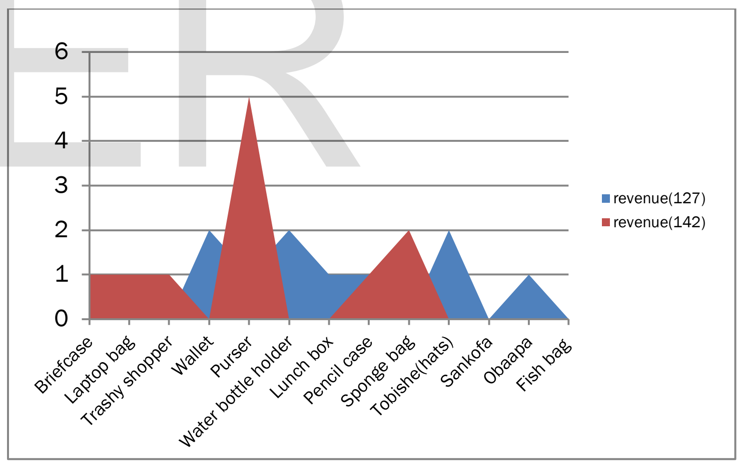

Figure 4.1 graph representing what can be produced when given GHC100.00

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

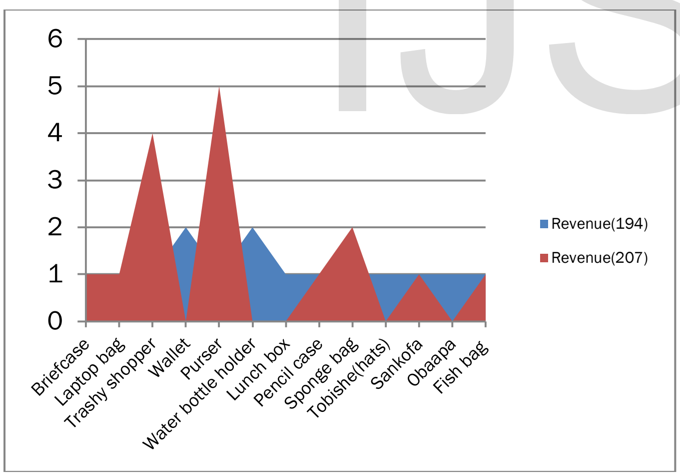

Figure 4.3 graph representing what can be produced when given GHC150.00

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 were 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.

5 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.

5.1 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