MATHEMATICAL MODEL TO REDUCE THE LEAD TIME AT WORKSTATIONS

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ABSTRACT

In the modern's era, the efficiency in workstations assembly line (AL) of manufacturing industry is very crucial and important in dealing with the customers and market demand. In addition, the automotive industry is one of the most important industries in the world nowadays. The automotive manufacturing industries have many shops and workstations. Each workstation has a number of operations including tasks that delegated. The operations and task is depend on the assemble product on body car. One of these shops is Assembly line shop. The scope of this study is focusing on the Assembly Line Shop (ALS) in the Automotive Assembly Line. The problems that occur in the assembly line shop concern queuing and idle time that will directly affect to the lead time between workstations. In this study, it discusses about to minimize the lead time at assembly line and to maximize the process time at workstations by using mathematical model. A mathematical model was applied to maximize the process time all operations in all workstations at the same time and to reduce the lead time in transferring the car structure and part between stations during assemble. The result showed that saving time and ensuring maximum production can increase profits in the automobile manufacturing industry. The time frame covered is one year it is in the year of 2013. This study is conducted by using the mathematical model and using MATLAB software to solve it.

Keywords: Lead Time, Queuing Time, Idle Time, Cycle Time, Mathematical Model, MATLAB Software, Assembly Line.

ABSTRAK

Dalam era moden ini , kecekapan selaras stesen kerja pemasangan (AL) industri pembuatan adalah sangat penting dan penting dalam berurusan dengan para pelanggan dan permintaan pasaran. Di samping itu, industri automotif adalah salah satu industri yang paling penting di dunia pada masa kini. Industri pembuatan automotif mempunyai banyak kedai-kedai dan stesen kerja. Setiap stesen kerja mempunyai beberapa operasi termasuk tugas-tugas yang diwakilkan itu. Operasi dan tugas adalah bergantung kepada produk memasang pada kereta badan. Salah satu kedai ini adalah Perhimpunan kedai talian. Skop kajian ini memberi tumpuan kepada Line Shop Perhimpunan (ALS) dalam Dewan Line Automotif. Masalah-masalah yang berlaku dalam kebimbangan kedai barisan pemasangan beratur dan masa terbiar yang akan memberi kesan secara langsung ke semasa utama antara stesen kerja. Dalam kajian ini, ia membincangkan mengenai untuk mengurangkan masa yang memimpin di barisan pemasangan dan memaksimumkan masa proses pada stesen kerja dengan menggunakan model matematik. Model matematik telah digunakan untuk memaksimumkan masa proses semua operasi di semua stesen kerja pada masa yang sama dan untuk mengurangkan masa yang utama dalam memindahkan struktur kereta dan bahagian di antara stesen semasa berhimpun. Hasilnya menunjukkan bahawa terdapat penjimatan masa dan memastikan pengeluaran maksimum boleh meningkatkan keuntungan dalam industri pembuatan kereta . Masa bingkai dilindungi adalah satu tahun ia adalah pada tahun 2013. Kajian ini dijalankan dengan menggunakan model matematik dan menggunakan perisian MATLAB untuk menyelesaikannya.

Kata kunci: Masa Tunggu, Masa Giliran, Masa Menunggu, Masa Kitaran, Model Matematik, MATLAB Perisian, Barisan Pemasangan.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

In the modern's era, the efficiency in workstations assembly line (AL) of manufacturing industry is very crucial and important in dealing with the customers and market demand. This is because the products that have been produce by the manufacturing industry is really need by the people nowadays. Furthermore, when the operation at workstations assembly line (AL) of manufacturing industry is efficiency can directly produce better productivity in a short time and operation not facing with the problem during the production.

In industrial, production the raw materials or product are change into finished good or finished products. The finished product is use by manufacturing company to create new product or transform new product and them to sell to customers or user. As the result, the manufacturing industry will fulfil the needs and demand of the market in the challenging era nowadays. In addition, Production department is the most important in producing the end product. In the department, the most important is assembly line. According to the Free Dictionary webpage, AL is define as an arrangement of tools, machines and workers in which a product is assembled in a particular sequence as it is moved along a direct line or route(Amer, 1910-15).

Whitney began using the assembly line to manufacture muskets that had interchangeable parts. Besides that, it was designed to manufacture products at production rates in the shortest lead time, cheaply and with the quality required as well as in the most productive way. On product production at assembly line, the product typically moves via automated means such as conveyor, through a series of workstations until completed.

The good assembly line operations it will optimize the production during the manufacturing processes in their assembly lines and directly will reduce the lead time, cost and errors in production of the company. Although the manufacturing company have greater production or profit to the company sometimes there are some problems in their production process for example in workstation assembly line. This problem will cause unbalancing time of assembly line.

In addition, assembly line balancing plays an increasingly important role in manufacturing industry. The problems that affected the assembly line such as longer lead time, idle time, queuing time, bottleneck and others. In order to maximize the profit, the company have to maximum the production of the company. There is a link between the lead time and the productivity. In order to improve productivity, we must first figure out how to reduce the lead time. If we can reduce the lead time at workstations of assembly line it will directly reduce the lead time that customer needs.

In industry, lead time reduction is an important. Operation or the lead times are not always known accurately. Manufacturing lead time is the amount of time between the placement of an order and the receipt of the order by the customer. In addition, lead time also includes a number of different components of the manufacturing process and can be predicted by a manufacturer with established systems in place for handling orders.

On other word lead time is purchasing systems, for an example the time between placing an order and receiving it like in production systems, the time wait, and movement of product, queue of product, setup, and run times for each component produced. Other problems that related with lead time in production line such as unbalance workload, unbalancing cycle time and queuing.

As we know, lead time is time to be the lengths of time from the release of the order to production to its completion as a finished product but in this study will be focus on minimize the lead time at workstation of AL and maximize the process time at workstation by using mathematical model of linear programming.

Meanwhile, to reduce the lead time at workstations of AL is quietly difficult because it have several problems that company should overcome. Furthermore, longer lead time problems in assembly line have been recognized as most important problems to manufacturing company because this problem will affect directly to company productions and profit.

In addition, the problem that related with longer lead time at workstations of AL is queuing and idle time. This problem is the biggest challenge that company will have. For example, if the customer orders the product, at the production of assembly line has the problem with this queuing and idles, so it will directly affect to the lead time. It will make the lead time become more longer.

This study will focus to minimize the lead time at workstations AL and to maximize the process time at workstations by using mathematical model of linear programming. In addition, software MATLAB will be used to solve the problems with the linear programming. Linear programming is applied to minimize the cost of the production in AL and to maximize the company profit.

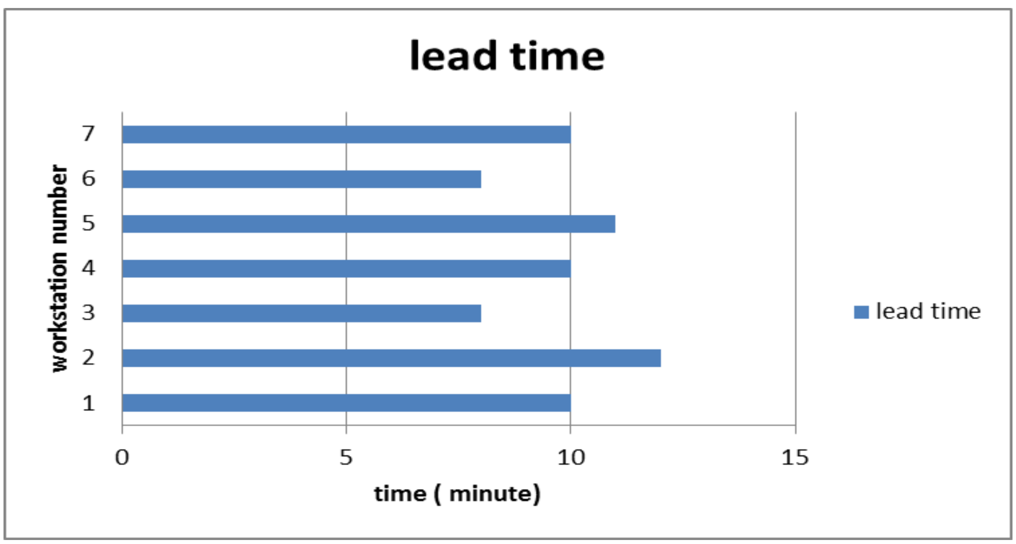

Figure 1.1: An illustration of lead time of each workstation at AL.

Figure 1.1 shows an illustration of the lead time of each workstation at AL. Each workstation has their own lead time require finishing assembly the product before move on to next workstation. For example, workstation no 1 has 10 minutes length of lead time require before goes to next workstation.

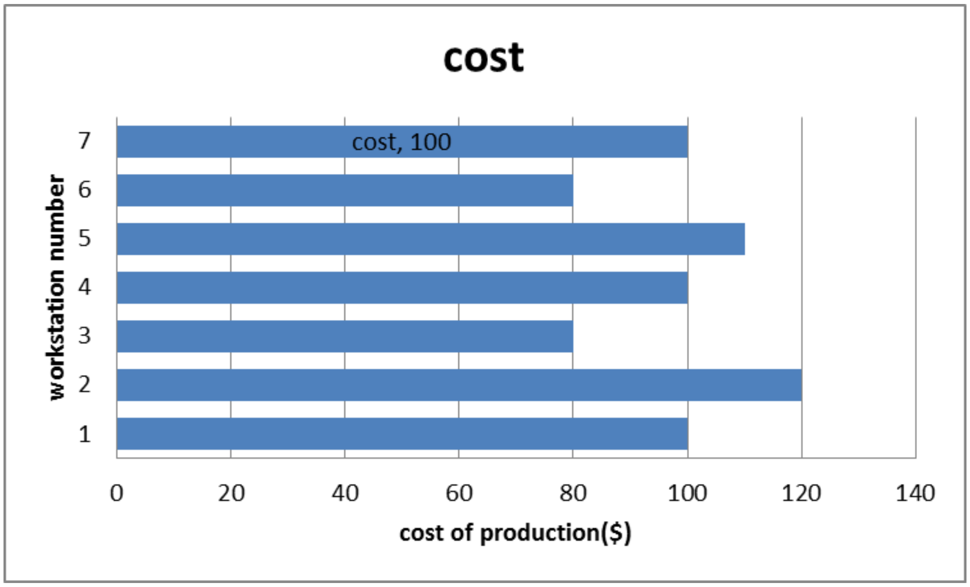

Figure 1.2: An illustration of cost at each workstation at AL.

Figure 1.2 shows the graph of cost of production at every workstation of AL. Manufacturing has to minimize the cost with the short lead time. For example at workstation 1 has 10 minutes length of lead time require while workstation no 2 has 13 minutes length of lead time so the cost of production for the workstation 1 is $100 lower that workstation 2 that have $120. When the short lead time at assembly line of workstation the cost of production will decrease while the longer the length of lead time it will directly affect to the increasing of the production cost. When company want to maximum the profit it should reduce the longer lead time at the production.

Last decade, manufacturing strategies have developed and focused on short lead time to win customer orders. In AL the products are often complex assemblies with many stage of workstation. In addition, this workstation will have several task regarding their component that need to assemble. Each product consists of a number of separate raw parts, which should be processed and assembled to each other.

Every each separate part of the product enters the production system according to a process and goes to the first stage workstation in its routing sequence of manufacturing operations. In addition, company want to providing competitive delivery lead times and managing to achieve a reliable delivery performance are typically as important as competitive prices for them.

When company want to maximum the profit it should reduce the longer lead time at the assembly line production to make the assembly line balancing. When the processes at workstation at assembly line are faster without problem such as longer lead time that consist of problem queuing and idle time it will give more available in this given period of lead time to produce more output (P. Kuhlang et al, (2011).

In addition, when mathematical model of linear programming is used in this study maybe the company will use this mathematical model of linear programming to minimize the lead time and maximize the process time in the workstation at AL and directly can generate more profit and reduce cost in their company production.

1.2 PROBLEM BACKGROUND

Nowadays, every company in the world are now competing against time. In addition, time-based competition involves in reducing of the time required to develop and produce products to meet the customers' highly demand (Bower and Hount, 1988). In other meaning, it means that the focus of processing time along the production process is always crucial in improving the productivity.

In today's highly competitive global marketplace, customers will quickly drop any manufacturer company that can't fulfil their demand or order. Furthermore, fierce levels of competition are forcing manufacturers to continually strive for an advantage. In manufacturing company, sometimes customer order can't be fulfil with according their lead time. In assembly line the products are often complex assemblies with many stage of workstation. In assembly line there are problem with the queuing and idle time at workstation. So this problem will directly effect to the workstation lead time.

In addition, when they have problem with the lead time at workstation such as queuing and idle time, it totally will affect the AL in production rate and cost of production will increase.

Table 1.1: lead time (minute) at workstations AL**.**

Lead time (minute)	10	12	8	10	11	8	10
Workstations (number)	1	2	3	4	5	6	7

Table 1.1 shows the problem with the lead time at workstation at AL. There are difference lead times at difference workstation. At workstation 1 have 10 minutes lead time while at workstation 2 have 12 minutes lead time and so on with the workstation 3,4,5,6 and 7 that have 8, 10,11,8 and 10 minutes of lead time required. The problem is the workstation 4 will have a queuing time because the time taken or the lead time at workstation 3 is less than workstation 4 so it will cause the longer lead time at workstation 4. While at workstation 6 it will cause idle time because the lead time at that workstation is less than workstation 5. As known, idle time is a waiting time. So it will cause the longer lead time. It will affect to the AL production and creates unbalancing AL. In addition, to get the optimal solutions, as well as improving the ability of workstation at AL with the high production rate, the lead time should be reduced (Razman and Ali, 2010).

Manufacturing company must reduce the lead time to avoid from problem with AL at production. A short lead time through a process chain will results in a higher output therefore in higher productivity will increases the overall added value with this given period output (P. Kuhlang et al (2011).

1.3 PROBLEM STATEMENT

Lead time problem among the workstations in AL is one of the most important stages in manufacturing. It will directly cause to unbalancing production line. These lead time problems at workstation consist of queuing and idle time. In addition, this lead time problem will cause the longer times and slowly to generate profit in production. Most of the company wants to achieve the optimum solution in their assembly line's production to maximize profit and minimize cost. Due to longer lead time, cost of the production and time to produce finished product will increase.

1.4 RESEARCH OBJECTIVE

1. To minimize the lead time at the workstations in the Assembly Line

2. To maximize the process time at workstations.

3. To develop the mathematical model to achieve the industry target.

1.5 OPERATIONAL DEFINITION

1.5.1 Cycle Time

Cycle time is used in differentiating total duration of a process from its run time. Cycle time is the total time from the beginning to the end of the process and the period required to complete one cycle of an operation; or to complete a function, task or job from start to finish. In addition, Cycle time includes process time, such as a unit is acted upon to bring it closer to an output, and the delay time, during which a unit of work is spent waiting to take the next action.

1.5.2 Assembly Line

Assembly Line (AL) is an arrangement of operators, machines and equipment in which the product being assembled passes consecutively from operation to operation until. It is also called production line and also consist of several workstations.

1.5.3 Mathematical Model

A mathematical model is a description of a system using mathematical concepts and used mathematical language in order to describe the behaviour of a system. It also using in any particularly in science and engineering fields like as physics, and electrical engineering. In addition, social sciences such as economics, sociology, engineers, also use this mathematical model most extensively. Eykhoff (1974) defined a mathematical model as 'a representation of the essential aspects of an existing system (or a system to be constructed) which presents knowledge of that system in usable form.

Mathematical models are in many forms, including but not limited to differential equations, dynamical systems, statistical models or game theoretic models. The purpose of this mathematical model is to find an optimal solution to a planning or decision problem. Furthermore, it also used to answer a variety of what-if questions. Other than that, it also used to establish understandings of the relationships among the input data items within a model and to attempt to extrapolate past data to derive meaning. In addition, this linear programming consists of a single objective function, where it representing either a cost to be minimized, or a profit to be maximized and a set of constraints that circumscribe the decision variables such as subject to linear equality and linear inequality constraints.

Mathematical model such as linear programming is use in this research to reduce the lead time in assembly line. Linear programming (LP or linear optimization) is a mathematical method use to determining a way to achieve the best outcome such as maximum profit or lowest cost in a given mathematical model for some list of requirements represented as linear relationships. Furthermore, linear programming is a specific case of mathematical programming (mathematical optimization).

1.6 SCOPE

The area of this study will be focused on to reduce the lead time at workstation of AL at DRB-Hicom (Mercedes Benz). AL is process that has been used in automotive manufacturer. Besides that, all of the details information on the production line such as process flow of workstations, cycle time of workstations, no of workers and others data will be collected and analysed. The target area to conduct this study will be done at DRB HICOM Company that located at Pekan, Pahang Darul Makmur.

1.7 SIGNIFICANCE OF STUDY

The effective lead time in assembly line is so important to manufacturing company to full fill what the demand from their customer or order because good or shorter the lead time will make the customer knows when to expect the product. It is very important to company to reduce their lead time to become balancing in assembly line to increase their maximum optimal solution of profit or income. This study can help those lead time researchers to deliver the information or message to the company which is where the lacking or error happened in the process flow. In addition, they can also propose the idea to make changes to the process flow with the mathematical modelling. The result from the mathematical modelling can come out with explanation on what should the firms to take the next action.

Furthermore, this study can also remind the company about the importance of lead time of their product to generate a higher profit in the automotive industry. In addition, according to Carlson, 1994; Vesey, 1991, 1992 to keep up with competition and continue to grow in the face of shorter product life cycles, company are being driven not just to get products to market as announced, but to move more products to market faster.

If mathematical model of linear programming is use maybe the DRB-Hicom company will use this mathematical model to minimize the lead time in the Assembly Line (AL) and maximize the process time at workstation that will directly can generate more profit and reduce the cost of production in their company.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, it shows about the model, literature review, exploration and information gathered which will help to have a better understanding about the study. The information is gathered are from reference book, journal and thesis. In term of literature review, ‘the literatures ‘have referred to the work that consulted in order to understand and investigate the research problem. According to Fink, A (1998), a systematics method is for evaluating, identifying and interpreting the work that have been produced by researchers, scholars and practitioners. While Wiersma (2000), states that literature review is a systematic process that requires careful and perceptive reading and attention in detail for the research. This section are concern mainly on certain knowledge which is directly related to the study to reduce the lead time in improving the productivity of workstation in assembly line with the use of mathematical model of linear programming. This area is being discussed in order to understand the purpose of this study more clearly.

In addition, some researchers did not pay attention to the lead time, because they thought it did not have a significant effect on the productivity of the production line. Furthermore, the losing of time between workstations will affect the productivity if the number of stations is increased.

2.2 MATHEMATICAL MODEL

A mathematical model is a description of a system using mathematical concepts and used mathematical language in order to describe the behaviour of a system. It also using in any particularly in science and engineering fields like as physics, and electrical engineering. In addition, social sciences such as economics, sociology, engineers, also use this mathematical model most extensively. Eykhoff (1974) defined a mathematical model as 'a representation of the essential aspects of an existing system (or a system to be constructed) which presents knowledge of that system in usable form.

Mathematical models are in many forms, including but not limited to dynamical systems, differential equations, statistical models or game theoretic models. The purpose of this mathematical model is to find an optimal solution to a planning or decision problem. Furthermore, it also used to answer a variety of what-if questions. Other than that, it also used to establish understandings of the relationships among the input data items within a model and to attempt to extrapolate past data to derive meaning. Mathematical model such as linear programming is use in this research to minimize the lead time in workstations AL. Linear programming (LP or linear optimization) is a mathematical method use to determining a way to achieve the best outcome such as maximum profit or lowest cost in a given mathematical model for some list of requirements represented as linear relationships. In addition, linear programming is a specific case of mathematical programming (mathematical optimization). This linear programming consists of a single objective function, where it representing either a profit to be maximized or a cost of production to be minimized, and also a set of constraints that circumscribe the decision variables such as subject to linear equality and linear inequality constraints.

2.2.1 Overview On Study Of The Mathematical Model

In the study of Nazanin shabani & Taraneh sowlati (2013) they developed the mathematical model to determine the material flow, transportation, storage and chipping location of energy systems, mainly heating plants. In the performance of evaluation of the study, they have mentioned that to improve the cost competitiveness of forest biomass for electricity generation, they use the mathematical programming model. Therefore, they have proposed that this mathematical model was developed to minimize the procurement and transportation cost and maximizes the biomass quality for biomass power plant and to manages and optimizes its supply chain. The first priority was given to procurement; the second priority was given to distance of procurement, and the third priority was given to biomass moisture content. Their single time-step model optimized the amount of each individual biomass type, including harvesting residues and poplar trees from different harvesting zones.

On the other hand, in the study of Amir Musa Abazari & Maghsud Solimanpur, (2012) they developed the mathematical model to solve the problem with machine loading problem in a flexible manufacturing system (FMS) encompasses various types of flexibility aspects pertaining to part selection and operation assignments. The evolution of flexible manufacturing systems offers great potential for increasing flexibility by ensuring both cost-effectiveness and customized manufacturing at the same time. They develop this linear mathematical programming model with both continuous and zero-one variables for job selection and operation allocation problems in an FMS to maximize profitability and utilization of system. The proposed model assigns operations to different machines considering capacity of machines, batch-sizes, processing time of operations, machine costs, tool requirements, and capacity of tool magazine. A genetic algorithm (GA) is then proposed to solve the formulated problem.

In addition, in the study of Aiying Rong et al., (2000) they develop a mathematical model, based on the just-in-time (JIT) idea, for solving machine conflicts in steel making-continuous casting (SCC) production scheduling in the computer integrated manufacturing system (CIMS) environment. In the performance of evaluation of the study they have developed model as a non-linear model based on actual production situations, considering both punctual delivery and production operation to going continuity. An example demonstrating the application of the proposed method is given. Therefore, Aiying Rong et al, (2000) also describes the implementation of an SCC production scheduling system in which the proposed model is used as an effective method to optimize production continuity and product delivery while eliminating machine conflicts.

According to Odd Inge Forsberg & Atle G. Guttormsen (2006) the most important visual quality characteristic of Atlantic salmon is the red or pink flesh colour. The primary source of this coloration in salmon is caused by the deposition of relatively large amounts of the pigments, such as astaxanthin that obtained from their diet. In addition Astaxanthin is more expensive, and in commercial farming practice, dietary colour pigments comprises about 15–20% of the total feed cost. The important operational process in commercial fish farms is therefore to minimize the pigment costs. In addition, based on recent models on the effects of dietary pigment concentration and fish size on visual colour perception of Atlantic salmon, in the study of Odd Inge Forsberg & Atle G. Guttormsen (2006) has built a mathematical programming model designed to optimize dietary astaxanthin concentrations throughout the grow-out period that results in well-pigmented fish at minimum cost. They have applied a mixed-integer non-linear programming algorithm to solve the problem. Other than that, various managerial implications of applying optimization models in product quality management of farmed salmon are discussed.

On the other hand, this author M. Arriaza & J.A. Gómez-Limón (2003) have done study to compares the predictive performance of mathematical programming models. By using the yields, cropping patterns and crop gross margins of 18 farms over a period of 5 years, they compare the models' optimum solutions with observed crop distributions after the Reform of the EU Common Agricultural Policy of 1992 and the results show that the best prediction corresponds to a model that includes expected profit and qualitative measure of crop riskiness. In the study shows that, in order to obtain the reliable predictions the modelling of farmers that responses to policy changes must consider the risk associated with any given cropping pattern. Finally, they test the ability of the proposed model to reproduce the farmers' observed behaviour with equally good performance under conditions of limited data availability.

Besides that, J.J. Glen & R. Tipper (2001) have study the problem in some semi-subsistence of agriculture systems, a long fallows have traditionally been used to maintain soil fertility, but in fallow periods are often shortened because of increased pressure on land, resulting in reduced crop yields. Furthermore, in such cases crop yields can often be increased by adopting agricultural methods based on the use of fertilisers, new crop varieties and herbicides. These will make an improved cultivation techniques must be introduced over a years, but the transition process has received with little attention in evaluating improvement of semi subsistence cultivation systems.

In this paper J.J. Glen & R. Tipper (2001) has developed a mathematical programming approach for planning the introduction of improved cultivation systems in a semi-subsistence farm in northern Chiapas, Mexico. In this new approach first uses a linear programming model to determine capital dependent steady state cultivation policies and the results from this steady model are then incorporated into a multi period mixed integer programming model for determining steady state policy and the associated improvement plan.

2.3 LINEAR PROGRAMMING

Linear programming (LP or linear optimization) is a mathematical method for determining a way to achieve the best outcome (such as maximum profit or lowest cost) in a given mathematical model for some list of requirements represented as linear relationships. Linear programming is a specific case of mathematical programming. Many operation management decisions involving making most effective use of organization resources can be resolved by applying linear programming techniques. Linear programming is a widely used mathematical technique designed to help in planning and decision making relative to the trade-off necessary to allocate resources (Joseph, 1987).

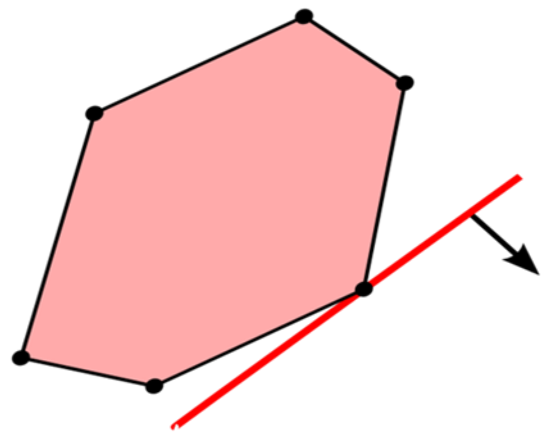

Figure 2.1: An illustration of simple linear programming forms a 2- dimensional polytypic

Figure 2.1 shows a simple linear programme with two variables and six inequalities. The set of feasible solutions is depicted in light red and forms a 2-dimensional polytypic. Then the linear cost function is represented by the red line and the arrow: The red line is a level set of the cost function, and the arrow indicates the direction in which we are optimizing.

In addition, linear programming is a technique for the optimization of a linear objective function, subject to linear equality and linear inequality constraints. On the other hand, its feasible region is a convex polyhedron, which is a set defined as the intersection of finitely many half spaces and each of which is defined by a linear inequality. Furthermore, its objective function is a real-valued affine function defined on this polyhedron. A linear programming algorithm finds a point in the polyhedron where this function has the smallest or largest value if such a point exists.

2.3.1 Overview On Study Of Linear Programming

This author Ahmad A. Moreb (1996), have done the study about problem of cost of earthwork involved in road construction can vary widely based on the roadway grades chosen by the designer. There is almost an infinite number of feasible grades available to the designer to choose from all of which satisfy the geometric specification of the road. Then for every feasible grade selected, a transportation problem must be solved which is a very tedious task. The roadway grade selection is usually considered as a stage and the earthwork transportation is at another stage. These two stages have always been treated separately in the literature. This author solve the problem by using the model presented combines the roadway grade selection stage and the earthwork transportation stage in a single linear programming problem, thus guaranteeing global optimality.

This author Pan, P.Q. (1998) have done the study on fundamental concepts in the simplex methodology basis is restricted to being a square matrix of the order exactly equal to the number of rows of the coefficient matrix. For example such as inflexibility might have been the source of too many zero steps taken by the simplex method in solving real-world linear programming problems which are usually highly degenerate. This author solve the problem by generalize the basis to allow the deficient case, characterized as one that has columns fewer than rows of the coefficient matrix. In addition, variations of the primal and dual simplex procedures are then made, and used to form a two phase method based on such a basis, the number of whose columns varies dynamically in the solution process. Then generally speaking the more degenerate a problem to be handled is the fewer columns the basis will have it will make this renders the possibility of efficiently solving highly degenerate problems.

2.4 SIMPLEX METHOD

Linear programming problems that have more than two variables were too complex for graphical solution. A procedure called the simplex method can be used to find the optimal solution to multivariable problems. Furthermore, the simplex method is actually an algorithm or a set of instructions with which we examine corner points in a methodical fashion until we arrive at the best solution or highest profit or lowest cost.

2.4.1 Overview Of Simplex Method

This author B. Han et al., (2000) have done study on this paper about the Simplex method that is re-examined from the computational viewpoints. In addition, efficient numerical implementation for the Simplex procedure is suggested. Some special features of artificial variables and variables with unrestricting in signs are exploited to reduce the computational efforts, and computer memory requirement. This author solve the problem