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INSTITUTE OF DISTANCE LEARNING

Cargo Loading Problem:

(A Case Study: Agate Transport and Services Ltd.)

BY

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A thesis submitted to the Department of Mathematics in partial fulfilment of the requirements for the award of degree of Master of Science in Industrial Mathematics

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CERTIFICATION

I herein certified that this work was carried out solely by FOSU SOLOMON KOFI(PG4066010) in the Department of Mathematics ,Institute of Distance learning in partial fulfilment of the requirements for the award of Master of Science in Industrial Mathematics.

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DECLARATION

I hereby declare that this submission is my own work towards the Master of Science degree and that, to the best of my knowledge it contains no material previously published by another person nor material which has been accepted for award of any other degree of the university except where due acknowledgement has been made in the text.

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ABSTRACT

The main function of logistic companies is to load and transport cargo. Loading operations are often done arbitrary without due regard to weight and volume constraints of the vehicle. This thesis seeks to model loading operations at ATS limited, Tema as a linear programming problem so that profits could be maximized. This involves the use of simplex algorithm and application of QM software to analyse the data. The study revealed an optimal profit of Gh 12140.00 was made. It also established an optimal loading plan in each of the three compartments of the vehicle used. Among other recommendations offered was that computer applications give a systematic and transparent solutions as compared to arbitrary method.

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CHAPTER ONE

1.0 INTRODUCTION

In the present global competitive market, the timely and shortest delivery period has increased the attention of the business community. The cargo loading industry has witnessed an increasing thrust to decide the optimum loading plan of the different type of cargoes. An individual cargo loading organization's annual turnover may be in of billions dollars. It has become a pivotal aspect for such organization to optimize their loading plan for cargoes. A small improvement in cargo pallet loading plan may result in savings of millions of dollars annually. This study focuses on the development of a decision support system for the optimization of the cost related to the cargo pallets selection and pallets loading (Yan et al., 2008).

1.1 BACKGROUND OF STUDY

The two principal challenges facing shippers are to satisfy both the customer and the shipper. The customer requires a secure and reliable method of carriage whilst the shipper requires that the space on his vehicle of carriage is fully utilised in order to receive maximum freight. To achieve compatibility between cargo owners and the owners of the means of transport requires knowledge of the cargo-handling procedures in transport. These procedures are described with reference to major characteristics of commodities and cargoes.

The methods of cargo carriage and packaging must be considered at the very outset of the shipping process. The size and quality of packages must be compatible with the transport technology contemplated, e.g. utilisation of containers depends on positioning packages to avoid empty space. Hence, the considered transformation of commodity to cargo carries significant commercial, operational and economic impact. Space with a container is not just loss of revenue but poses the danger of goods shifting during transit and so sustaining damage (Pan et al., 2008).

Basically, packaging performs the following three basic functions, which we may call the three P's of packaging, namely: protection, preservation and presentation.

A package should protect and preserve the contents during storage and transit from the harvesting (for agricultural products), manufacturing (for manufactured goods) or mining (for ore or other mineral products), to the consuming centre. Protection is required not only against loss, damage and pilferage, but also, depending on the nature of the contents, against moisture entering or leaving the package, high or low temperatures, light, gases, insect infestation, contamination and other natural hazards.

Commodities and cargoes may be in solid dry form, or they may be liquids or gases. The physical state has clear implications for storing, handling and movement of commodities. Different forms require different transport modes, means and packaging.

Gases and liquids have to be contained in some form. They may be packed into containers or flasks, or alternatively be moved without packaging in pipelines and special carriers. When gas is moved in tanks onboard ships, it is often liquefied by low temperature. This is a highly specialised form of transport requiring not only expensive, purpose built carriers, but also special terminals and handling equipment. There are two forms of gas which are shipped by sea, liquefied natural gas (LNG) and liquefied petroleum gas (LPG). The traditional liquid cargoes are mainly crude oil and its refined products, vegetable oils, wines, latex, various chemicals and even water. In bigger lots liquid cargoes are carried loose in ships, i.e. they are pumped from tanks on shore through pipelines to tanks onboard the ship and vice versa. This is the practice for very large crude carriers (VLCC).

In smaller lots liquids and gases are stored and moved in containers or flasks. When packed in this way, the commodities may be regarded as dry cargo from a transport point of view. The dry cargoes embrace raw materials, semi-finished or finished goods. They do not require the same containment as gases and liquids. The number of dry cargo types is almost endless. The type of commodity, the level of finishing, and the transport method will determine the need for packaging and storage requirements. Detailed recommendations of methods of cargo carriage, cargo handling, and transport requirements for various types of goods are found in many literatures.

Storage requirements will tend to determine the choice of transport method. Some commodities have to be kept frozen (e.g. meat) while others need refrigeration (e.g. fruit). Flowers need to reach the customers quickly, while other cargoes need adequate ventilation to avoid combustion (e.g. grain, coal and copra). The shipper must choose a transport method which secures proper storage and speed of delivery. There are several international conventions as well as common practices ship owners will have to follow to secure proper handling of different cargoes onboard ships.

Packaging will also have to be considered relative to the transport method chosen. Some raw materials, like ores, need not be packaged at all. If finished goods are moved in containers, the packaging required is much less than if the goods are transported in individual cases.

In general, commodities are either moved in bulk or as general cargo. Bulk and general cargoes are defined relative to their means of transport and the cargo mix onboard. If, for example, a ship carries a homogeneous cargo lot which is not packed in any form, this is a bulk cargo: oil carried directly in tanks, grain carried directly in holds or pig iron loaded directly, in holds.

When cargoes are packed and mixed onboard, it is referred to as general cargo. Most finished goods are shipped as general cargo, while raw materials in bigger lots are usually bulk cargoes. The distinction between bulk cargoes and general cargoes is not strict. There are examples of more than one bulk cargo being carried onboard the same ship, in different holds or sections. Similarly, there are general cargoes which fill up the whole carrier, e.g. shiploads of sugar in bags. This is referred to as unit loads of general cargoes (which does not necessarily involve pallets or containers). The opposite, where the ship carries different cargoes packed differently is referred to as general break bulk cargoes. Such cargoes may consist of pallets, unpacked machinery, drums, and crates and so on.

Commodities, dry as well as liquid, may be shipped in unit loads, in break bulk or as bulk cargo. It should be noted that terminology with regard to the above is not fully consequent, and that additional terms are in use. The term "parcel bulk" in chemical carriers is one example of this; up to 30 different chemicals may be transported simultaneously onboard the same ship.

There exists a third; "hybrid" form of moving cargoes, involving slurry techniques. Dry bulk cargoes may be transformed into slurries and moved in a form similar to that of liquid bulk. This has been applied to coal and iron ores, where the ores or the coal are mixed with water and transported by means of pipelines.

On a world wide basis, almost all the liquid commodities, measured in tons, are moved in bulk. Important dry goods, like grain, coal, ores, tapioca, copra and salt are similarly moved in homogeneous unpackaged lots. Such bulk cargoes can be handled in many different ways. Liquids are moved in pipelines, grain are mostly loaded by conveyors or chutes and unloaded pneumatically, while ores and coal are mostly moved with conveyors or grabs.

The cargo characteristics will influence the choice of ship needed for a specific job. Different ships are constructed to carry different bulk cargoes.

Similarly, the cargo access equipment has been constructed to cater for different commodities. The equipment available for cargo handling at the intended ports of loading and discharge will also be reflected in the type of ship needed for a specific job. If, for example, no cranes are available in the discharging port, a ship equipped with cranes will have to be chosen for the transport task.

General cargo is a term that covers a great variety of goods. In regard to modern cargo handling it refers to loose cargo that has not been consolidated for handling with mechanical means such as unitised or containerised cargo. It refers to individual items of any type of cargo, bagged or baled items, cases or crates, individual drums or barrels pieces of machinery or small items of steel construction.

If general cargo is to be loaded on a ship in general stow it is usually man handled into place. Hence the reason why general cargo is rarely seen in developed countries today, the cost of handling such items is prohibitive and the time taken is unacceptable for most maritime operations.

In stow, general cargo is susceptible to crushing damage from other items of cargo or damage from the ship's steel work, general handling damage, sweat damage and from pilferage. Hence cargo stowed in this state must be protected with suitable dunnage depending on the type of cargo and the risk of such cargo in stow. For example, bagged cargo if susceptible to moisture damage should never be stowed against the steel in the cargo compartment, some type of dunnage or cargo battens must be placed between the cargo and the steel work.

Cargo susceptible to crushing must be placed in top stow. Food stuff can often taint other cargoes so must be stowed apart. Some cargoes need ventilation and must be stowed accordingly. Cargo that has a value to any individual must be protected from pilferage; examples of this are shoes and clothing, beer and spirits, grocery items and electrical goods.

General cargo must be appropriately labelled. Usually with the port of destination and the consignee's identification, this is called the ‘cargo mark’. And it is this mark that is also shown on the Bill of Lading and the Cargo Manifest.

It is the responsibility of the shipper to ensure that general cargo is presented for shipment suitably packaged to prevent damage in handling. If there is any risk in handling damage then the items should be clearly marked with the international symbols.

Due to the numerous small parcels making up general cargo, it is usual to tally such cargo onto the vessel while loading and in some instances discharge tallies are also conducted. Cargo quantity on board is confirmed by the ship's officers signing a Mate's Receipt, details from the Mate's Receipt then make up the information on the Bill of Lading.

Tallies, Mates Receipts and thence Bill of Ladings must accurately record the quantity and condition of the cargo. The ship is then obliged to discharge the cargo at its destination in the same quantity and condition as stated on the Bill of Lading. If it does not then the carrier (the ship owner) is liable.

It is important therefore, that any defects, damage, lack of suitable packaging or any deterioration whatsoever to general cargo sighted by the ship during or prior to loading is outlined on the Mates Receipt. The Bill of Lading must then be suitably claused prior to signing by the ship's Master or his agent.

Obviously the usual type of ship carrying general cargo are general cargo vessels, although it is not unusual for bulk carriers to carry certain types of general cargo such as forest or steel products. In addition it is fairly common for bulk carriers to also carry large quantities of bagged cargo, although this is often referred to a specialised or particular bulk cargo.

General cargo moving between countries today is usually containerised and carried on cellular container or Ro/Ro vessels.

Almost any commodity can be containerised. The great advantages to the industry with containerisation are that the cargo is not man handled on and off the ship; instead the container is handled with fast and sophisticated handing equipment. Naturally in developed countries where labour is expensive significant savings can be made, less so initially for developing countries but over time as they become developed this will change the cargo itself therefore needs less protective packaging. The cargo can be stowed in the container away from the wharf, often by the shipper himself. The container fit into predetermined positions on board ship, complicated stowage planning is not necessary. Documentation and identification of cargo is simplified as the container number replaces the cargo mark. Computers and electronic data interchange now play a large part in ensuring the correct cargo movement, there is no need to tally the cargo.

The containers themselves are owned or leased by the shipping companies and are responsible in ensuring that sufficient empty units are available for shippers at the load ports. To achieve this often large quantities of empty units are carried at the ship owner's expense to high demand areas.

The containers themselves were originally designed to fit international standards of specific sizes. However, ship owners have pushed the actual dimensions of the units to their absolute limits; consequently there are a variety of heights, widths and even lengths of units in the system today.

There are of course many specialised or special purpose containers in use.

Compared with general cargo carried break bulk, cargo damage in containers is considerably reduced, however, it still exists. Some of the more common forms of damage are explained below.

. Cargo not properly secured or trimmed-off within the container will damage either due to heavy rolling of the ship or from shunting if transported by rail. The further a container is stowed away from the ship's centre of motion the greater will be the acceleration forces on the cargo and therefore the greater risk of damage in heavy weather.

. Water damage can be expected if the container has a leaking roof, although the majority of water damage sustained by a substandard box is caused at the terminal while the container is waiting in the stacks. Water damage on board is usually caused by a flooded hold due to blocked bilges or a leaking ballast tank. Another source of water damage is often caused when a container is stowed outside on deck where the seas can reach the underside of the unit.

Refrigerated cargo damage can occur due to a malfunction of refrigeration machinery, or through a hot spot within the container due to insufficient cold air circulation in the stow caused by poor packing or lack of adequate separation through the stow.

Container and cargo within the container can be damaged due to inappropriate or inadequate securing arrangements when containers are stowed on deck.

Despite cargo being stowed in containers it is still possible for some products to taint due to being stowed in close proximity of badly smelling cargoes. Foodstuff stowed close to wet salted hides is a classic example.

Some cargoes can spoil in the close confines of a container due to lack of ventilation. Sweat damage is as much of a problem with some containerised cargoes as it is with some general cargoes in an open hold.

Pilferage can still take place with containerised cargo. Despite the fact that the door leaves are sealed it is still possible for the doors to be sprung open with the use of heavy machinery, individual items within the container can then be stolen and the doors sprung shut without the door seal being broken. Although in most cases of container pilferage the entire container is hijacked and box and contents disappear without a trace.

Packing a container should always be done on level plane either on the ground, on a railcar, or on a trailer**.** In the case of a trailer, care should be taken to ensure the trailer cannot tip whilst being packed especially if a forklift truck is being used. If necessary the trailer should be propped. Brakes should be securely applied and wheels choked.

Stowage should be planned before packing is commenced. This should make it possible to produce either a tight or a secured stow, in which the compatibility of all items of cargo and the nature i.e. Type and strength of any packages or packaging involved are taken into account. The possibility of cross-contamination by odour or dust as well as physical or chemical compatibility should be considered.

The planned load should not weight more than the payload of the container which is marked upon it. This ensures that the permitted maximum gross weight of the container on the CSC Safety Approval Plate (which includes the payload) will never be exceeded.

Notwithstanding the load limitations on a container mentioned above, any limitation along the projected route that may be dictated by regulations or other circumstances (such as lifting and handling equipment or road restrictions on height and weight) should be complied with. Such limit may be considerably less that the permitted gross weight already referred to. In case of doubt, the container operator should be consulted.

Stowage planning should take account of the fact that containers are generally designed assuming the load to be evenly distributed over the entire floor area. Where substantial deviations from uniform packing could occur, specialist advice should be sought.

When a heavy indivisible load is to be shipped in a container or vehicle, due regard should be given to the localised weight bearing capability of the container. If necessary, the weight should be spread over a larger area than the actual bearing surface of the load, for example, by use of timber bulks. In such a case the method of securing the load should be planned before packing occurs and any necessary preparations made.

1.2 PROBLEM STATEMENT

This thesis seeks to solve the cargo loading problem of a distribution company.

In warehouse logistics, cargo loading operation involves two problems: determining the minimum number of containers that are required and loading each container to better utilize its capacity. Mathematically, the cargo loading problem can be seen as a specific aspect of the three-dimensional bin packing problem (3BPP), i.e., allocating without overlapping a finite set of rectangular items (cargos) into bins (containers) so as to meet certain objectives. Some examples are:

1. Minimize the number of the bins to pack all items.

2. Maximize the total volume of items that can be packed into one bin.

3. Find a method to pack all given items into one bin.

In real applications, certain constraints are often added to the optimization process.

For example, item orientation, spatial relationship, packing sequence, etc. These additional constraints further complicate the process to optimize the objectives. Generally speaking, the cargo loading problem is NP-hard. Therefore, heuristic methods are often used for its solution.

1.3 OBJECTIVES

Cargo loading or container loading is an important operation in modern logistics. Hundreds of containers are loaded daily at many large distribution centres and manufacture warehouses. Unfortunately, loading operations are still manual in many warehouses. Improvement on container capacity utilization and loading efficiency can significantly reduce logistics costs.

The goal of this research is to model the cargo loading problem of a company as linear programming problem and proposed simplex method for solving the problem.

1.4 JUSTIFICATION

The cargo loading problem is a special case of the 3D bin packing problem. It is known that this problem is NP-hard. Hence, heuristic methods are often used as alternatives to give "acceptable "solutions within a comparatively short time. Over the last two decades, there have been considerable advances in methods for solving a wide variety of this problem. In the first exact branch-and-bound algorithm was proposed for 3BPP. Extensive computational results showed that only small scale problems (less than 90 items) can be solved through this method within a reasonable time. When the problem size increases, the computational time of the exact method grows exponentially. Therefore, recent research on this problem is more focused on heuristic algorithms.

In view of these, studies of the cargo loading problems and their application to solving real-life problems is an area of much interest in the contribution to academic knowledge, hence the reason for solving the dynamic programming problem.

1.5 METHODOLOGY

For our methodology, we propose simplex algorithm for solving our problem. First, the algorithm will be presented. A real life computational study will be performed and QM Software will be employed to analyze our data.

1.6 SCOPE OF THE STUDY

This study is limited to cargo loading problems by land, and does not take into consideration balanced constraint. The study uses a load planning decision-making system to generate planning information for cargo loading for actual land transport (car loading), services. The system is therefore designed to maximize carrier space, minimize transport trips, and lower transportation costs.

1.7 LIMITATION OF THE STUDY

The major limitation of the study is the problem of acquisition of materials and data to undertake the study. For taxation purposes, most institutions feel reluctant in given out data, and mostly, the data given may not reflect the true real-life problem one may want to solve.

1.8 ORGANIZATION OF THE THESIS

In chapter one, we presented a background study of the cargo loading problem.

In chapter two, related works in the field cargo loading problem will be reviewed.

In chapter three, simplex algorithm proposed for solving our problem will be introduced and explained.

Chapter four will provide a computational study of simplex algorithm applied to real-life instances of the cargo loading problem.

Chapter five will conclude this thesis with additional comments on cargo loading problem.

In the next ensuing chapter, we shall review relevant literature in the field of cargo loading.

1.9 SUMMARY

In this chapter of the thesis, we gave an overview of cargo loading problem; a brief description of the problem statement of the thesis is also presented as well as the objectives, the methodology, the justification and the organization of the thesis.

In the next chapter, relevant literature in cargo loading problems shall be reviewed.

CHAPTER TWO

LITERATURE REVIEW

Given a finite set of three-dimensional boxes in different sizes and an unlimited set of containers in the same size, the cargo loading problem is to determine the minimum number of containers that can contain all the boxes. The problem is NP-hard. Li Pan et al., (2008) studied cargo loading problem and proposed a Tabu search optimization with a tree-based heuristic cargo loading algorithm as its inner heuristic to solve this problem. This approach is more flexible in taking different box conditions into consideration. Experimental results have shown that the new approach could find better solutions on average than those by other recent meta- or heuristic algorithms.

Geir and Bjorn (2006) presented a Dantzig-Wolfe procedure for the ship scheduling problem with flexible cargo sizes. This problem is similar to the well-known pickup and delivery problem with time windows, but the cargo sizes are defined to be within intervals instead of having fixed values. The authors showed that the introduction of flexible cargo sizes to the column generation framework is not straightforward, and handled the flexible cargo sizes heuristically when solving the sub-problems. This leads to convergence issues in the branch-and-price search tree, and an optimal solution cannot be guaranteed. Hence the authors introduced a method that generates an upper bound on the optimal maximization objective. The authors compared their method with an a priori column generation approach, and their computational experiments on real world cases showed that the Dantzig-Wolfe approach is faster than the a priori generation of columns, and we are able to deal with larger or more loosely constrained instances. By using the techniques introduced here, a more extensive set of real world cases can be solved either to optimality or within a small deviation from optimality

Fok et al.,(2004) presented a mathematical optimization model to assist air cargo load planning for an air cargo company, one of the world's top 10 air cargo carriers. The airline handles roughly 80 to 90 thousand tones of cargo each month. With this volume of cargo, even the slightest improvement in the load planning process will have a major impact to overall performance and efficiency. The authors developed a Web-based application to firstly perform long-term forecasting based on an analysis of historical data and then secondly operational load planning with mathematical optimization. Forecasting is important as the data will assist the airline in drafting its long-term contracts and determination of allotments. Load planning, on the other hand, is for operational term planning of how ULDs (Unit Load Devices – air cargo containers/pallets) are loaded into aircrafts. This process is usually done roughly 2 hours before departure when all the details of the cargo are present. Therefore, the performance of the application is crucial.

There are many approaches to solve the cargo loading problem. One computerized approach is to use Heuristic Methods. This can generate a reasonably good solution in a short time. Larsen and Mikkelsen (1980) and Amiouny et al., (1992) suggested heuristic approaches to determine a feasible load plan for a single aircraft. The authors developed an interactive, computer-based procedure for solving variant of vehicle loading problem encountered when loading containers and pallets into an aircraft. It used two heuristics concerning ground stability, combined load limits, position and compartment capacity constraints and balance.

Amiouny et al. (1992) presented an approach for the one dimensional cargo loading problem where the constraint is to balance around the aircraft’s midpoint. It is concerned with the following cases, (a) all given containers must be loaded; (b) containers are to be positioned on a one dimensional hold. The problem considered was airlift cargo, which must be entirely loaded, in a specified prioritized sequence (through branch and bound – take into account of expertise of highly trained loadmasters.)

Martin-Vega (1985) studied a model which mainly focused on generating a feasible plan for cargo loading rather than an optimal one. It considered a manually dominated process. The heuristic method involves experienced ground personnel trying to obtain an acceptable loading (satisfy the above stated constraints) by manual trial and error process without maximizing.

Clive et al., (1998) for Federal Express developed a heuristic method to determine a feasible packing which minimized non-productive time. Time is a critical factor for overnight couriers, such as Federal Express. Their ground crews usually start packing planes even before all the containers arrive. However, this assumption may not be applied for airlines. Before all the containers arrive, airline ground crew need to load baggage containers, mail containers and containers with preferred positions (e.g., transferred containers offloaded in next leg). Moreover, in Hong Kong, the distance from the container packing area to the plane is short. Therefore, we assume containers with no preferred position would not be preloaded before the load plan is issued.

Ramm and Samerkae (2009) presented a container loading problem and proposed a solution for solving the problem. The solution uses mathematic and computer methods which genetic algorithm, tabu search algorithm, simulated annealing algorithm. The authors compared the strengths and the weaknesses and discuss the effectiveness of each method. The test data is rectangular boxes that have many sizes and standard rectangular container.

Simulated Annealing Algorithm (SA) is a generic probabilistic meta-heuristic for the global optimization problem of applied mathematics, namely locating a good approximation to the global minimum of a given function in a large search space. It is often used when the search space is discrete. Peng al. et, (2009) presented a hybrid simulated annealing algorithm for container loading problem with boxes of different sizes and single container for loading. A basic heuristic algorithm is introduced to generate feasible solution from a special structure called packing sequence. The hybrid algorithm uses basic heuristic to encode feasible packing solution as packing sequence, and searches in the encoding space to find an approximated optimal solution.

Tabu search algorithm (TS) is to pursue local search whenever it encounters a local optimum by allowing non-improving moves; cycling back to previously visited solutions is prevented by the use of memories, called tabu lists that record the recent history of the search. Bortfeldt and Gehring, (1998) presented a parallel tabu search algorithm for the container loading problem with a single container to be loaded. The emphasis is on the case of a weakly heterogeneous load. The distributed-parallel approach is based on the concept of multi-search threads. Several search paths are investigated concurrently. The parallel searches are carried out by differently configured instances of a tabu search algorithm, which cooperate by the exchange of (best) solutions at the end of defined search phases. The parallel search processes are executed on a corresponding number of LAN workstations.

Genetic algorithm (GA) are implemented in a computer simulation in which a population of abstract representations called chromosomes of candidate solutions to an optimization problem evolves toward better solutions. The evolution usually starts from a population of randomly generated individuals and happens in generations. In each generation, the fitness of every individual in the population is evaluated multiple individuals are stochastically selected from the current population and modified to form a new population. The new population is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population. Gehring and Bortfeldt, (1997) used GA in solving container loading problem. The main ideas of the approach are first to generate a set of disjunctive box towers and second to arrange the box towers on the floor of the container according to a given optimization criterion. The loading problem may include different practical constraints. The performance of the GA is demonstrated by a numerical test comparing the GA and several other procedures for the container loading problem. The developed GA seems to be suitable for container loading problems where simple stability requirements are sufficient. The method promises high container utilization for problems with both weakly heterogeneous and strongly heterogeneous assortments of boxes. Designed for the latter case, however, the GA performs particularly well for higher numbers of box types. The procedure meets some practical constraints and the required computing times appear to be acceptable with respect to practical requirements.

Parreno et al., (2008) presented a greedy randomized adaptive search procedure (GRASP) for the container loading problem. This approach is based on a constructive block heuristic that builds upon the concept of maximal-space, a non-disjoint representation of the free space in a container. This new algorithm is extensively tested over the complete set of Bischoff and Ratcliff problems, ranging from weakly heterogeneous to strongly heterogeneous cargo, and outperforms all the known non- parallel approaches that, partially or completely, have used this set of test problems. When comparing against parallel algorithms, it is better on average but not for every class of problem. In terms of efficiency, this approach runs in much less computing time than that required by parallel methods. Thorough computational experiments concerning the evaluation of the impact of algorithm design choices and internal parameters on the overall efficiency of this new approach are also presented.

General cargo handling is of special importance because it generally corresponds to most of the costs incurred by the loading and unloading of ships at port. Semih and Canan (2007) studied a model which addresses the loading process of general cargo-type export products. The theoretical structure of a general port optimization model is described, and an optimization model is applied to a general cargo port located at the Marmara Sea in Turkey as a real-world case study. The main objective of this study is to display the methodology for increasing the ship loading rate. The present ship loading rate is measured as a baseline, and the factors that affect the baseline loading performance are identified. Simulation and statistical techniques such as hypothesis tests and correlation analyses are used to optimize equipment and verify variables. The problem was solved with minimal spanning tree and dynamic programming models. These models are integrated with fuzzy methods to tackle uncertainties in the data. The results of the models are compared, and sensitivity analysis is applied to each mathematical model.

Marine ports always play a strategic role in the development of domestic and international trade. Port-generated economic activities include shipping and related enterprises, trade services, and inland transportation, and cargo and ship activities. Since goods can arrive in different forms such as dry and liquid bulk cargo, containers, general cargo, and so on, cargo handling in ports is a major activity of transport operations. Among those activities, general cargo handling is of special importance because it generally corresponds to the highest costs incurred by ship loading and unloading at port. There are many studies related to the management of the port operations mentioned above. Lee et al., (2008) presented a model and applied the framework of supply chain modeling and analysis to the port industry supply chain by using a simulation approach.

Cargo loading is an NP-hard problem that regards various constraints, such as cargo volume, weight, compartment space, centre of gravity, and load sequence. Current load planning studies fail to consider numerous practical requirements, such as visualized data presentation, cargo-loading prioritization, complexity of mathematical models, and no-cost analysis. Cargo load planning is critical to transport carriers, especially for an industry heavily influenced by increasing fuel prices and costs. Improving cargo loading efficiency can result in several benefits: a reduced number of transport trips, lower transportation costs, improved energy efficiency, and a boost in customer satisfaction. A large number of researchers have developed computer programs to handle complex calculations. However, the resulting parameters and calculations are still difficult to apply. Therefore, from a practical viewpoint, simple parameter settings, optimized computations, easily understandable results, and the generation of relevant work reports are essential for the logistic industry.

Chen and Huang (2004) studied a model that uses AutoLoad Pro to assist transport carriers in planning their cargo loading operations. AutoLoad Pro is a container loading software optimized through a simulated annealing algorithm and tabu search technique, designed to solve a two-stages loading problem: Item-Pallet and Pallet-Container. AutoLoad Pro can simultaneously generate loading and unloading reports, along with a 3D visualized representation of loading results, and can concurrently process shipment characteristic information: shape, size, weight, and load sequence. Concerning sea, land, and air transportation, AutoLoad Pro has provided a decisive reference for load planning operations.

A container is defined as a large receptacle in which goods are held for transport from one place to another. A cargo loading problem can be defined as the effective storing of cargoes during the transport process. Bortfeldt and Gehring (2001) studied logistics applications, a cargo loading problem as a three-dimensional stacking problem.

In relevant research, Wu (2010) put forward a cargo loading problems as a rectangular packing problem and transportation methods (freight by sea or air), with the chief objective to use a minimum number of cartons to pack a limited number of items, involving a number of practical constraints, such as weight, centre of gravity, irregular shape, and loading priority.

Bischoff and Ratcliff (1995) studied a model and indicated that the limiting elements in seaborne container loading problems include the restriction of direction, load stability, handling restrictions, and isolation of goods.

Davis and Bischoff (1999) presented a cargo loading problem and proposed that solutions to the problem should be considered for container weight distribution and space utilization.

Bortfeldt and Gehring (2001) presented a cargo loading problem and proposed a hybrid genetic algorithm be used to solve the problem of loads of different carton sizes.

Vis and Koster (2003) reviewed literature regarding decision making on transiting seaborne containers, including the loading/unloading process, container mobile facility and vehicles, and multimodal transport.

Bischoff (2006) studied a cargo loading problem and recommended the use of heuristic algorithms to generate placement rules ensuring that the goods are not crushed during stacking when the bearing capacities of goods vary.

Gehring and Bortfeldt (2002) presented a cargo loading model that considered limited directions of placement of each goods and limited space inside the container during load planning.

Wu (2010) recommended the use of a mixed integer programming model for loading in bi-directional air cargo booking and pallet of goods distribution, with the first stage determining the type and the number of pallets for the booking, and the second stage planning the required pallet type, quantity, and cargo loading under various circumstances. The results showed that this randomized model could provide a cost effective, flexible, and responsive cargo shipping system.

Chan et al., (2006) proposed a two-stage decision support system for a two stage air cargo loading plan. Since air pallets have different shape and size specifications, they belong to a three-dimensional bin-packing problem. Thus, the first stage involved the use of linear planning to determine the lower limit for the overall cost of the pallet relative to weight and quantity. The second stage involved the creation of a loading plan for each pallet.

Yan et al., (2008) developed a stochastic demand cargo container loading plan model for the air express industry. The model belongs to a class of non-linear mixed integer programming problems designed to minimize total operation costs of pallet management under associated operational limits. The aforementioned studies reveal that practical programming or algorithm based mathematical models used to solve loading problems when considering realistic load limits yield results that are often difficult for operators to understand during stacking prioritization, due to calculations being too complex. Moreover, few studies have used information software systems to address practical loading problems, resulting in loading problems remaining at the academic research stage. This study focused on AutoLoad Pro software with a simulated annealing algorithm and tabu search technique designed to support truck loading plans, sea and air container loading plans, wooden box and carton box loading plans, pallets, containers, and air pallets stacking plans.

In recent years, there has been a strong demand for fast and reliable door-to-door pickup and delivery services. International air express carrier service networks thus have grown rapidly, making the markets very competitive for the carriers. Davidson et al., (2010) developed a stochastic-demand cargo container loading plan model with the objective of minimizing the total operating cost, subject to the related operating constraints. The model is formulated as a nonlinear mixed integer program that is characterized as NP-hard. The authors employed a problem linearization technique, coupled with a mathematical programming solver, to develop a solution method. To preliminarily evaluate the model and the solution method, we perform a case study using data from an international air express carrier. The results showed that the model and the solution method could be useful for air express carriers.

Reinaldo et al., (2010) studied the application of an optimization model to solve problems of arranging products (packed in boxes) on pallets, and arranging loaded pallets on trucks. Initially the model is applied to solve thousands of randomly generated experiments. Then, in order to assess the effectiveness of the solutions in practice, the model is applied to two Brazilian case studies: a food company distribution centre and a large wholesale distribution centre. The authors also discussed the use of this approach for optimizing the sizes of packages, pallets and trucks. In particular, the authors analyzed the performance of the Brazilian standard pallet (PBR), adopted by the Brazilian Association of Supermarkets (ABRAS) and recommended by the Brazilian Logistics Association (ASLOG), in comparison with other standard pallets. By examining not only the loading of products on pallets, but also the loading of pallets on trucks, we can obtain global utilization indices which are useful to evaluate the economical performance of unit load systems in the logistics chain of a company.

According to the characteristics of multi-variety and freight loading problems with priority, establish target function fully utilizing capacity and cubage of loading tools. Ren and Wang (2009) presented a model for solving this type of problems using an improved hybrid genetic algorithm. The procedure firstly adopts binary code so as to make the problem more succinctly. On the basis of cubage-weight balance algorithm, construct initial solution to improve the feasibility. Retain the best selection so as to guard the diversity of group. Secondly, the study adopts 2- exchange mutation operator, combine hill-climbing algorithm to strengthen the partial searching ability of chromosome. Finally, the example can be shown that the above model and algorithm is effective and they can provide for large-scale ideas to solve practical problems.

Roesener (2006) presented an algorithm to solve the Airlift Loading Problem (ALP). Given a set of cargo to be transported from an aerial port of embarkation to one or more aerial ports of debarkation, the ALP seeks to pack the cargo items onto pallets (if necessary), partition the set of cargo items into aircraft loads, select an efficient and effective set of aircraft from available aircraft, and to place the cargo in allowable positions on those aircraft. The ALP differs from most partitioning and packing problems described in the literature because, in addition to spatial constraints, factors such as allowable cabin load, balance, and temporal restrictions on cargo loading availability and cargo delivery requirements must be considered. While classical methods would be forced to attack such problems in a hierarchical fashion by solving a sequence of related sub-problems, this research develops an algorithm to simultaneously solve the combined problem by employing an advanced tabu search approach.

Cost effectiveness is central to the air freight forwarders. Yanzhi and Tao (2009) presented a study on how an air freight forwarder should plan its cargo loading in order to minimize the total freight cost given a limited number of rented containers. To solve the problem efficiently for practical implementation, the authors proposed a new large-scale neighbourhood search heuristic. The proposed large-scale neighbourhood relaxes the subset-disjoint restriction made in the existing literature; the relaxation risks a possibility of infeasible exchanges while at the same time it avoids the potentially large amount of checking effort required to enforce the subset-disjoint restriction. An efficient procedure is then used to search for improvement in the neighbourhood. We have also proposed a sub-problem to address the difficulties caused by the fixed charges. The compromised large-scale neighbourhood (CLSN) search heuristic has shown stably superior performance when compared with the traditional large-scale neighbourhood search and the mixed integer programming model.

In today's competitive logistics business environment, airfreight forwarders need to optimize every aspect of their logistics operations. However, forwarders still heavily rely on human brain and working experiences for calculating complex cargo packing and scheduling problems. Although recent research studies related to cargo packing and scheduling problems have resulted in the development of a number of advanced techniques of cargo planning, it can be seen that most of the research work is focused on the optimization of space in order to achieve the maximum possible amount of cargo to be packed in the minimum of space. After numerous site evaluation and end-user feedbacks, it is found that space optimization does not necessarily cause profit optimization, which is the ultimate aim of logistics providers. A study of contemporary research publications indicates that there are inadequate research studies related to profit-based optimization in cargo packing areas. Lau et al.,(2006) presented a profit-based air cargo loading information system (ACLIS) that embeds an innovative technology known as heuristics iterative reasoning technology (HIRT) that supports loading plan generation, focusing on maximization of the profit margin. In general, the proposed system is meant to maximize the profit in the airfreight forwarding business. It adopts an objective function governed by a list of constraints together with rule-based reasoning to provide expert advice to support the generation of appropriate loading plans.

Tang (2010) presented a solution method for solving air express cargo loading problems under stochastic demands. The method is designed by combining the scenario decomposition and genetic algorithm (GA) techniques. Numerical tests are performed to evaluate the performance of the solution method using data for the Asian operations of an international express carrier. The results show that the solutions obtained from our method are very close to the optimal solutions. Furthermore, our method has an advantage in terms of computation time over the CPLEX optimization algorithm.

Wu (2010) studied air container renting and cargo loading problems experienced by freight forwarding companies. Containers have to be booked in advance, in order to obtain discounted rental rates from airlines; renting or returning containers on the day of shipping will incur a heavy penalty. The authors first proposed a mixed-integer model for the certain problem, in which shipment information is known with certainty, when booking. The authors then presented a two-stage recourse model to handle the uncertainty problem, in which accurate shipment information cannot be obtained when booking, and all cargoes have to be shipped without delay. The first-stage decision is made at the booking stage, to book specific numbers of different types of containers. The second-stage decision is made on the day of shipping, depending on the extent to which the uncertainty has been realized. The decisions include number of additional containers of different types that are required to be rented, or the number of containers to be returned, under the scenario that might occur on the day of shipping. We then extend the recourse model into a robust model for dealing with the situation in which cargoes are allowed to be shipped later. The robust model provides a quantitative method to measure the trade-off between risk and cost. A series of experiments demonstrate the effectiveness of the robust model in dealing with risk and uncertainty.

Real-world distribution problems raise some practical considerations usually not considered in a realistic way in more theoretical studies. One of these considerations is related to the vehicle capacity, not only in terms of cubic meters or weight capacity but also in terms of the cargo physical arrangements. In a distribution scene, two combinatorial optimization problems, the Vehicle Routing Problem with Time Windows and the Container Loading Problem, are inherently related to each other. Moura et al., (1995) presented a model to integrate these two problems using two different resolutions methods. The first one treats the problem in a sequential approach while the second uses a hierarchical approach. In order to test the quality and efficiency of the proposed approaches some test problems were created based on the well-known Solomon, Bischoff and Ratcliff test problems. The results of the integrated approaches are presented and compared with results of the Vehicle Routing Problem with Time Windows and the Container Loading Problem applied separately. Keywords: Vehicle Routing Problem with Time Windows, Container Loading Problem, GRASP. 1.

Mathematical models for the problem of loading rectangular boxes into containers, trucks or railway cars have been proposed in the literature, however, there is a lack of studies which consider realistic constraints that often arise in practice. Leonardo et al., (2010) presented a mixed integer linear programming models for the container loading problem that consider the vertical and horizontal stability of the cargo and the load bearing strength of the cargo (including fragility). The models can also be used for loading rectangular boxes on pallets where the boxes do not need to be arranged in horizontal layers on the pallet. A comprehensive performance analysis using optimization software with 100s of randomly generated instances is presented. The computational results validate the models and show that they are able to handle only problems of a moderate size. However, these models might be useful to motivate future research exploring other solution approaches to solve this problem, such as decomposition methods, relaxation methods, and heuristics, among others.

Nance et al., (2009) presented a new, two-dimensional bin packing algorithm that feasibly loads a set of cargo items on a minimal set of airlift aircraft. The problem under consideration is called the Mixed Payload Airlift Loading Problem (MPALP). The heuristic algorithm, called the Mixed Payload Airlift Loading Problem Tabu Search (MPALPTS), surpasses previous research conducted in this area because, in addition to pure pallet cargo loads, MPALPTS can accommodate rolling stock cargo (i.e. tanks, trucks, HMMMVs, etc) while still maintaining feasibility. To demonstrate its effectiveness, the load plans generated by MPALPTS are directly compared to those generated by the Automated Air Load Planning Software (AALPS) for a given cargo set; AALPS is the load planning software currently mandated for use in all Department of Defense load planning. While more time consuming than AALPS, MPALPTS required the same or fewer aircraft than AALPS in all test scenarios.

Projected cargo airships for the flexible transport of large loads exceed the dimensions of existing aircrafts and gave rise to various technical problems. In order to study the dynamics of the load exchange process Andreas and Kreuzer (2004) presented a mathematical model of the airship including the oscillating load frame are developed. The hull and the load frame are represented by a multi body system. Crucial aspects contributing to the system's dynamics are the floatation of the flying crane and nonlinear couplings between hull and load frame. Furthermore, added masses of the surrounding air are considered. Oscillations of the load frame are excited by wind loads, airship maneuvers, and winding up the cables.

Container loading problem is a kind of space resources optimization problem which consists of various constraints. The solution can be extended to aircraft, cargo loading for ships, even the memory allocation for computer, and other applications. Zhu and Hong (2009) proposed a new algorithm for loading a variety of different goods into a single container with multi-batches. With the concept of "plane" and "block", the algorithm uses "depth priority" strategy to locate for the suitable space. The algorithm also allows goods to rotate in any possible directions, while under the guarantee of efficient space usage, it improves the placement stability. With the priorities of each goods assigned by the algorithm, we should could allocate more goods at the same location. The optimal algorithm is supposed to withdraw when the last batch packing is unsuitable. Experimental results show that the algorithm is effective to solve such problems.

Kristjánsson (2004) studied a model with the objective of defining the load capacities of 40' feet dry cargo containers with and without damage. As the cargo industry demands larger and larger container ships, the containers need to withstand the increasing loads, which they are exposed to, as the container stacks grow higher. In bad weathers, large acceleration of the ship results in high loads on the container stacks, running a risk of them collapsing. This is costly and calls for research so this can be avoided. This project only covers a part of this research. That is documenting the load capacity of the containers. This is done using construction drawings and material data supplied by Maersk Container Industries. The FEM-programme Ansys is used for modelling and solving the problem. Dents are defined on crucial load carrying components of the container, the reduced load capacity is then found. The stacking load capacity of the nondamaged container is found to be 1290 kN on each corner casting. This load capacity decreases to less than 1000 kN when large dents are applied to the corner post. The racking load capacity of the container is found to be 300 kN and is less affected by damage on the main frame of the container. The research shows that the capacity of the container used in this analysis exceeds the strength demands set by the ISO standard and DNV, who both agree on the container strength ratings as 150 kN in stacking mode and 848 kN in racking mode.

Trafficking of newly synthesized cargo through the early secretary pathway defines and maintains the intracellular organization of eukaryotic cells as well as the organization of tissues and organs. The importance of this pathway is underlined by the increasing number of mutations in key components of the ER export machinery that are causative of a diversity of human diseases. Schmidtk and Stephens (2010) presented a molecular mechanisms that dictate cargo selection during vesicle budding. While, in vitro reconstitution assays, unicellular organisms such as budding yeast, and mammalian cell culture still have much to offer in terms of gaining a full understanding of the molecular basis for secretary cargo export, such assays have to date been limited to analysis of smaller, freely diffusible cargoes. The export of large macromolecular complexes from the ER such as collagens (up to 300 nm) or lipoproteins (~500 nm) presents a clear problem in terms of maintaining both selectivity and efficiency of export. It has also become clear that in order to translate our knowledge of the molecular basis for ER export to a full understanding of the implications for normal development and disease progression, the use of metazoan models is essential. Combined, these approaches are now starting to shed light not only on the mechanisms of macromolecular cargo export from the ER but also reveal the implications of failure of this process to human development and disease.

A barge line which accepts various cargos for timely delivery between pairs of ports in its district must determine the routing and timing of movements of barges and towboats to execute the agreed freight movements at minimum fleet cost. Schwartz (1968) presented a linear discrete programming model of this optimization problem. The cargo movements to be made and the times needed for transit, loading, and unloading are assumed known. A solution of the model gives the numbers of barges and towboats of each size required to provide the service, with the consequent minimal cost. It also provides a complete schedule for the barge line, specifying the location and status of the barges, boats, and freight at every time unit of the scheduling period.

Shangyao et al, (2006) studied a cargo container loading plan model based on the operations of FedEx, the international air express carrier. The objective was to minimize total container handling cost, subject to related operating constraints. The model is expected to be a useful planning tool whereby international air express carriers such as FedEx can decide on container loading plans that will lead to lower operating costs, thus enhancing profits and market competitiveness. The model was formulated as a non-linear mixed integer program that is characterized as NP-hard. A solution method is then developed, with the use of the mathematical programming solver, CPLEX, to solve the problem efficiently. To evaluate the model and the solution method, we perform a case study using data from FedEx. The preliminary results indicate that the model and the solution method are both efficient and effective.

More than ever before, the airline industry must manage its operations very carefully if it is to adapt to the changes in its environment. One important planning problem is the scheduling of freight handling employees at air cargo terminals. Indeed, this area is particularly critical for achieving cost reductions while maintaining customer service levels. Yves and Roy (1998) presented a new model and an appropriate solution approach for the work-scheduling problem. In particular, a demand leveling procedure is introduced to take advantage of the flexibility that is often encountered in such problems. Experimental results obtained with actual data from a major airline are also presented.

The delivery problem consists of finding a set of routes for a fleet of capacitated vehicles to satisfy the cargo delivery requirements of customers. The vehicles are located in a central depot, and have to fulfill the delivery requirements in a sequence that minimizes total delivery costs. Each vehicle tour starts and terminates at the central depot, and each node is supplied by exactly one vehicle. All vehicles have the same cargo carrying capacity.

Kemal and Bezalel (1991) presented parallel savings algorithms (PSAs) for generating feasible solutions to this problem. The new algorithms combine the savings approach, with matching based procedures. In computational tests the heuristic produces better solutions than the best known solutions for six problems out of a standard set of 14 difficult test problems. Augmented Lagrangean based lower bounding procedures are developed, and used to evaluate the quality of the solutions generated by PSAs. The lower bounds generated by the augmented Lagrangean are the tightest bounds known for delivery problems. The performance of the PSAs is also compared to tour partitioning based heuristics which have better worst case error bounds. The average quality of solutions generated by PSAs is shown to be significantly superior on large sets of test problems.

Loading design is a key stage in ships' design process, and directly affects ships' stability, strength, and attitude at sea. The problem of loading design is a multi-objective combinatorial optimization problem with multiple nonlinear constraints. Jing et al., (2009), based on the complex technical requirements of ships' loading design, a mathematical model was constructed, taking the overall longitudinal strength and the intact stability performances as objectives, and the limits of ship's attitude, stability and strength, etc. as constraints. A strategy of tanks being fully-loaded-first was adopted and the corresponding improved genetic algorithm was presented where a novel heuristic dynamic adjusting rule was proposed to dynamically adjust the normalizing coefficients of the non-commensurable objectives. Finally, a real case study on the loading design of a 50,000 DWT double hull product tanker was conducted to illustrate the effectiveness of the proposed method.

Chen and Lee (1995) studied the problem of loading containers with cartons of non-uniform size and presented an analytical model to capture the mathematical essence of the problem. The container loading problem is formulated as a zero-one mixed integer programming model. It includes the consideration of multiple containers, multiple carton sizes, carton orientations, and the overlapping of cartons in a container. This model is then extended to formulate some special container loading problems. Numerical examples are used to validate the model.

Since no exact analytical method for solving the three-dimensional cargo-loading problem has been developed, the heuristic approaches with practical assumptions are still useful. A dynamic programming approach to this problem is proposed was proposed by Ching et al., (1989). Loading a three-dimensional cargo space is done layer by layer, a special property which is taken advantage of in the proposed algorithm. The computational performance of this heuristic is demonstrated by comparing its results with suggested values published by the General Services Administration, Washington, DC.

Gould (1971) presented a linear programming model for minimizing the steady state cost of moving cargo carriers over certain routes subject to numerous constraints on both the cargo and carrier movement. There are several types of cargo and carriers, transshipment is allowed, cargo and carriers are linked by capacity constraints, and requirements are specified in terms of movement from a specified origin to a specified destination. The model is fairly general in that it should be applicable to certain types of cargo movement via either air or surface transportation. Studies that can be made by use of the model include (i) cost-effectiveness analyses of policy questions (such as those involving utilization rates and frequency requirements), as well as evaluation of alternatives for (ii) mix of cargo carriers, (iii) best routes for certain carriers, (iv) mix of bases or depots, (v) transshipment policy, and (vi) physical and operating characteristics of carriers.

CHAPTER THREE

METHODOLOGY

3.0 INTRODUCTION

Generally speaking, the cargo loading problem is NP-hard. Therefore, heuristic methods are often used for its solution. The general problem is modelled as:

Maximize Z = $\sum_{i=1}^{M} \sum_{j=1}^{N} PjXij$

Subject to:

$\sum_{i=1}^{M} Xij \leq W_i \quad \forall j$

$\sum_{j=1}^{N} Xij \leq W_j \quad \forall i$

$\sum_{j=1}^{N} VjXij \leq C_i \quad \forall i$

Where;

P : Profit or cost charge of each item

M : number of containers or cargo

N : number of items

W_j : Weight of each item

V_j : Volume of each item

C_i : capacity of each container

Xij : Number of tonnes of cargoes(i) that is put into compartment (j)

This chapter provides an in depth explanation of the simplex algorithm which we shall employ in solving our problem.

In order to understand the value of simplex algorithm in linear programming, it is necessary to have a good understanding of some of the background polyhedral theory for general linear programming problems.

Linear programming problem can be formally stated as:

Maximize: $c^T x$

Subject to: $Ax \leq b$

$x \geq 0.$

Where $A \in R^{n \times m}$, $x \in R^{m}$, $b \in R^{1 \times m}$.

Solving linear programming problem can be difficult and time consuming. A great deal of research has been performed to improve the solving times and ease of linear programming problem. One of the major areas which research has been done in is the polyhedral theory.

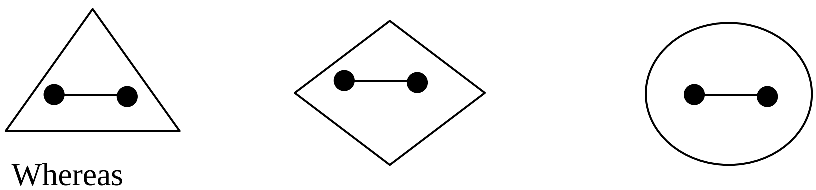
3.1 Polyhedral Theory

Polyhedral theory is an important body of knowledge that helps describe and develop solutions to both linear and integer programming problems. The basic idea behind polyhedral theory is to derive a good linear formulation of the set of solutions by identifying linear inequalities that can be proved to be necessary in the description of the convex hull of feasible solution. The feasible region of any linear programming problem can be represented as a polyhedron, and it is this polyhedron that polyhedral theory seeks to describe. The following basic definitions are noted.

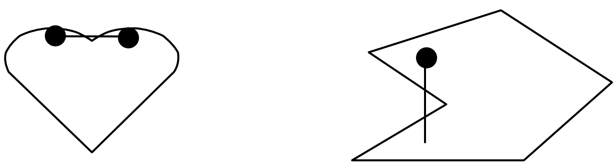
A subset S of R^n ($S \subseteq R^n$), is said to be convex if for any two elements x_1, x_2 in S, the line segment between the two points $[x_1, x_2]$ in S is also contained in S. Thus, a set

$S \subseteq R^n$ is convex if and only if for every $\lambda \in [0, 1]$ and for every point $[x_1, x_2]$ in S,

$\lambda x_1 + (1 - \lambda) x_2 \in S$. We note that in the plane, the following sets are convex



Whereas



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Are not convex, (Amponsah, 2008).

Similarly, given a set $S \subseteq R^n$, the convex hull of S, denoted by conv(S) is defined to be the set of all convex combinations of vectors from S. Thus, conv(S):= $\{S = \sum^{k}_{i=1} \lambda_i v_i : \lambda_i \geq 0, \sum^{k}_{i=1} \lambda_i = 1$ and $\forall_i \in S\}$. In other words if $S \subseteq R^n$, then the convex hull, conv(S), is defined as the intersection of all convex sets that contain S. The convex hull of two points is a line segment.

A half-space is the set of points that satisfy a linear inequality, $\{x \in R^n : a^T x \leq b\}$.

A polyhedron is a finite intersection of half-spaces and hyper planes. In other words, a polyhedron is a set of the form $\{x \in R^n : Ax \geq b\}$, where $A \in R^{nxm}$ and $b \in R^n$.

Clearly, a polyhedron is a convex set. Furthermore, the solution space of a linear programming problem is also a polyhedron.

A polyhedron $X \subset R^n$ is bounded if there exists a constant k such that $|X|\text{-}1 < k\ \forall\ x \in X, \forall\ i \in [1, n]$.

A polytope is defined as a bounded polyhedron.

A hyper plane is a set of points that satisfy a linear inequality at equality point,

$\{x \in R^n : a^T x = b\}$. It is also said to be the intersection of two closed half-spaces.

A line segment joining the points $[x_1, x_2] \in X$ is the set

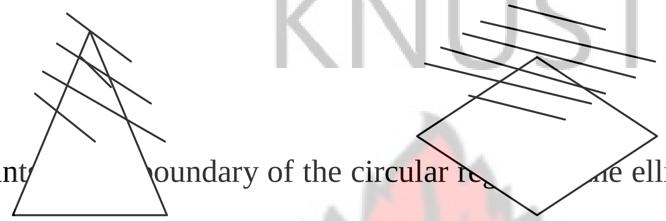
$[x_1, x_2] = \{x \in R^n : x = \lambda x_1 + (1 - \lambda) x_2, \text{ for } 0 \leq \lambda \leq 1\}$.

A point on the line segment for which $0 < \lambda < 1$, is called an interior point of the line segment.

A point x in a non-empty convex set X is said to be an extreme point of X if it is not an interior point of any line segment in X. Thus, x is an extreme point of X if there are no two distinct points x_1, x_2 of X such that $x = \lambda x_1 + (1 - \lambda) x_2,\ 0 < \lambda < 1$.

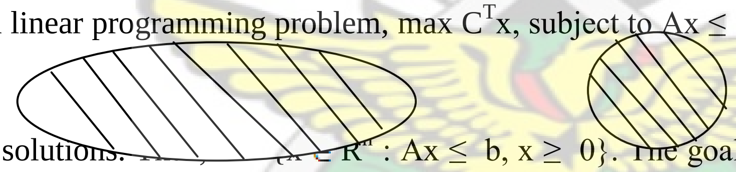
Equivalently, x is an extreme point of X whenever $x = \lambda x_1 + (1 - \lambda) x_2$, for $[x_1, x_2]$ in X, and $0 \leq \lambda \leq 1$, $x_1 = x_2 = x$. Thus, an extreme point of a polyhedron is any point that is not a convex combination of two other points in the set.

We note that in the plane, the only extreme points of the following regions are the vertices



Whereas the point[s on the b]oundary of the circular re[gion and th]e elliptical region shown below are clearly extreme points of the region. They cannot be the interior points of any segment lying in the regions, (Amponsah, 2009).

Given a linear programming problem, max $C^T x$, subject to $Ax \leq b$, $x \geq 0$, let P be the set of all



feasible solutions. ... $\{x \in R^n : Ax \leq b, x \geq 0\}$. The goal of polyhedral theory in linear programming is to completely describe the conv (P), which will be referred to as P^{ch}. The fact that P^{ch} is a polyhedron is vital to linear programming research.

Two types of polyhedron points are also critical to this research. Let $x' \in P^{ch}$, then x' is an extreme point if and only if there does not exist $[x_1, x_2] \in P^{ch}$, $x_1 \neq x_2$, such that $x' = 0.5x_1 + 0.5x_2$. Any point that is not an extreme point is called an inner point. See Nemhauser and Wolsey (1988) for a complete discussion on this topic. It can be observed that the extreme points of P^{ch} are always integer and that an optimal solution to any linear integer programming problem will always occur at an extreme point.

3.2 The Simplex Algorithm

The simplex method is the name given to the solution algorithm for solving linear programming problems developed by George Dantzig in 1947 (Amponsah, 2009). The simplex algorithm was invented in 1947 by George Dantzig. It was intended to create an efficient way to solve linear programming problems and remains the most common way to solve standard maximization problems. The formula allows an individual to reach a goal that includes constraints. It's also used to find a set of real positive numbers that satisfy the linear inequalities in the problem, maximizing the linear function. In addition, the algorithm can determine if there is no solution to the problem.

The Dantzig method is used to solve a number of specific linear programming problems. It works with = inequalities with independent coefficients that are greater than or equal to zero, as long as the inequality is changed to standard form. Most problems that can be expressed in the standard form can be solved with the simplex algorithm if the goal is to maximize the linear expression. Typically, the method works best when there are only a few variables as it can become very inefficient if too many come into play.

A simplex is an n-dimensional convex figure that has exactly n+ 1 extreme point. For example, a simplex in two dimensions is a triangle, and in three dimensions it is a tetrahedron.

The simplex method refers to the idea of moving from one extreme point to another on the convex set that is formed by the constraint set and non-negativity conditions of the linear programming problem. By solution algorithm, we refer to an iterative procedure having fixed computational rules that leads to a solution to the problem in a finite number of steps (i.e., converges to an answer). The simplex method is algebraic in nature and is based upon the Gauss-Jordan elimination procedure. Although the procedure is relatively straightforward, it does require some practice and skill to execute manually. Consequently, in practice, the algorithm is usually programmed and executed on a digital computer. Many computer codes embodying the essence of the simplex method are in existence. The widespread development and use of these codes attests to the importance of linear programming in decision making.

In simplex method, basic solutions are very important since every corner-point solution can be represented as a basic solution. To determine the basic solutions, we first convert the constraint set to a set of linear equalities. This conversion process involves adding dummy variables to the inequalities to change them to equalities. Using the simplex method in solving a linear programming problem, we first sequentially generate a set of basic feasible solutions that correspond to the extreme points of the feasible solution space.

The basic solution to a set of m equations in n variables (n > m) is obtained by setting (n-m) variables equal to zero and solving the resulting system of m equations in m-variables. The m variables are referred to as the basis variable or as the variables in the basis. The variables are referred to as the non-basic variables or as the variables not in the basis. A basic feasible solution is defined as being a basic solution where all n of the basic variables are non-negative (≥ 0). A non-degenerate basic feasible solution is defined as being a basic solution, where all m of the basic variables are greater than zero (≥ 0).

The major steps in the simplex algorithm are as follows:

Step 1: Given the problem formulation with m equalities in n unknowns. Select set of m variables that yield an initial basic feasible solution.

Step 2: Analyze the objective function to see if there is a non-basic variable that is equal to zero in the initial basic feasible solution, but that would improve the value of the objective function if made positive. If no such variable can be found the current basic feasible solution is optimal, and the simplex algorithm stops. If however, such a variable can be found, the simplex algorithm continues to step 3.

Step 3: Using the non-basic variable selected in step2. Determine how large it can become before one of the m variables in the current basic feasible solution becomes zero. Eliminate (drive to zero) this current basic variable and replace (increase to the maximum permissible value) the non-basic variable selected in step 2.

Step 4: Solve the problem using the Gauss-Jordan elimination procedure, for the current m variables. Return to step 2.

Give that a feasible solution exists and that the optimal value of the objective function is finite, the simplex algorithm, as outlined in the preceding steps, will lead to an optimal solution in a finite number of iterations.

3.2.1 The Two-Phase Method

The two-phase method is a way to deal with the artificial variables in the simplex algorithm. The two-phase method first completes a supplementary problem to lower the sum of artificial variables in the problem. After this, the final board is reorganized and a second phase begins, which completes a regular simplex to solve. With the two-phase method, complicated big M calculations are completely avoided because the contribution of the artificial variables to the objective function is considered first. The second phase then reintroduces the decision variables back into the problem to reach optimality.

3.2.2 The Revised Simplex Method

The revised simplex algorithm was designed to order all calculations so no unneeded calculations are made. This version of the algorithm is more efficient for computing solutions as the original simplex method stores all numbers in the tableau, even those that are unnecessary. Although this method begins in the same way as the simplex method, it presents it as many linear algebra computations. The revised version completes all large computations at the beginning of each iteration instead of the end. The revised method is also the form most commonly used by computer software for solving linear programming problems.

The simplex algorithm has been used for over sixty years by linear programming experts to improve efficiency and save time. Despite disadvantages, it is one of the easiest methods to solve standard linear programming problems and find a set of positive real numbers to satisfy many linear inequalities. The method has become a basic tool for experts and has been improved upon numerous times since its creation.

CHAPTER FOUR

DATA COLLECTION AND ANALYSIS

4.0 INTRODUCTION

In this chapter, a computational study of linear programming for solving our cargo loading problem shall be presented.

We shall choose a real life problem in the AGATE transport and distribution services which is a private cargo distribution company in Tema whose main goal is the carriage of goods from a source center to a destination center. The aim is to determine the optimal loading plan in its compartment so that the most valuable cargo is loaded without exceeding the maximum cargo weight. The general practice currently is that the establishments do not have a well structured plan on how to load the goods into the various compartments. Goods are loaded by trial and error basis and at the discretion of the loading personnel's in charge. These methods are faulted, and are basically inefficient as returns are not optimal.

4.1 Data Collection and Analysis

An AETS transport and distribution service which is a private cargo distribution company in Tema has three compartments for storing cargo: front, centre and rear. These compartments have the following limits on both weight and space as shown in Table 4.1 below:

Table 4.1: Limits on weight and space

COMPARTMENT	WEIGHT CAPACITY (TONNES)	SPACE CAPACITY (CUBIC METRES)
Front	10	6800
Centre	16	8700
Rear	8	5300

The data given in Table 4.2 also shows the following four cargoes that are available for transport:

Table 4.2: Cargoes available for transport:

CARGO	WEIGHT (TONNES)	VOLUME (CUBIC METRES/TONNE)	PROFIT (GH₵/TONNE)
C1	18	480	310
C2	15	650	380
C3	23	580	350
C4	12	390	285

Any proportion of these cargoes can be accepted and transported to the destination. The problem here is to determine how much (if any) of each cargo C1, C2, C3 and C4 should be accepted and how to distribute each among the compartments so that the total profit for the transport is maximised.

The problem is modelled as:

$$\text{Maximize } Z = \sum_{i=1}^{M} \sum_{j=1}^{N} PjXij$$

Subject to $$\sum_{i=1}^{M} Xij \leq W_i \quad \forall j$$

$$\sum_{j=1}^{N} Xij \leq W_j \quad \forall i$$

$$\sum_{j=1}^{N} VjXij \leq C_i \quad \forall i$$

Where;

P : Profit or cost charge of each item

M : number of containers or cargo

N : number of items

W_j : Weight of each item

V_j = Volume of each item

C_i : capacity of each container

We need to decide how much of each of the four cargoes to put in each of the three compartments. Hence letting:

x_{ij} be the number of tonnes of cargo i (i=1,2,3,4 for C1, C2, C3 and C4 respectively) that is put into compartment j (j=1 for Front, j=2 for Centre and j=3 for Rear) where x_{ij} >=0 i=1,2,3,4; j=1,2,3

Constraints

- we cannot pack more of each of the four cargoes than we have available

$$x_{11} + x_{12} + x_{13} <= 18$$

$$x_{21} + x_{22} + x_{23} <= 15$$

$$x_{31} + x_{32} + x_{33} <= 23$$

$$x_{41} + x_{42} + x_{43} <= 12$$

- the weight capacity of each compartment must be respected

$$x_{11} + x_{21} + x_{31} + x_{41} <= 10$$

$$x_{12} + x_{22} + x_{32} + x_{42} <= 16$$

$$x_{13} + x_{23} + x_{33} + x_{43} <= 8$$

- the volume (space) capacity of each compartment must be respected

$$480x_{11} + 650x_{21} + 580x_{31} + 390x_{41} <= 6800$$

$$480x_{12} + 650x_{22} + 580x_{32} + 390x_{42} <= 8700$$

$$480x_{13} + 650x_{23} + 580x_{33} + 390x_{43} <= 5300$$

Objective

The objective here is to maximise total profit, thus;

Maximise $310[x_{11}+ x_{12}+x_{13}] + 380[x_{21}+ x_{22}+x_{23}] + 350[x_{31}+ x_{32}+x_{33}] + 285[x_{41}+ x_{42}+x_{43}]$

Now, putting all the above together, our overall model then becomes:

Maximise $310[x_{11}+ x_{12}+x_{13}] + 380[x_{21}+ x_{22}+x_{23}] + 350[x_{31}+ x_{32}+x_{33}] + 285[x_{41}+ x_{42}+x_{43}]$

Subject to $x_{11} + x_{12} + x_{13} <= 18$

$x_{21} + x_{22} + x_{23} <= 15$

$x_{31} + x_{32} + x_{33} <= 23$

$x_{41} + x_{42} + x_{43} <= 12$

$x_{11} + x_{21} + x_{31} + x_{41} <= 10$

$x_{12} + x_{22} + x_{32} + x_{42} <= 16$

$x_{13} + x_{23} + x_{33} + x_{43} <= 8$

$480x_{11} + 650x_{21} + 580x_{31} + 390x_{41} <= 6800$

$480x_{12} + 650x_{22} + 580x_{32} + 390x_{42} <= 8700$

$480x_{13} + 650x_{23} + 580x_{33} + 390x_{43} <= 5300$

The QM software was used for the data analysis and the following computational iterative values were obtained.

At the end of the first iteration, the QM software gave a non-integer solution value of 12151.58. This was as a results of loading seven tonnes of items into the front of cargo two, eight tones of items into the rear of cargo two, three tonnes of items into the front of cargo three, a non-integer value (12.94737) tonnes of items into the centre of cargo three, and a non-integer value (3.052632) tonnes of items into the centre of cargo four.

Since this is a non-integer value, the QM optimizer executes the next iteration.

At the end of this iterative stage, the QM software gave an integer solution value of 12,140. This was as a results of loading two tonnes of items into the centre of cargo one, seven tones of items into the front of cargo two, eight tonnes of items into the rear of cargo two, three tonnes of items into the front of cargo three, twelve tonnes of items into the centre of cargo three, and two tonnes of items into the centre of cargo four.

The QM optimizer executes the next iteration.

At the end of this iterative stage, the QM software gave a non-integer solution value of 12147.69. This was as a results of loading seven tonnes of items into the front of cargo two, eight tones of items into the rear of cargo two, three tonnes of items into the front of cargo three, thirteen tonnes of items into the centre of cargo three, and a non-integer value (2.974359) tonnes of items into the centre of cargo four.

Since this is a non-improving solution, the QM optimizer executes the next iteration.

At the end of this iterative stage, the QM software gave a suboptimal solution value of 12115.42. This was as a results of loading a non-integer value (0.791667) tonnes of items into the centre of cargo one, seven tones of items into the front of cargo two, eight tonnes of items into the rear of cargo two, three tonnes of items into the front of cargo three, thirteen tonnes of items into the centre of cargo three, and two tonnes of items into the centre of cargo four. Since this is not a better solution, the QM optimizer executes the next iteration.

At the end of this iterative stage, an infeasible solution is obtained and it is the final execution stage.

The optimal solution reported is ₵12,140. This means that the company should load two tonnes of items into the centre of cargo one, seven tones of items into the front of cargo two, eight tonnes of items into the rear of cargo two, three tonnes of items into the front of cargo three, twelve tonnes of items into the centre of cargo three, and two tonnes of items into the centre of cargo four.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.0 INTRODUCTION

The two principle challenges facing shippers are to satisfy both the customer and the shipper. The customer requires a secure and reliable method of carriage whilst the shipper requires that the space on his vehicle of carriage is fully utilised in order to receive maximum freight.

To achieve compatibility between cargo owners and the owners of the means of transport requires knowledge of the cargo-handling procedures in transport. These procedures are described with reference to major characteristics of commodities and cargoes.

The methods of cargo carriage and packaging must be considered at the very outset of the shipping process. The size and quality of packages must be compatible with the transport technology contemplated, e.g. utilisation of containers depends on positioning packages to avoid empty space. Hence, the considered transformation of commodity to cargo carries significant commercial, operational and economic impact. Space with a container is not just loss of revenue but poses the danger of goods shifting during transit and so sustaining damage.

Basically, packaging performs the following three basic functions, which we may call the three P's of packaging, namely: protection, preservation and presentation.
A package should protect and preserve the contents during storage and transit from the harvesting (for agricultural products), manufacturing (for manufactured goods) or mining (for ore or other mineral products), to the consuming centre. Protection is required not only against loss, damage and pilferage, but also, depending on the nature of the contents, against moisture entering or leaving the package, high or low temperatures, light, gases, insect infestation, contamination and other natural hazards.

Our research focused on the cargo loading problem of a distribution company in Ghana. It can however be applied to any situation that can be modeled as such.

5.1 CONCLUSIONS

This study seeks to solve a real-life problem of a Company in Ghana by modeling it as a cargo loading problem. The optimal solution reported was ₵12,140. This means that the company should load two tonnes of items into the centre of cargo one, seven tones of items into the front of cargo two, eight tonnes of items into the rear of cargo two, three tonnes of items into the front of cargo three, twelve tonnes of items into the centre of cargo three, and two tonnes of items into the centre of cargo four.

Currently, as at the time of this work, there is no such method for determining what items should be loaded into which compartment of the cargo. The items are loaded into the compartments of the cargos by the discretion of the people in charge.

This put undue pressure on the cars that are used for the services, and also pose a serious threat to road users.

5.2 RECOMMENDATIONS

The use of computer application in computation gives a systematic and transparent solution as compared with an arbitrary method. Using the more scientific Cargo Loading problem model for the company's cargo loading problem gives a better result. Management may benefit from the proposed approach for its cargo loading to guarantee optimal returns. We therefore recommend that the cargo loading problem model should be adopted by the company for cargo loading planning.

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