A STUDY OF FLIGHT AND MAINTENANCE SCHEDULING FOR THE AIRLINE INDUSTRY

A Thesis

by

ALAA A. ELKODWA

Submitted to the College of the Graduate Studies
Texas A&M University- Kingsville
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 1996

Major subject: Industrial Engineering

UMI Number: 1381508

UMI
300 North Zeeb Road
Ann Arbor, MI 48103

A STUDY OF FLIGHT AND MAINTENANCE SCHEDULING FOR THE AIRLINE INDUSTRY

A Thesis

by

ALAA A. ELKODWA

Approved as to the style and content by:

Kambiz Farahmand, Ph.D., P.E.
(Graduate Coordinator)
(Chairman of Committee)

Robert McLauchlan, Ph.D., P.E.
(Department Chairman)

Yousri Elkassabgi, Ph.D., P.E.
(Member)

Alberto M. Olivares, Ph.D.
Dean of College of Graduate Studies

May 1996

ABSTRACT

A Study of Flight and Maintenance Scheduling for the Airline Industry

May 1996

Alaa Elkodwa B.S., Parks College of Saint Louis University

Chairman of Advisory Committee: Dr. Kambiz Farahmand

With ever growing demand for air travel and improving and expanding of global market, and with the increasing of global population the air travel volume has exploded. During the past few years airline industries have suffered big losses, resulting in job cut and sever blow to the economy. That growing demand will force the entire industry to move toward a more efficient approach to flight and maintenance scheduling. The propose of this study to apply industrial engineering to airline business. Industrial engineering techniques provide the perfect tools for the task at hand. This means using computers and algorithms, or heuristics to determine optimum or near optimum solutions.

ACKNOWLEDGMENT

I Would like to express my sincere gratitude and appreciation to my thesis advisor, Dr. Kambiz Farahmand, for his adoption, supervision, and patience during the undertaken of this thesis. My special thanks go to the Department of Mechanical and Industrial Engineering for helping me to become one of their team.

Also, I wish to appreciate the people that give the time and suggestion while doing this project. Finally to my beloved family for their support throughout my career.

TABLE OF CONTENT

Page

LIST OF FIGURES

Page

LIST OF TABLES

CHAPTER 1

INTRODUCTION

SOUTHWEST AIRLINE

Southwest Airline has been chosen as the focus of this study. The current status of this airline and their operating practices has been analyzed to produce the optimum operating schedule for minimum cost.

A small aviation company started in Texas 242 years ago, South West operates among three local cities as a commercial airlines. It has succeeded and survived the hard days. In 1993 the total loss for the airline industry in U.S. was $1.5 Billion. Southwest airline made a profit of $155 million, Southwest airline kept growing with minimum expenses, and at the same time other airlines were shutting down. As an industrial engineer I will focus on operation research, activity scheduling, and cost analysis.

Southwest airline serves about 38 cities in the continental USA 1565 flights a day, with 156 airplane, that means each plane has to fly 10 flights and operate about 12 hours a day. It spends less time on the ground about 20 minutes between flights VS. the industry's average of 45 minutes. This airline operates through Dallas, Houston, and Phoenix as major stations. Having at least 12 to 15 flight every day between major and minor destination, in a way these flights will cover all of the connections for the cities they serve. This airline saturated the market with high frequency flights over short routes.

1. Southwest operates with one kind of aircraft which is 737- series this airplane is the most fuel efficient, less costly to maintain, and a minimal cost to train the employees in one kind of airplane.
2. No assign seat policy saved the company $25 million in fees and computer cost every year.
3. No plastic boarding cards are used.
4. Not serving meals during the flights.
5. Pay less salaries to its employees.
6. Pilots and flight attendant are paid per hour not per trip.
7. On many routes Southwest fares are so low.

This thesis follows the format used by Ashae Journal.

The following are the statistical data about Southwest revenues and expenses, for 1992 and 1993 fiscal year.

Table 1. Southwest Airline Revenues

	1992	1993
Operating revenues	$1,623,828	$1,991,763
Operating Expenses:		
Salaries & Wages	$521,983	$600,877
Fuel & Oil	$257,481	$273,490
Maintenance	$257,481	$145,715
Commission	$113,504	$132,086
Aircraft rental	$77,472	$83,210
Landing Fees	$105,929	$120,576
Depreciation	$101,976	$113,475
Others	$317,269	$316,000
Net income	$91,000	$157,000

Note: all the values in the above table x 1000

Average profit per passenger is $3.25 in 1992, and $4.75 in 1993, and passenger carried in 1992 were 27839284, and in 1993 are 33508686.

Scheduled flight forecasting models are now being widely used in the analysis of the traffic impacts of proposed developments. They commonly used to identify improvements needed to maintain adequate levels of service, and to identify the number of trips on each specific city link attributable to individual developments. Serving any new station, Southwest consider the following factors:

1. Market demand:

   Taking an estimate of quality service index (the number of people who fly each year, the destination they travel ties it to the present routes serviced today).

2. Demographic basis:

   The city's population, or how big the city is a requirement to met with forecasted flights, and to which airport to operate through if there is more than one airport.

3. Flight rate:

   What is the fare value, and the cost to fly, to come up with new fare to compete in the market.

Southwest Airline they don't use any scientific tools related to engineering, their operation based on experience and expertise.

Table 2. Southwest flight chart

	ABQ	AMA	AUS	BWI	BHM	BUR	MDW	CLE	CMH	CRP	DAL	DTW	ELP	HOU	IND	MCI	LAS
ABQ		2							7		4			2	7		7
AMA									7								
AUS											5	13					
BMI						3											
BHM																	
BUR															12		
MDW							8	5		10			4	16			
CLE																	
CMH																	
CRP												8					
DAL										6		35				8	
DTW																	
ELP												7			3		6
HOU																	
IND																	
MCI															3		
LAS																	13
LIT																	
LAX																	
SDF																	
LBB																	
MAF																	
BNA																	
MSY																	
OAK																	
OKC																	
ONT																	
PHX																	
RNO																	
HRL																	
SMF																	
STL																	
SAT																	
SAN																	
SFO																	
SJC																	
TUL																	

Southwest Airline Maintenance Program

A. Fleet size as of September, 1993

B737-200	50 Aircraft
B737-300	81 Aircraft
B737- 500	25 Aircraft

B. Check accomplished on overnight aircraft with in Southwest hangars

1.	"A" Check	14 days	2 men 8hrs
2.	"3A" Check	45 days	3 men 8 hrs
3.	"C" Check	90 days	12 men 10 hrs

C. Maintenance staffing

Function	Dal	Hou	Phx	Mdw	Oak
A& 3A Check	39	36	34	15	--
B Check	--	14	24		
C Check	--	42	43		
Total 247					

D. Maintenance Hangers

Dallas	Two aircraft hangar where we accomplish Ron visits.
Houston	Up to six aircraft hangar where "B" checks and 200/-500 "C" checks are performed.
Chicago	Up to six aircraft hangar. Only overnight maintenance (RON) currently being scheduled.
Phoenix	Up to six aircraft hangar where "B" checks and 300/500 "C" checks are performed.

CHAPTER 2

LITERATURE REVIEW

The literature review in this chapter establishes the foundation for this thesis to study flight and maintenance scheduling in commercial airline industry. It is the propose of this study to apply industrial engineering to airline business. The way to approach this goal is by using I.E. (industrial engineering) techniques and to determine the success rate by integrating these two issues.

Since the advent of the industrial revolution, the world has seen a remarkable growth in the size and complexity of organizations. As an integral part of this revolutionary change there has been a tremendous increase in the division of labor and segmentation of management responsibilities in various organizations. Airline operation is a good example of these changes effecting the entire industry.

The rate set by the aviation industry are affected by the market demand. If the rates is high, the influence of aviation on marketing is greatly restricted. Even though, the rate has been decreasing. Because it has direct impact on employment, the economy, and this will cause so called the rescission.

In well functioning competitive market the desirable rate and quality of production are determined directly by interplay of cost and benefits. But in the domestic airline market regulator is interposed between producer and consumers. In recent decades, commercial flights became as a major mode of transportation, where the skies have become crowded, or have become a major traffic hazard carrying a wide variety of product, and people from one destination to another. Scheduling became an important issue, it can be reviewed in many different ways, and it is an emerging topic. Because very little work in this area has been documented. A lot of effort was done to gather more information about this particular subject, after a long search in many libraries, and some companies, the only data was provided for this study by Southwest Airline. In later section will discuss Southwest Airline as profit making industry.

Market analysis is a basic tool that enables the top management to place the effect where the result will be the greatest and often said to be its starting point. This analysis might help to achieve three objectives with minimum efforts by giving attention to the various items according to their importance. The reason of this study to increase demand, reduce cost, and expansion.

The U.S. aeronautical system including aircraft, engines and parts manufacture; airline airports, and the general aviation estimated to employ than 4 percent of the working force in United State.

The history of the airline industry in Untied State started by Untied State Post Office in the early 1920's. Using slow speed aircraft's, serving mail to the north portion of the country. In 1924 airplanes became equipped for passenger usage. In spite of such merger, the number of airlines started to grow until by the end of 1930 no less than forty-three companies were in service.

States were confined to small populated areas based on primitive kind of transportation. With development of aviation dwelling areas spread out at a wider radius from the center of the state. The larger the community the need for faster transportation became more essential, so more population will lead for more demand on the air transportation.

Some studies showed people living in small town take more trips per person than people living in large cities. Because of the fact small communities do not provide all the professional and commercial service required or desired by their resident. This very important fact because this country widely speared over large land especially 64% of the population lives in small towns. In 1940 the median number of flights per day from town about 10000 population was two flights per day, and for towns from 10000 to 25000 was four flights a day.

One way of approaching the problem of estimating the future passenger traffic is to assume that the trend of growth in the past will continue in the future. Before making such an assumption, however, it is desirable to ask weather there are any obvious factors which will operate to prevent or otherwise change greatly the extension of past rates of growth into the future.

in considering the future of passenger traffic, we shall depend a good deal on the projection on the past trends. This can be done logically only if (1) there are no unusual or insuperable obstacles ahead and (2) if the various factors affecting the trends in the past, such as improvement in the future. These observations indicate that all factors affecting the growth in the past are expected to continue their growth, except that, first, there may be rather more effective competition from the railroads than in the past, and secondly, the stimulation of the past may wane somewhat.

Service expansion is far more important concern for management in the coming years. The increased acceptance of air travel by the public will create a demand for new routes between cities that are at the present without direct service. This development followed carefully so, the service can be timed to take advantage of the demand. In the past route expansion was a prominent factor in most domestic airlines. This type of expansion considered only when natural flow of travel and shipment of mail to new terminal points.

Design trends of equipment necessitate, from time to time, plans for service revisions within the system. At the present the range and flight characteristics stress long haul express scheduling. Plans suitably designed for local high speed service are now much in demand.

In the early era of the airline's maintenance required a corps of competent overhaul personal at each station with all the necessary tools and material for complete overhaul. Such duplication of skill was expensive, and it was barely possible to complete each day's maintenance, and it was rare occurrence indeed when motors or planes remained in the repair until routine inspection reached them.

Commercial travel constitutes the bulk of air passenger traffic and will continue to do so for some years, mainly because of price and speed factors. The service provided by the network of domestic airlines, has done much to reshape merchandising and methods of management with the result that each month sees a marked increase in air passenger traffic.

In the air transportation industry, competition may exist when two or more carriers are authorized to perform essentially the same service . Of course, it is not possible for the services offered by the tow air carriers even over the same route to be identical as in the perfect competition identical product sense similar to the service in south Texas between Southwest and Continental Airline, because each carrier has its own distinctive schedule pattern, history, experience, safety record, passenger services, equipment, and other aspects of its product package which tend to differentiate it from that of the other carriers.

Thus, competitive airlines tend to offer luxurious, but comparable, customer services. For those passengers to whom these amenities are important, this has been and continues to be a highly desirable effect of competition. On the other hand, the growth of coach service indicates that for many passengers these service features have been unnecessarily expensive, and that elimination or contraction of some of them with corresponding rate reductions is a preferable alternative.

CHAPTER 3

AIRLINE OPERATION

3.1 FLIGHT PLANNING

By serving routes to different city's world wide. In some instances many airlines operate with high level of frequency for the same destination. Route densities or poor aircraft scheduling that results in lower utilization and increased the operating cost.

When attempting to determine the completion date for any task, a plan must be prepared to do so. The need for planning has always been present, but the complexity and competitiveness of modern tasks require. This need should be met rather than just recognized. Ideally, plans are made before the starting of an operation, or other plans have to be made to deal with context.

A. Schedule Design

This involves both determinations of which route to fly and detail design of each route. Decision regarding schedules to be made based on input information from marketing to provide answers to questions. Like how many times will it fly to this particular destination.

Scheduling design involves both the determinations of which particular flight is to used and the time detailed design of the entire flight connection. The schedule designer must be aware of the degree of uncertainty that exists concerning the mission of the flight. Flight frequency decisions referred to city market forecasting, city size, location, airport location within the city, and also can be determine from market forecast. The more specific input detailed process, and schedule designs, the greater the likelihood of optimizing to meet with airline needs.

Market information

Route	1st quarter	2nd	3rd	4th
A	22000	26000	29000	20000
B	49000	54000	62000	51000
C	31000	24000	24000	28000

As a minimum, the market information given in table needed, information regarding the dynamic value of demands to be place on scheduling design. If such information is available, a schedule plan can be develop for each route with sufficient flexibility to meet the quarterly fluctuation in the business market.

Because of the expensive equipment involved and the impact of time on jet operating costs, airline scheduling today often utilizes computerization "W. L. More Jr." Indicated that preparation of a major schedule including tinting effort for more than two years. Naturally, the scheduling efforts must go on consecutively in order to be available when needed.

Schedule should be adjusted, to accept the deliveries of substantial numbers of new tube of aircraft, most of the airplanes available for the peak hours, or the peak season. Weather should be consider for the small airplane. Also scheduling for require more factors for the operation

1. Equipment: Equipment to be used in service for schedules for including charter flights or extra sections. A range of out service commitments includes overhaul, maintenance, training, special projects. Maintenance requires station facilities and personnel to complete the task.
2. Group qualifications: the scheduling must ensure that pilots, copilots, engineers and other crew member have adequate training on the type of aircraft on which they will be schedule.
3. Route and environment factors: in addition to special as such as the weather, airport condition, communication facilities must be considered in the schedule.
4. Traffic requirements: The location of the point to point stops, departure frequency and spreads, intermediate stops, and other competitive services are all factors which must be included.
5. Approvals. As in most things, government approvals are important facet and must be include in the preparation time allowed for the scheduling.

B. Flow Pattern and Planning

Macro flow consideration to define the overall environment for the best pattern could be applicable similar to those in work stations. Motion studies in economic consideration are important in establishing the flow within the servicing cities. Because some of the planes start in a certain city and ending up in a different one late during the day. If most the planes would work with high effective hours, and for best fit it has to schedule at this way.

Practice of providing service to points A, B, C, D, E, F, G, H, I, K, L, by scheduling flights in the following manner:

1. A, C, E, G, I, K and B, D, I, J, L.
2. A, D, G, J and B, E, H, K and C, F, I, L.
3. Combinations.

The advantage of such principle is to provide faster service between the operating cities. And the disadvantage of this principal is not providing service between the consecutive cities. Local service is being operated by most airlines with shorter range aircraft making all stops on a segment and connecting at larger intermediate stations to or from long rang aircraft. That type of scheduling can be best illustrate:

Table 3. Flow pattern and planning

stations	short range	long range	short range
A	X		
B	X		
C	X----------------->X		
D		X----------------->X	
E			X
F			X

X: denotes a scheduled stop

---------> : connote connection to other flight

This type of approach provides faster service, but in the other hand it involves a lot of change in planning flow pattern & planning.

This kind of flow will be favorable if planning circle increase or decrease based on the flight frequency. For example:

Houston - Dallas

Dallas - little rock

Little rock - New Orleans

New Orleans - Houston

In real life some of these covered, but adding new one will generate more demand and increase the amount of travelers depending on what city the operation will take place.

C. Measuring Flow

The arrangements of flow by using certain route or others' alternatives, flow may be specify in quantitative measure, qualitative measures. Quantitative measure may include the duration and distance of flights(low frequency, because of the demand is low, but having significant connection and routing interrelation). Qualitative measures may range from absolute necessity of two stations based on demands (high frequency and high demand).

One type of system with frequent stops along the route of a line between many cities. Is similar to the present bus line service. The disadvantage of its pattern is that traveling time will increase and the cost will go up. However the passenger potential would increase and these increase the schedule frequency.

3.2 MAINTENANCE SCHEDULING

The maintenance is very sensitive and important in airline operation function in such organization. The exact size and location of the maintenance depend on financial capability of the company, because it could be done with in the company or assign to a maintenance contractor.

Maintenance means keeping the airplane operational with good maintenance to secure safe use, by having an efficient team to run such duty, and maintain the right inventory as spare parts, equipment's and facilities.

The development of service and maintenance in the transportation field guided and paced by the improvement in flying equipment. The organization of maintenance and overhaul scheduling technique and the development of systematic overhaul periods have advanced with evolution of planes and power plants.

Hundreds of parts belongs to the modern transport planes, from the nuts and bolts up to the very complex part need to be checked according to the time in service, or flying hours, these parts require to be replaced, or overhauled, a study should be made to keep all the information and Details of all the parts of the plane. Check periods either refers to a certain manual, or to the condition of this part. Because of this, is recommended if the maintenance schedule to be updated using computers. All the major checks, and overhauling to be did care by the airline maintenance. There must be backup planes available to replace or take care of any delays or emergency. The maintenance schedules need full time efforts to prevent any accident, or delays to the entire operation.

In addition to the maintenance work scheduled for the field station, there are the service of all planes using the field and the duties necessary to maintain ground equipment, plant and structure. The size of the field station and the number of maintenance service personnel employed vary with the number of planes scheduled into or through the station. The terminal and junction points are mannered by the more complete ground crews. Plane service at the terminal points consists of the routine inspection and cleaning of the ships, the grounds warm up and instrument and controls check just prior to each flight. Intermediate stops have a much smaller force, consisting of the personal to handle oiling, gassing, the loading and unloading of cargo, handling of passengers, and the routine inspection before takeoff. The larger field stations set up to run the more complete routine inspection such as the 150 hour check (a check).

Organization, or lack of it, has often been blame for the deficiencies of airline management, although personal administration of assigned responsibilities, rather than faults of organization, may more often be responsible. The role of organization, is most important in all airline functions and should be consider of prime importance for proper airline management. The vigorous growth of airline in the past has caused constant changes in basic organizational policies, and the future will probably require the solution of even greater organizational problems. Moreover, the organizational problems of airlines are unique and more complex than those of industries, outside transportation and other public utilities, because of the twenty-four hours a day, seven days a week work schedule and widely dispersed nature of their operations.

In deciding one or another plan of organization for an airline maintenance, consideration must be give to a number of the inherent characteristics of the industry and conditions under which the organization must operate.

1. Interdependence of activities. One of the unique characteristics of the airline business is that, to a greater extent than almost any other business, most activities are interdependent.
2. System wide vs. geographic activities. Certain airline activities can best be direct by regional and local management, while others do not lend themselves to decentralization and can best be plane, administered, and controlled centrally.
3. Need for flexibility. The airline industry must be operate with an extreme amount of flexibility to provide for the change and uncertainty that is an inherent condition and to make proper provision for it.
4. Rapid obsolescence and technological change. There is a very rapid obsolescence and high technological change in the airline industry. This means that top management must be free to concentrate their attention on the development of better equipment and methods and in planning for the future.
5. Nature of costs. Airline organization effected by the economics of air transportation. Compared with many other industries this is a low profit margin, high risk business, with many a higher proportion of payroll costs and very large number of independent profit centers as represented by each airline station.

3.3 COST ANALYSIS

Comprehensive list of air travel cost items

1. Direct flying expenses

   Salaries, fuel, Airplane prices, depreciation, maintenance, assurance, passenger supplies, route utilization, taxes, and airplane load factor.

2. Indirect flying expenses

   Cost of ground facilities, communication, meteorological expenses, more fuel cost, crew operating cost, taxes.

3. Traffic and advertising cost
4. General administrative expenses

Direct Expenses

Airlines have relatively low fixed charges, particularly when compared to the railroads, since their airways cost them little and their airport facilities generally provided at low cost by governmental agencies. Also, the high speed of aircraft lessens the amount of capital equipment required per passenger or ton mile over what would otherwise be necessary.

However, a substantial portion of airline costs is constant costs, in the sense that they do not vary in proportion to changes in the volume of business handled. Some of these true fixed costs (but not fixed charges) in the sense that they would continue whether the firm operated flights or not; salaries of higher officials and some depreciation charges. These will continue so long as the firm continues to exist, even if it suspends actual operations. The bulk of the constant costs not fixed costs but is constant (as compared to the direct) type of variable cost that is one that will cease if the firm suspends operation but which will not vary directly in proportion to output. As suggested above, many of the station expenses are not adjustable to the volume of business; the same is true of those for supervisory, administrative, and clerical personal.

In addition, with a given number of flights, up to the limit of plane capacity, the plane operating cost _ fuel, wages, maintenance, etc. Are almost completely independent of the volume of passenger, freight, and other traffic handled. Just as a railroad requires about the same expenditures for fuel, wages of operating personnel, and maintenance of equipment whether a train carries five passengers or fifty and requires only a few additional ones if it carries five hundred, so an airline will pay out almost the same amounts for plane operation maintenance regardless of the loads handled, with a given number of flights. These operating costs will, of course, increase if traffic rises to the point at which additional flights added.

Thus, with a given number of flights, the only actual direct variable costs, those changing more or less in direct proportion to changes in volume of business are those resulting from the selling of additional tickets, serving of more meals, use of some additional fuel because of the greater Weight. So the marginal cost the addition to total cost from the handing of the additional units of business is extremely small. As the average load carried per flight rises, the average cost per ton or passenger mile drops very sharply, since total of constant costs is being spread over more units. As business expanded to the extent that additional flights are necessary, the plane operating costs will rise, in total, more or less in proportion to the additional business. The other constant costs those not directly dependent upon the number of flights will not increase in proportion, and average cost will continue to decline. Likewise, over a larger period, as an airline continues to expand, it may be able to realize some economies of lager scale production, specially the use of larger capacity planes and the introduction of increased specialization in management. Thus it may obtain still farther reduction in average cost per ton or passenger mile.

Common and Separable Costs (Indirect Expenses)

When airlines handle more than one type of traffic passenger, mail, express, freight as they usually do, a portion of their costs is common among the various types, since no one of the type of traffic is responsible for any particular part of these costs. For example, if particular flights handle freight, passengers, and express the costs of the plane operation are common among the three. No one of the three is responsible for any particular part of the wages of the pilots or the fuel costs, except to.the extent that the latter increased from the greater weight resulting from the carrying of the particular type of business.

Not all airline costs are common, however. The wage of the flight attendant, for example, is a separable cost for which the passenger service alone is responsible. The costs of selling tickets or of soliciting freight and the cost of handling the freight and express are separable costs.

With each general category of service, likewise, some of the costs may be common, if a number of different types of freight rate handled, a portion of the costs separable to the freight as a whole will be common among the various products. This true likewise if separate aircraft maintained for freight operation alone; all the operating costs of this aircraft are chargeable to freight, but many are common among the various types of commodities handled.

Much confusion has arisen over the relationship of the concept of marginal cost, so widely used in economical analysis today, and separable cost per unit of traffic, or out of pocket cost, the latter generally being employed in transportation industries. Marginal costs consist of the addition to total cost resulting from the production of an additional unit of output the carrying of an additional passenger, for example. On the other hand, out of pocket cost per unit of business consist, of the total separable cost for which the type of traffic handled. Frequently, in reference to a relatively short period of time, only those separable costs that are variable cost included in calculating out of pocket cost.

In any type of business, there is no necessary way in which the total common costs must be allocate among the various products or types of traffic. Frequently, business firms will make allocations for various purposes; but these are, of necessity, arbitrary.

The costs around the airport per unit transportation are subject to reduction with the increase of traffic. The desire for mass market is always greater toward a lower cost in order to induce more travel.

Farther light on the cost of passenger transportation may be by inquiring how low aviation cost can go. Adopting the policy by reaching larger market lowering prices except for low rate profit on big number of sales will gross a larger profit, than higher rate of profit on a small number of sales. At the present time air passenger fares are somewhat comparable to those of railroad even to the bus considering the biggest major factor is time. Commonly speaking the airplane will take away much of the traffic that travels over three hundred of miles. Even if the original cost of the airplane itself is ten times that the bus or may be the railroad train, the airplanes require a larger crew, and landing fee. But airplane has bigger capacity of passenger, faster to travel, and more convertible.

To operate efficiently and economically, the aviation industry requires a payload factor of not less than 60 percent. Fares can be reduce if the value of passenger traffic increases. The reverse is also true, if the costs are lower. More passenger from small communities will travel by air. The labor cost coefficient should not go higher than 35% of total airline operating expenses, it must be always around .05 probability level to count 95% degree of confidence.

To find minimum cost of fuel tankering policy for an airline flight schedule based on fuel prices in each city this airline serves, station constraints and supplier constraints. These represent upper and lower bound on the amount of fuel that could purchase at a particular station for all flights, or on the particular supplier at all stations. The problem formulates as a linear program. However, if there are no station or supplier constraints, it can reduce to a network problem by series of transformation on the constraint and variables. If there is station or supplier constraints, but not both, can reduced to a generalized network problem.

Transportation hubbing over some airports, which is best by severe capacity problems. While serving a high proportion of passengers, is explored from both a historic and an economical standpoint, because it was within range of new cities for continental U.S. air traffic.

A model of airline network competition applied to the U.S. market. This models simulate the behavior of profit maximizing airlines with different network types and hub locations, finding cities of comet equilibrium. In baseline run corresponding to the predicted demand will increase to strengthened connectivity of alternate hubs to be explore. Hubbing will increase at somewhat slower pace than overall demand as new services become feasible for connecting traffic, and to increase airline network efficiency and to reduce operating costs. Alternately, hubbing viewed as marketing strategy permitting airlines to take advantage of market preferences for the increased frequencies that the strategy permits.

To measure the degree of hubbing, by concentration of the airline operation, all based on distribution of annual scheduled departures. To have lower cost as a consequence of being able to operate with larger aircraft or higher load factors or both. As flow of passengers on a link increase, some combination of increased frequencies, larger and more efficient aircraft, and higher load factors must result. Each of these consequences reduces total per passenger transportation cost, the firsts through improved passenger convince and lower unit cost for airline.

The Theory of Rate Making for Air Transportation

To present a simple theory of rate making for the air transport industry is not an easy task. Many of the problems are comparable to those relating other carriers, around which controversy has centered for many years. Only a brief summary statement is possible.

In general, airline management's seek to attain the maximum profit possible. The intent of regulatory policy is that actual profit earned should not exceed a normal or fair rate of return on capital investment, comparable to the profit that can typically be arend in competitive industries. So long as maximum profit which the airlines can make under existing conditions is less than a normal return, as probably been the typical situation the industry, there is no general conflict between the aims of regulatory policy and those of the companies, although disagreements may arise over relative rates for different services; and those services that would provide maximum contribution toward profit may some times be considered contrary to public welfare. If situations permit the airlines to earn an excess return, however, a real conflict arises, since regulatory agencies will attempt to hold the general rate level below that desired by the companies.

A passenger fare between a pair of points generally constructed by applying a constant rate per mile to the mileage by way of the shortest route of any carrier via all certificated intermediate points on its route. Other carriers serving the same pair of points ordinarily meet this fare, even though the mileage along their routes is greater. The fare so constructed becomes the maximum charged between any other pair of intermediate points on the competing segments, on the theory that fares between any pair of intermediate points should not be higher than those between more distant points. A circuitous carrier, therefore, could have intermediate points on its route for which it would be compile to charge fares identical to the fare between the competitive points based upon the shorter route of another carrier.

Competitive between carriers is highly desirable, and no affective competition would exist if carriers could not charge the same fares for travel between the same points. The practice of meeting fares between points reduces the average revenue yield of the longer route carriers, and in same cases this reduction is very substantial.

3.4 FORECASTING

Forecasting is prediction, projection or estimation of the occurrence of uncertain future or levels of activity. It's propose is to make use of the best available present information to guide advance developments toward better organization.

All forecasting techniques depend on the manner in which the basic data collected, evaluated and used for their reliability. The data collection depends upon factors such as classification, reliability, accuracy, source, and cost. Many techniques are available in forecasting. Each firm will have to carefully assess its data processing, skills and the operating environment so as to select techniques that are most suitable.

Planner are interested in timing, magnitude and effects of event that influence their operation, forecasting for them is the window into the world to seek new achievements, form this point view the importantance of forecasting became essential in governments, companies, universities and so on, even in the commercial airline Sector.

Some factors could influence the demand of the airline to generate new station based on forecasting

1. Economic political and technological conditions
2. Flight routing and service
3. Process and methods
4. Scheduling and control

Forecasting component's

It's a set of time ordered observance on a variable during successive and equal time cycle. By studying how a variable change over time, relationship between demand and time cycle can be formulating the components then projected forward for the next time cycle. If historical components persist into the future, a reliable forecast will be obtain, which are:

1. Level component:

   The present time schedule for running season

2. Trend component:

   It will recognize the rate of increase or decline in number of flights over next season

3. Seasonal variation:

   Its annually reoccurring movement above and below the trend level when demand fluctuates in repetitive fashion year to year, this has to do with traditional holidays, school opening, summer season.

4. Cyclical variation:

   Is long term oscillation, the cycles may or may not be periodic, but they are the results of business cycles of expansion and contraction of economic activity over number of years.

5. Random variation:

   Have no discernible patterns, based on irregular variation, such as conventions, sports seasons, major unexpected events, which may require a chatter flight.

In developing travel demand models it is generally assumed that the base year data used in developing the parameters. As well as the forecasted data to be used as independent variable for the design year, are of acceptable quality. This study is to present the application of error propagation theory in assessing the predictive quality of one type of travel demand forecasting models.

The collection and distribution system of the passengers impose a series problem, because it dose not met effectively with their mode by some routing is not favorable such problem requires a complete study of the collection and distribution system that could satisfy the requirement by analysising air line and the traveler demand to identify the system To the related factors that are:

A. System requirement

1. Volume (how many travelers)
2. Destination of Travelers
3. Time phase
4. Trip time & cost
5. Network (where to fly)

B. Traveler requirement

1. Trip cost
2. Trip time and convenience
3. Safety and reliability

These factors are dependent on any city that belong or could be add to the system.

3.5 SIMULATION OF COMMERCIAL AIRCRAFT RELIABILITY

For a revenue flight in compliance with airworthiness regulation, safety, reliability, economy and comfort become its main factors. Under the condition of maintaining continuing airworthiness and implementation of reliability monitoring program, the dispatch reliability (DR) and scheduled reliability (SR) of commercial aircraft (CA) become the important indexes to evaluate the fleet reliability. They have an effect on the reputation of aircraft and airline as well as economy so the research and evaluation of DR and SR will be significant.

In order to study fleet DR and SR more comprehensively and accurately, it is not enough to consider aircraft Reliability and maintainability (R&M) only. Some more relevant factors that support the CA system operation should be consider. In addition to CA, R&M indexes, minimum equipment list (MEL), equipment configuration, time of finding failure, principal of air turn- back, and diversion, route structure, number of aircraft, flight dispatching, weather condition, scheduled or un-maintenance, spare parts supply, etc. Also should be considered in the simulation model. Obviously, so many factors affect DR and SR it is difficult to get results by using analytical methods. Therefore, the Monte Carlo simulation used to establish a CA simulation.

The main task is to determine the target of reliability simulation analysis before establishing the CA system simulation model, because it will decide the basic characteristic and output requirement of the simulating model. According to simulation analysis target, CA system reliability simulation model established on the basis of determining the definition and intention of this system correctly. Then test the correctness and evaluate the function of this simulation model. The following has vital effect on the revenue operation and economics of CA:

1. CA dispatch level
2. Scheduled flight success level
3. CA utilization level
4. Maintenance man hour required level
5. Spare parts required level

DR (mechanical) is the probability that the scheduled flight leaves within a specified delay time caused by product malfunction or failure (mech.). SR is the probability that the scheduled flight operates normally without mechanical delay, cancellation, aborted take-off, airplane substitution, air turn-back, diversion caused by product malfunction or failure (mech.). Both of them are the main indexes for evaluating the level of DR and flight operation.

In addition to mechanical factors, the CA system also contains other factors such as the Number of aircraft, flight schedule, management regulations, route weather conditions, inspection and repair methods, spare parts supply, etc. These factors will have a comprehensive effect on aircraft's actual level of DR and scheduled flight operation. DR and SR (in broad sense) are the main comprehensive indexes for evaluating the actual level of dispatch and flight operation, and to improve integrated management and increase revenue economical effectiveness.

The CA system reliability analysis model, using the Monte Carlo simulation method has multi-input, output and powerful function for analysis, this to be used by software package running on the VAX-8350 computers.

System Simulating Model

The analytical software package using Monte Carlo Simulation Method Includes 10 programs and some subroutines:

1. Aircraft supply program
2. Scheduled flight generation program
3. Aircraft dispatching program
4. Weather condition program
5. Aircraft operating program
6. Inspection program
7. Repair program
8. Spare part supply program
9. Data input program
10. Result output program

Simulation Output

By using the multiple output of Monte Carlo simulation method, many useful output results can be obtain, and they will assist airline in simulation analysis for whole fleet or for certain fleet of a local airline as required. The main result's simulation output is as follows:

1. CA basic operation status
   Including such as: daily utilization rate, mean flight hours per month, mean take-off and landing per month, mean flight leg time.
2. DR dispatch reliability
   Mechanical or in broad sense DR
3. Scheduled reliability
   Mechanical or in broad sense SR, delay rate, Cancellation rate, air turnback, diversion rate.
4. The effect on CA's DR (mech.), SR (mech.) caused by system failure.
5. The effect on CA's DR (mech.), SR (mech.) caused by airborne equipment failure.
6. Mean time to repair (MTTR)
   A/C , system, airborne equipment MTTR
7. Mean maintenance man hour per flight hour (MMH/FH)
   New or repaired spare part's consumption rate and amount.
8. Sensitivity analysis (SA)
   Single or multiple factors SA.

The correctness of simulation results, not only depends on the correctness of established model and written software, but also depends on the accuracy of input data. The simulation results of that CA system listed below:

a. The simulation results of fleet Dr (mech.), SR (mech.), daily utilization comparing with actual statistical data.
b. The relative rate Psi of CA delay , cancellation, air or ground interruption, air turn-diversion caused by ith system failure.

   $$Psi = \frac{\text{total delay, can., inter., turn-back, diver. caused by ith system failure}}{\text{total delay, can., inter., turn- back, diver.}} \quad \text{(Equ. 1)}$$

c. The relative rate Pij of system delay, cancellation, air or ground interruption, air turn-back, diversion caused by Jth equipment of that system.

   $$Pij = \frac{\text{total No. of sys. CA delay, can., inter., return, caused by jth equipment failure}}{\text{total No. of CA sys. delay, can., return, diver.}} \quad \text{(Equ. 2)}$$

d. Each equipment's relative percentage of repair man hour (MH%) and mean amount of spare part's consumption per year

   $$MH\% = \frac{\text{total equipment repair man hour per year}}{\text{total Ca repair man hour per year}} \quad \text{(Equ. 3)}$$

e. Sensitivity analysis (SA)

   in order to study the effects of various factors in this CA system, it is necessary to study SA for some input indexes related to output results. Suppose the basic value of certain input index is X0 the arbitrary specified value of that index is Xi the variation percentage relative to basic value is Ki, then

   $$Ki = \frac{Xi - X0}{X0} \quad \text{(Equ. 4)}$$

Under the condition of unchanging other input indexes, the variation trend of certain output indexes can be obtain from system simulation.

Y= f(Ki) or

Y= f(Xi)

SA results indicate that the frequency of charter flight an impact on fleet operation when scheduled flight is unchangeable. The index that has a strong impact on SR (in broad sense) is weather condition, so optimization of management regulation or properly increasing the ability of CA instrument landing equipment will be significance.

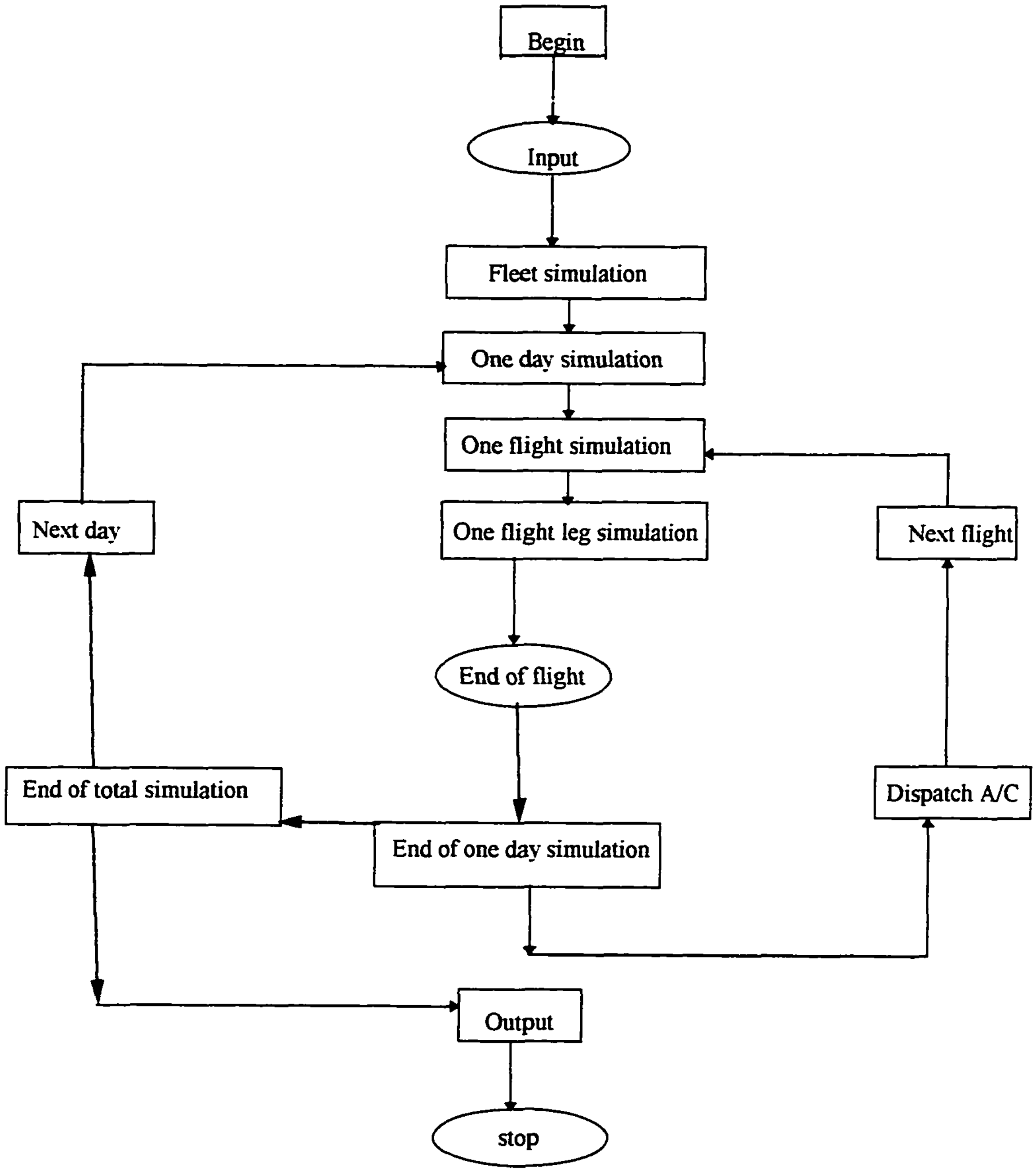


Figure 1. Fleet flight simulation flow chart

CHAPTER 4

OPERATION ANALYSIS TECHNIQUES

4.1 FLIGHT PLANNING

A. Activity Relationship

Study the flexibility of flow to provide basis for many decisions in planning process, and to assign flight priority, this can be express in terms of number of flight, and average passenger load. Flow relationships are quite important to the planner, who view flow of the flights to assign certain frequency between stations.

In better study for activity relationship is looking inside the flight schedule for any sample airline such as Southwest airline, we will notice that there no connection between the major station (not having direct flights from Dallas to phoenix) or the present flying schedule doesn't cover all destination with direct service. By consolidation flight connection, primarily when you have to change flight at certain airport. Assign priority value for the essential station by centralizing the operation, having in mind the amount of flow, maintenance, airplane cost, fuel cost, facility use.

The table below shows the number of flights, route density of some cities, where it could be assign according to that station importance and flight frequancy.

Table 3. Activity relationship chart

1	3
2	8
3	11
4	18
5	10
6	11
7	8
8	7
9	4
10	5
11	1
12	2
13	4
14	2
15	1
16	1
17	3
18	1
19	1
25	1
35	1
No flights	No cases

B. Line Balancing

Line balancing algorithm to measure the degree of efficiency between flying time and time on the ground for any airplane that are useful in consolidation of the flight routing, The development of schedule for completion of operation hours for each airplane, as explain in the following example.

Table 5. Operating hours efficiency

Stations	Time	Operating Time	Waiting Time
phn- elp	7.00-8.00	1.00	.33
elp-sat	8.20-9.40	1.33	.33
sat-hou	10.00-10.45	0.75	.25
hou -msy	11.00-11.55	0.92	.33
msy- bhm	12.15-01.15	1.00	.25
bhn -nas	1.30-2.20	0.83	.33
nas -mdw	2.40-3.45	1.08	.25
mdw -mci	4.00-5.15	1.25	.33
mci- tul	5.35-6.25	0.83	.33
tul-hou	6.45-8.00	1.25	.33
hou- dal	8.20-9.10	0.83	
11 flights	(850m)	11.05	3.05
		(665m)	(185m)

Efficiency = 665/850=0.782 (78.2%)

The procedure for arriving to the decision discussed above by having all flying time short if compared to long range flights, but in this case high number of flights represented with least times on ground.

4.2 MAINTENANCE SCHEDULING

Southwest Airline Maintenance Program

A. Fleet size as of September, 1993

B737-200	50 Aircraft
B737-300	81 Aircraft
B737- 500	25 Aircraft

B. Check accomplished on overnight aircraft with in Southwest hangars

1.	"A" Check	14 days	2 men 8hrs
2.	"3A" Check	45 days	3 men 8 hrs
3.	"C" Check	90 days	12 men 10 hrs

C. Maintenance staffing

Function	Dal	Hou	Phx	Mdw	Oak
A& 3A Check	39	36	34	15	--
B Check	--	14	24		
C Check	--	42	43		
Total 247					

D. Maintenance Hangers

Dallas	Two aircraft hangar where we accomplish Ron visits.
Houston	Up to six aircraft hangar where "B" checks and 200/-500 "C" checks are performed.
Chicago	Up to six aircraft hangar. Only overnight maintenance (RON) currently being scheduled.
Phoenix	Up to six aircraft hangar where "B" checks and 300/500 "C" checks are performed.

Man work hours are eight hours a day, five days a week, 50 week a year is: 2000 hours. Every aircraft requires 1512 hours of persons work a year, plus another 500 hour of staffing (engineers, support personal, and office personal).156 aircraft's requires 313872 hours for the entire fleet. With 247 persons employed will equal 494000 man's hour. The total utilization of human beings will be 90, about 36% of total number of the employees.

The next table developed for organizing maintenance plane for the plane in according to their check dates, Ghant chart also made for the same reason (look appendix for more detail).

Table 4. Boeing 737 maintenance chart

Date	Check	Man hrs
15-Jan	check-a	16-hr
30-Jan	check-a	16
15-Feb	check-3a	24
1-Mar	a	16
15-Mar	a	16
30-Mar	b	120
15-Apr	a	16
30-Apr	a	16
15-May	3a	24
30-May	a	16
15-Jun	a	16
30-Jun	b	120
15-Jul	a	16
30-Jul	a	16
15-Aug	3a	24
30-Aug	a	16
15-Sep	a	16
30-Sep	b	120
15-Oct	a	16
30-Oct	a	16
15-Nov	3a	24
30-Nov	a	16
15-Dec	a	16
30-Dec	check-c	800

The demand for independent service by the maintenance department and the desire to increase number of their maintenance personnel and the size of the carrier, the importance of proper maintenance scheduling became a very sensitive matter to avoid any delays and comply with any demands when it's needed. From the above it becomes the responsibility of establishing an engineering department is to organize as a department of cooperation and collaborating, it primary function is to assist all operating division's problem and creating their activity. The activities of this department are divided into three categories: first, operation maintenance and servicing of flying equipment. second, making tradeoff analysis and recommendations of all airplanes and their purchase. third, efficiency study of every route in the operation.

The work responsibility, of the engineering department toward constantly trying to improve the scheduling for flights and maintenance, so that by introducing faster methods it will keep the operation running smooth. The subordinator maintenance and scheduling department closely related to each other by following the seasonal changes so that they can schedule properly the changes made over during peak seasons. The successful completion of each schedule attempted is the primary duty of the department. To emphasize further the correlation necessary to carry on a successful operation is to study all the details that belong to each activity as an individual operation.

The tentative schedule plan by the engineering departments studied by the operation department to determine its operating efficiency. There are a number of operating problems involved. It is most important to get high daily average of flying hours for all equipment. The scheduling should insure equipment distribution at overhaul point so that the maintenance and routine inspection will not cause excessive peaks in the overhaul man- hours needed during any 24- hour period. not only are these peaks an inefficient use of man power but they also cause a needless outlay of capital expenditure in setting up physical plants to handle the overhaul.

Completely efficient use of equipment is dependent upon traffic demands and cannot yet be achieved because of the necessity of having reserve equipment for bad weather. However, by effecting a compromise between the schedules set up by the engineering department and the maintenance requirements of the operations, it is possible to handle the traffic requirements with a minimum number of ships. This saving carries through all the associated departments: in the number of flight crews needed, the amount of inventory in maintenance and overhaul stock, and the complete structure of labor and facilities.

4.3 FORECASTING

The moving average technique is a compromise between the last period demand and the arithmetic average technique with the advantages of both and the disadvantages of neither. If the demand rate is steady, the moving average will respond with fairly constant forecasts, does the average method. However, when the average demand does change, the moving average forecast, like the last period demand forecast, responds fairly quickly to use the change, but without the extreme fluctuations that are characteristic of the last period demand forecast. Increasing the number of periods in the moving average will produce forecasts closer to the arithmetic average forecast. Decreasing the number of periods will produce forecasts closer to last period demand forecast.

The next period's forecast by averaging the actual demand for the last time periods to calculate the future passenger forecasting.

Table 7. Next period demand forecasting

year	demand	forecast demand	absolute deviation	average forecast
1991	14876582			
1992	17958263	14876582	3081680	
1993	19830941	17958263	1872678	16417422
1994	22669942	19830941	2839001	17555262
1995	27839284	22669942	5169342	18833932
1996		27839284		20635002

4.4 OPERATION RESEARCH

A. Linear Programming

Linear programming it is a standard tool that saved many millions of dollars for most companies or businesses of even moderate size in the various industrialized countries. The variety of situations to ranging from the allocation of production facilities, to the allocation of national resources, so in other words it is planning of activities to obtain an optimal result. The simplex method is common and efficient solution in linear programming. Because the airline industry is part of these investments it could formulate as linear programming problem to maximize profit according to the fares of such flight, and the time to fly each trip. Look at the following example:

The time to fly certain destination is introduced as slack variables 135, 165, and 240 minutes, with basic variables of x1, and x2, to come with the optimal profit for the fares of 79, and 117 dollars.

$$\text{Max } z = 79x1 + 117x2$$

$$1x1 + 0x2 <= 135$$

$$1x1 + 1x2 <= 165$$

$$2x1 + 1x2 <= 240$$

$$x1 >= 0,\ x2 >= 0$$

And after adding equality constraints the problem will be replace to:

Max z

$$z - 79x1 + 117x2 \qquad = 0$$

$$1x1 + \qquad x3 \qquad = 135$$

$$1x1 + 1x2 \qquad +x4 \qquad = 165$$

$$2x1 + 1x2 \qquad + x5 = 240$$

$$\text{and } Xj >= 0$$

The basic feasible solution is (0, 165, 135, 0, 75)

z = 19305 dollars

Table 8. Linear programming (a. Initial tableau)

Basic variables	z	x1	x2	x3	x4	x5	right side
z	1	-79	-117	0	0	0	0
x3	0	1	0	1	0	0	135
x4	0	1	1	0	1	0	165
x5	0	2	1	0	0	1	240

(b. Final tableau)

Basic variable	z	x1	x2	x3	x4	x5	right side
z	1	38	0	0	117	0	19305
x3	0	1	0	1	0	0	135
x2	0	1	1	0	1	0	165
x5	0	1	0	0	-1	1	75

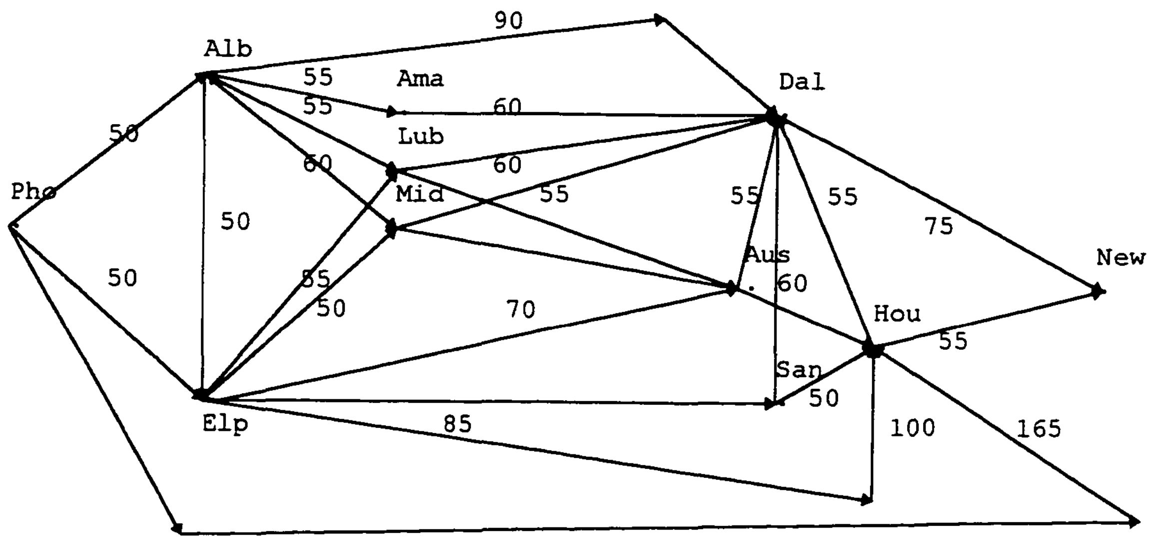


Figure. 2 Southwest flights time

B. Transportation Models

This is to emphasize the wide applicability of linear programming, the model type shares several key characteristics, by presenting our stations as constraints and variable in the distributing models.

C. Pert CPA Method

This network representation also widely used for problems in such divers areas as distribution, planning, resource management, and financial planning. By applying Pert techniques on some of the routing that has higher demand than the others using the following methods

shortest path

Minimum spanning tree

Maximum flow

minimum cost flow

Minimal spanning tree

Pho-Elp 50

elp-mid 50

mid-aus 55

aus -hou 45

hou-new 55

255

Shortest path

pho- elp 50+0=50

pho -alb 50+0=50

pho- hou 165+0=165

alb-dal 50+90=140

alb-ama 50+55=105

alb-lub 50+55=105

alb-mid 50+60=110

alb-elp 50+50=100

elp-hou 100+100=200

elp-san 100+80=180

elp-aus 100+80=180

elp-mid 100+50=150

elp-lub 100+55=155

elp-dal 100+85=185

mid-dal 150+55=205

mid-aus 150+55=205

mid-hou 150+70=220

aus-hou 205+45=250

aus-dal 205+50=255

hou-new 250+55=305

D. Air Routes

Airplanes can fly in any direction it would seem to be no problem, as far is the atmosphere concerned. But routes must construct, in a way it will help in lighting, flying over the water, emergency landing fields, weather stations, radio and electronic devices.

4.5 STATISTICAL ANALYSIS

Statistic is about design, build, operate, or improve physical system and product. Aeronautical engineers design and improve a my riad of different aircraft; industrial engineers design and operate manufacturing facilities. And so on.

The subject of engineering statistics has its goal to provide the concepts needed to serve as adequate guides to a solution. It supplies principals of how to efficiently acquire and process empirical information for use in understanding and manipulating engineering systems. By collecting the data, describe or summarize, and draw a practicable conclusion on this basis. The following study developed to compare data according to time rate factors, in this way we will be able to rates as factor of time.

Table 5. Flights statistics out of Phoenix

des	time/cost	time	cost	no flight
pho-alb	0.967	60	62	14
pho-ama	0.927	115	124	6
pho-bur	1.29	80	62	6
pho-hou	0.662	145	219	12
pho-los	1.21	75	62	25
pho-lit	0.784	160	204	2
pho-nas	0.788	190	279	2
pho-stl	0.882	180	204	8
pho-tul	0.678	135	199	5

Table 6. Flights statistics out of Dallas

des	time/cost	time	cost	no flight
dal-alb	0.909	80	119	9
dal-ama	0.822	65	79	7
dal-aus	0.696	55	79	13
dal-elp	0.854	100	117	10
dal-hou	0.759	60	79	32
dal-new	0.757	75	99	10
dal-okl	0.608	45	74	9
dal-san	0.696	55	79	14
dal-tul	0.675	50	74	10

Dot Diagram

Dot diagram is a study produces moderate amount of univariate quantitative data. By presenting each observation as a dot placed at a position corresponding to its numerical value along a number line (x, y) to compare them. In our case the X, and Ys were use as frequency factor of fares, and time, or for time Vs time, and fares Vs fares.

Frequency made by breaking the interval into an appropriate number of smaller intervals of equal length then recorded to indicate the number of data points falling into each interval.

Table 11. Flights out of Phoenix (dot chart)

Cost	frequency	relative frequency	cumulative relative fre.
62	4	0.4	0.1
124	1	0.1	0.5
204	2	0.2	0.7
219	1	0.1	0.8
279	1	0.1	0.9
199	1	0.1	1.0
	10	1.0	

Table. 12 Flights out of Dallas (dot chart)

Cost	frequency	relative frequency	cumulative relative fre.
74	2	0.2	0.2
79	5	0.5	0.7
99	1	0.1	0.8
110	1	0.1	0.9
117	1	0.1	1.0
	10	1.0	

Quantiles

The quantile is a descriptive analysis of the distribution. For a number p among 0 and 1 quantile of a distribution is a number. Such that a fraction p of the distribution lies to the left and a fraction 1-p of the distribution lies to the right. (That is, the p quantile has the same rough interpretation as the 100p percentile.) Because of the basic discreteness of finite data sets, it is necessary to adopt some convention as to exactly what meant by the quantiles of a data set.

Table 7. Quantiles of Phoenix time distribution

60	0.05
75	0.15
80	0.25
115	0.35
120	0.45
135	0.55
145	0.65
160	0.75
180	0.85
190	0.95

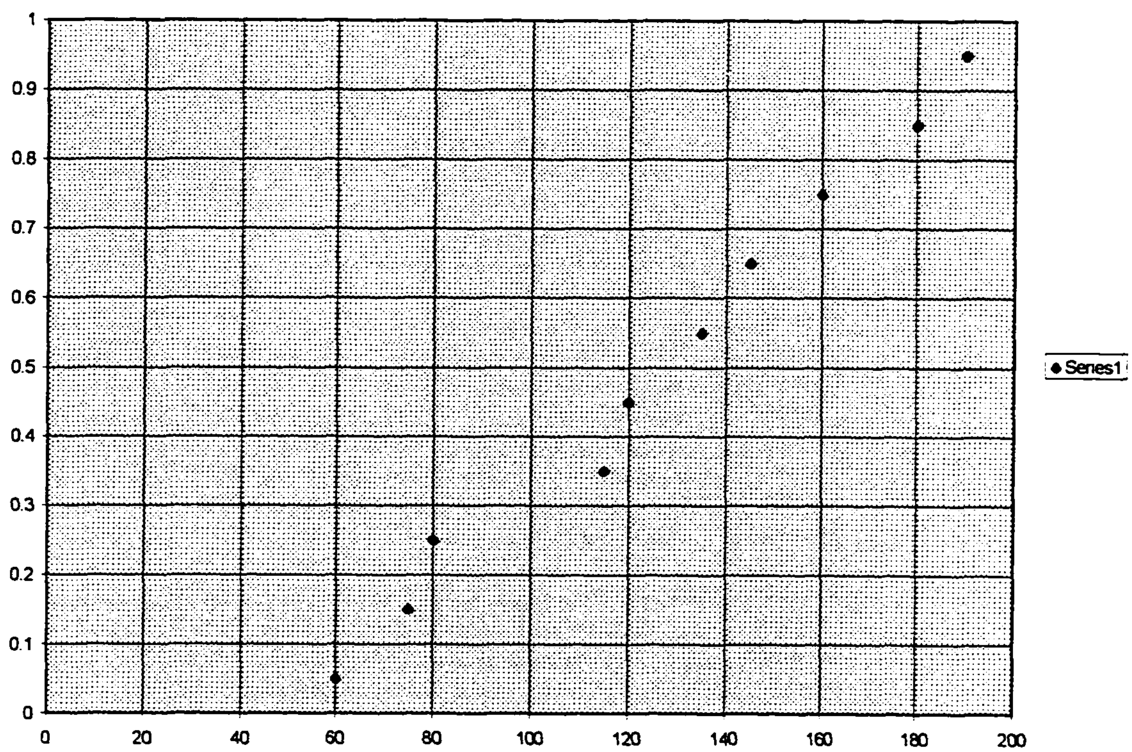


Figure 3. Quantile plot of time (Phoenix)

Table 8. Quaniles of Dallas time Distribution

45	0.05
50	0.15
55	0.25
55	0.35
60	0.45
65	0.55
65	0.65
75	0.75
100	0.85
100	0.95

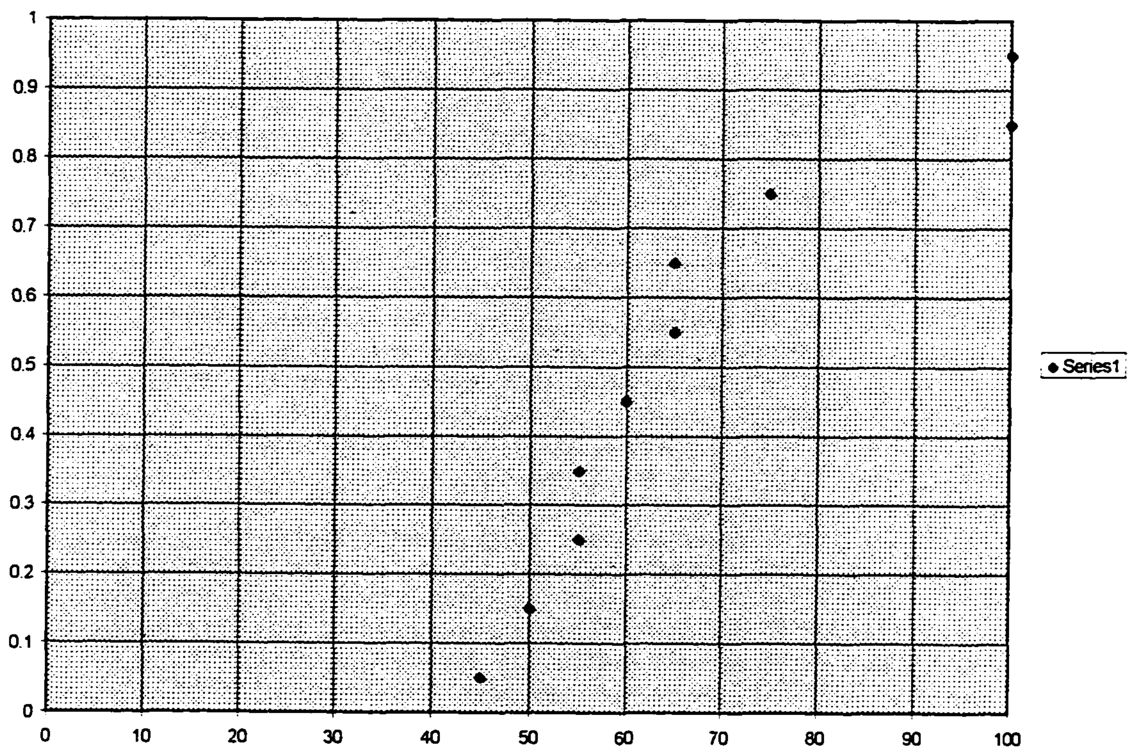


Figure 4. Quantile plot of time (Dallas)

Table 15. Standard normal quantile (a. Phoenix)

I	I-5/10	data point	standard normal Quantile
1	.05	60=q(.05)	-1.65
2	.15	65=q(.15)	-1.04
3	.25	75=q(.25)	-0.67
4	.35	80=q(.35)	-0.39
5	.45	115=q(.45)	-0.13
6	.55	120=q(.55)	0.13
7	.65	145=q(.65)	0.39
8	.75	160=q(.75)	0.67
9	.85	180=q(.85)	1.04
10	.95	190=q(.95)	1.65

Table 15. (b. Dallas)

I	I-5/10	data point	standard normal Quantile
1	.05	45=q(.05)	-1.65
2	.15	50=q(.15)	-1.04
3	.25	55=q(.25)	-0.67
4	.35	55=q(.35)	-0.39
5	.45	60=q(.45)	-0.13
6	.55	65=q(.55)	0.13
7	.65	65=q(.65)	0.39
8	.75	75=q(.75)	0.67
9	.85	100=q(.85)	1.04
10	.95	100=q(.95)	1.65

$q1(.5)=(1-.5)q(.45)+.5\ q(.55)=.5(60)+.5(65)=62.5$ median of a distribution (Equ. 5)

$q2(.5)=(1-.5)q(.45)+.5\ q(.55)=.5(115)+.5(120)=117.5$ median

1st quartile	3rd quartile	
$q1(.25)=55$	$q1(.75)=75$	(Equ. 6)
$q2(.25)=75$	$q2(.75)=160$	(Equ. 7)

Boxplots

A boxplot distribution location through the placement of the box along a number line. It shows distribution spread through the extent of the box, with the box enclosing the middle 50% of the distribution.

$IQR1= q(.75)-q(.25)=75-55=20$ mint (Equ. 8)

$1.5\ IQR= 30$ mint (Equ. 9)

$IQR2= q(.75)-q(.25)=160-75=85$ mint

$1.5\ IQR= 127.5$ mint

$Q1(.75)+1.5\ IQR=75+30= 105$ mint (Equ. 10)

$Q2(.75)+1.5\ IQR=160+127.5= 287.5$ mint (Equ. 11)

$Q1(.25)-1.5\ IQR= 55-30=25$ mint

$Q2(.25)-1.5\ IQR= 75-127.5=-52.5$ mint

Q-Q plots

Q-Q Plot is to compare the shapes of two distributions, if they have any linear relation, and it is easiest to explain the notion for empirical context.

Data set 1

45 50 55 55 60 65 65 75 100 100

Data set 2

60 65 75 80 115 120 145 160 180 190

45-45=0	60-60=0
50-45=5	65-60=5
55-45=10	75-60=15
55-45=10	80-60=20
60-45=15	115-60=55
65-45=20	120-60=60
65-45=20	145-60=85
75-45=30	160-60=100
100-45=55	180-60=120
100-45=55	190-60=130

Table 9. Q-Q Plots of Phoenix time-fares chart

Time	Fares
60	62
75	62
80	62
115	124
120	199
135	199
160	204
180	204
145	219
190	279

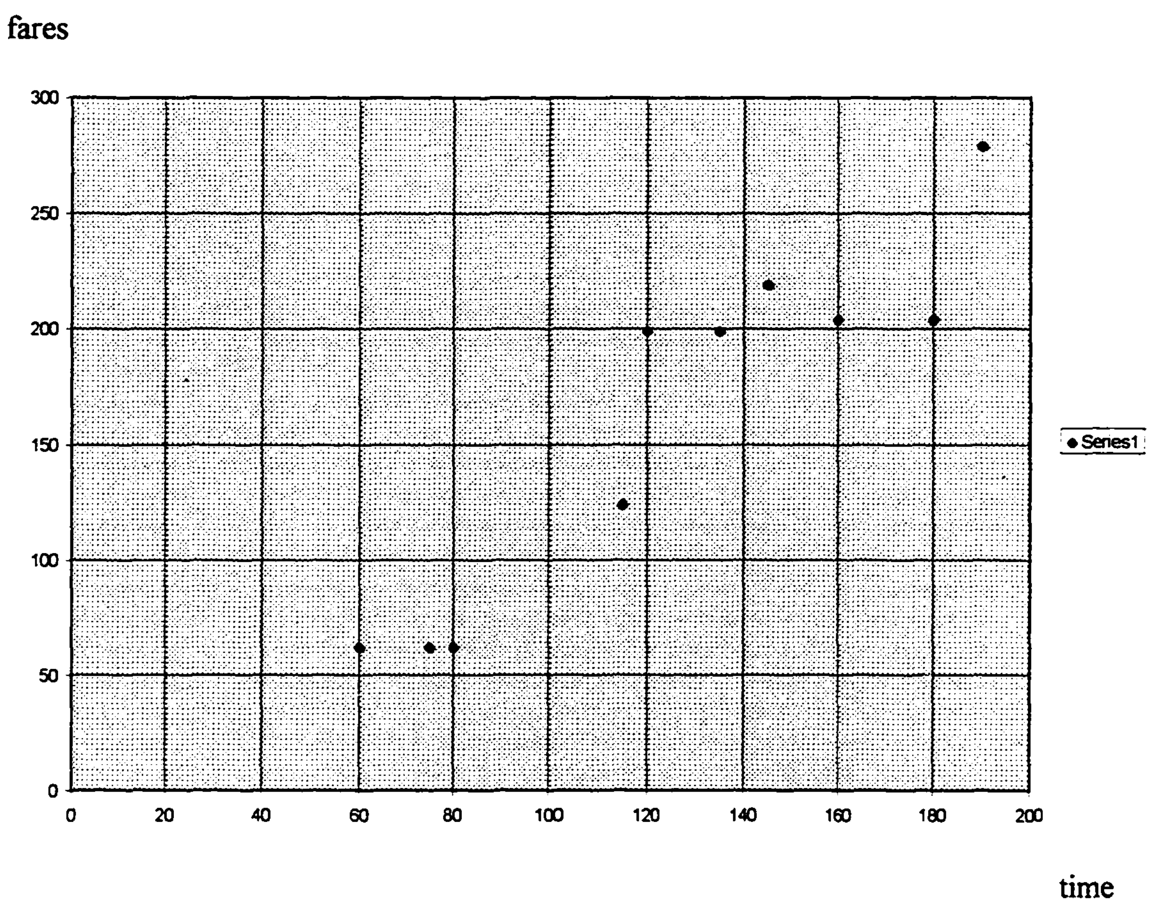


Figure 5. Q-Q Plots (Phoenix)

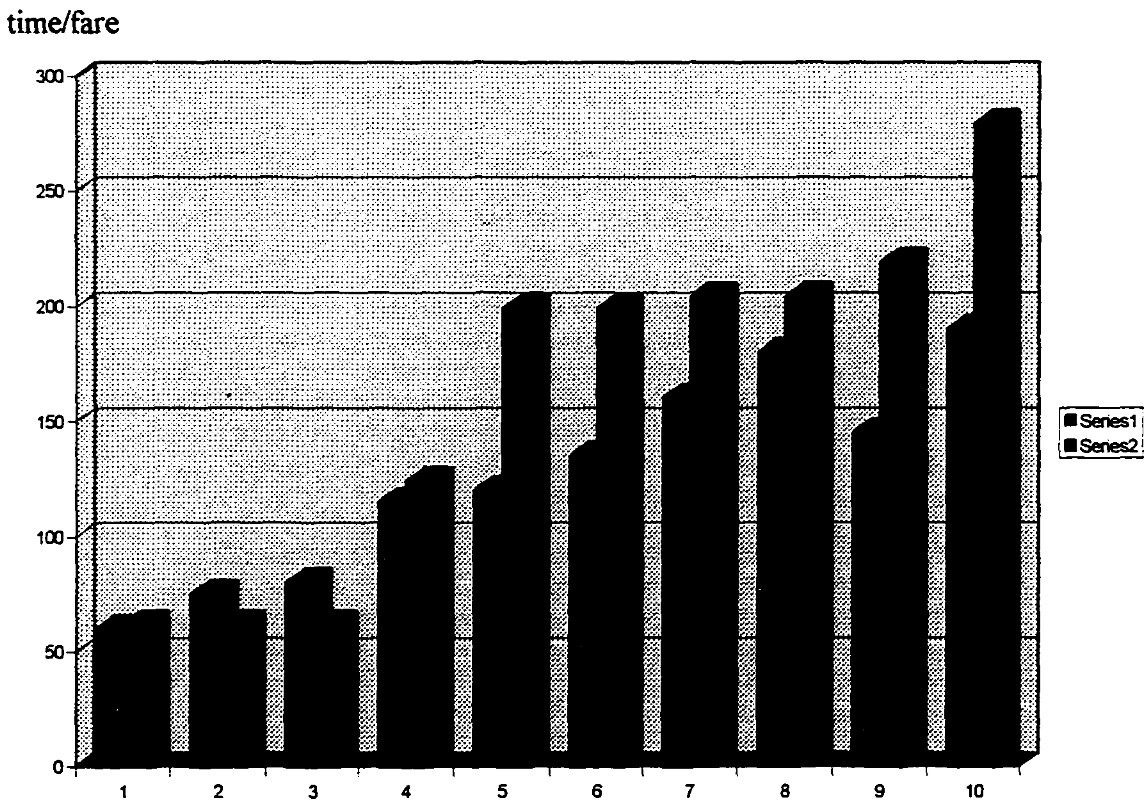


Figure 6. Q-Q Plot (Phoenix)

1-time

2- fares

Table 10. Q-Q plot of Dallas time-fare chart

time	fares
45	74
50	74
55	79
55	79
60	79
65	79
75	99
100	110
100	117

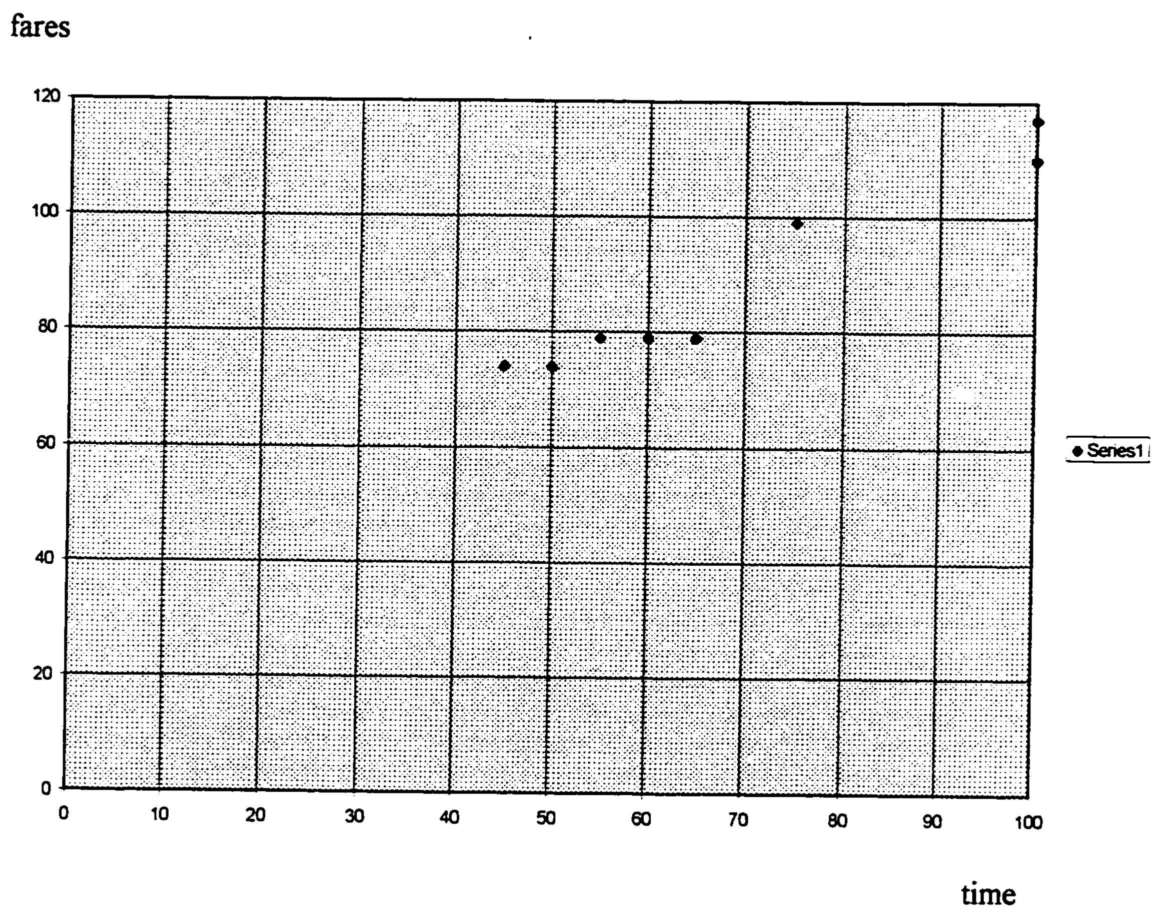


Figure 7. Q-Q Plot time/fare (Dallas)

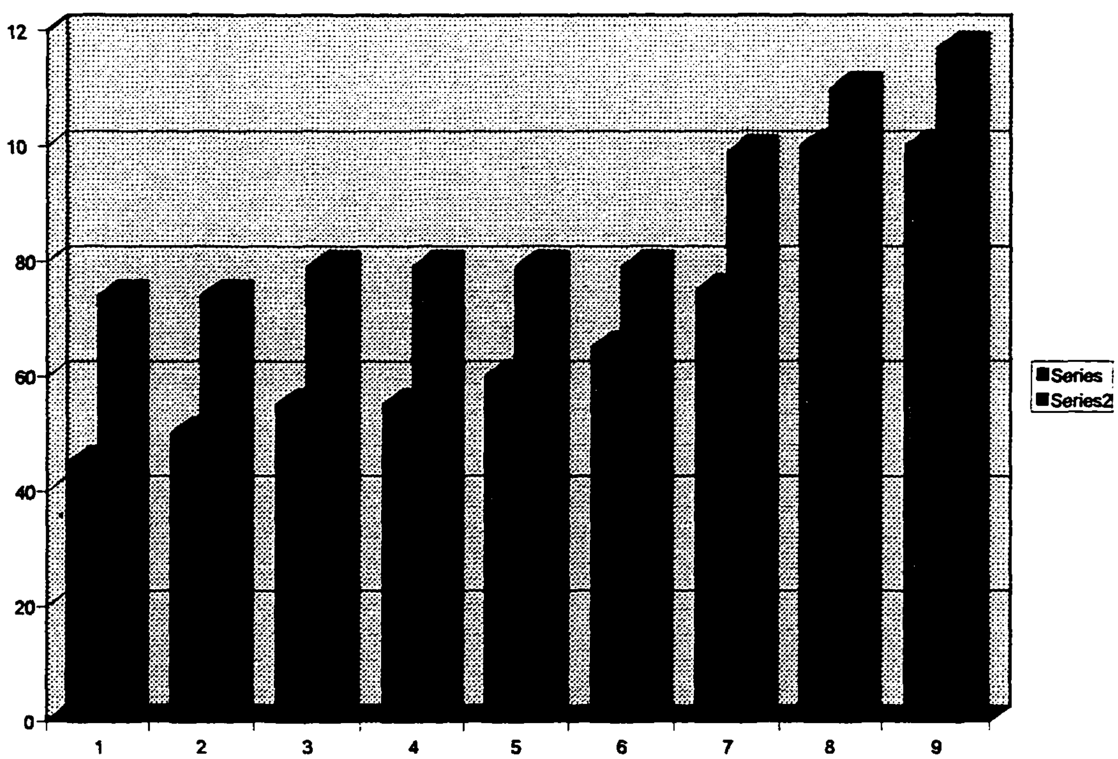


Figure 8. Q-Q Plot time/fare (Dallas)

1-time

2- fares

The Arithmetic Mean

The arithmetic mean of a sample of quantitative data, some times called the first moment or the center of mass distribution drawing on an analogy to mechanics. If one thinks of placing a unit mass along the number line at location of each value in a data set, the balance point of the mass distribution is at x.

$\bar{x} = X = 1/n\ (x1 + x2 + x3 + \ldots\ldots\ldots\ldots)$. (Equ. 12)

$\bar{x}1 = 1/10(45+50+55+55+60+65+65+75+100+100)=67$

$\bar{x}2=1/10(60+65+75+80+115+120+145+160+180+190)=119$

The Range

The range of a Data set consisting of ordered values, for example data range from 3-21, so the range is (21-3)=18. The range always based on the smallest and the largest points in a data set, it is necessarily sensitive to outlay the values. Because it easily calculated. However, most methods of formal statistical inference based on a way of measuring spread that is somewhat to find the range and interquartile range.

$R= Xn- X1$ (Equ. 13)

$R1=100-45=55$

$R2=190-60=130$

Sample Variance and Sample Standard Deviation

It's the measure of variation, IOR, R, and S are not directly comparable.

S**= 1/n-1 [(x1- X)**2 + (x2- X)**2 + (x3- X)**2 + (x4- X)**2+ ....] (Equ.14)

S1**2= 1/10-1[(45-67)**2+(50-67)**2+2*(55-67)**2+(60-67)**2+2*(65-67)**2+(75-67)**2+2*(100-67)**2] =

373.33

S1=19.32%

S2**2=1/10-1[(60-119)**2+(65-119)**2+(75-119)**2+(80-119)**2+(115-119)**2+(120-119)**2+(145-119)**2+

(160-119)**2+(180-119)**2+(190-119)**2]=

2332.22

S2= 48.3%

Principle of Least Squares

It's of the descriptive statistical analysis is the fitting of a straight line to a set of bivariate data. The fewest squares used for the following consideration: summarization, interpolation, extrapolation, and process optimization or adjustment based on the data. In the context of fitting a line to a set of (x,y) data, the amount to choosing a slope and intercept. So to minimize the sum of squared vertical distances from (x,y) data points to the line in question.

Table 18. Principle least square slope cost-time data

Sample1		Sample2	
costXi1	timeYi1	costXi2	timeYi2
74	45	62	60
74	50	62	65
79	55	62	75
79	55	62	80
79	60	124	115
79	65	199	120
79	65	204	160
99	75	204	180
110	100	219	145
117	100	279	190

Table 11. Time versus time distribution

45	60
50	65
55	75
55	80
60	115
65	120
65	145
75	160
100	180
100	190

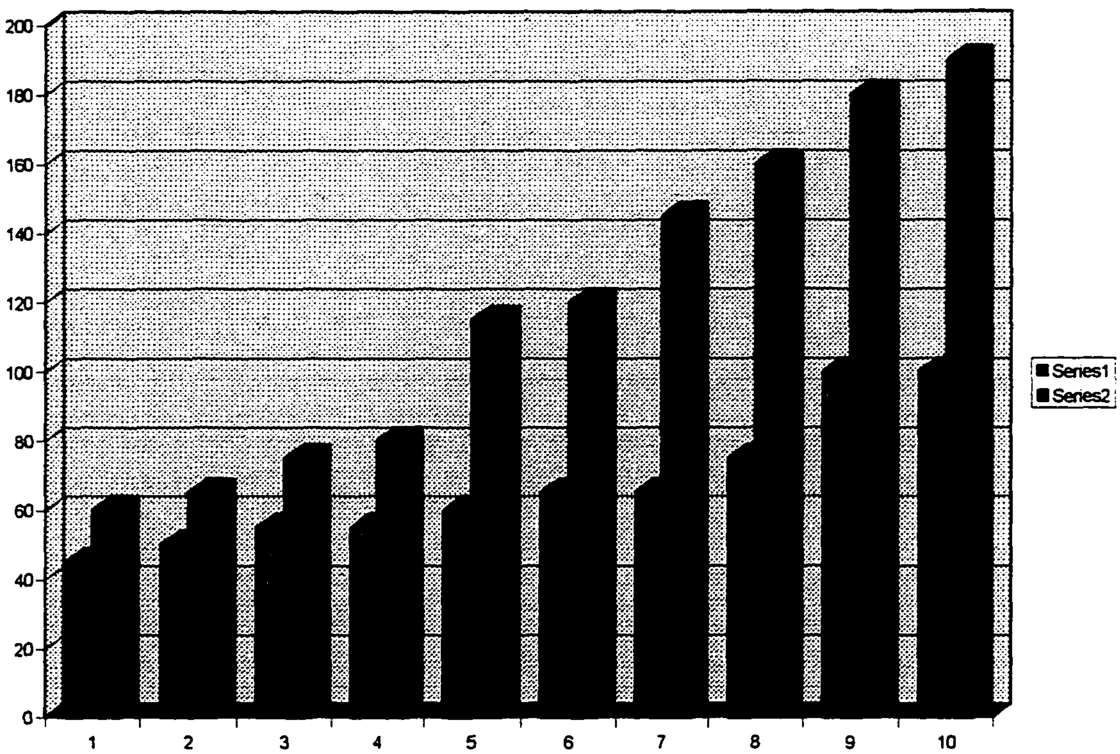


Figure 9. Scatterplot time versus time

sumxi1=869 sumxi1**2=755161

sumyi1=670 sumyi1**2=448900

sumxi2=1477 sumxi2**2=2181529

sumyi2=1190 sumyi2**2=1416100

sumxi1.yi1=582230

sumxi2.yi2=1757630

10B0+869B1= 670 (Equ. 15)

869B0+755161B1= 60855

B1= 60855-(670)(869)/10/755161-(670)**2/10 =

60855-58223/755161-44890=2632/710271=.0037 (Equ. 16)

B01=869/10-(.0037)(67) = 86.65 (Equ. 17)

^Y1=86.65+.0037x (Equ. 18)

10B0+1477B1=1190

1477B0+448900 =214275

B1=214275-(1190)(1477)/10/2140369-(1190)**2/10=

214275-175763/2140369-141610=38512/1998759=.01926

B02=1477/10-(.019)(119)=145.4

^Y2=145.4+.019x

Sample Linear Correlation

The sample linear correlation it's a helpful method of quantifying the quality of that fit. The sample correlation always lies in the interval form -1 to 1.

r1= ___________60855-(869)(670)/10____________
//{(755161)-(670)**2/10}{44890-(869)**2/10}

=____60855-58233__________=
(755161-44890)(448900-75516.1)

2632/514979.37=.00511 (Equ. 19)

r2=_________214275-(1477)(1190)/10________________
//{(1416100)- (1190)**2/10}{2140369-(1477)**2/10

=214275-175763/(1998769)(1997947.1)=

38512/1547391.3=.024

Table 12. Sample linear correlation

time/cost	time/cost
0.909	1.29
0.854	1.21
0.822	0.967
0.822	0.927
0.759	0.882
0.759	0.784
0.757	0.681
0.696	0.678
0.675	0.662
0.608	0.603

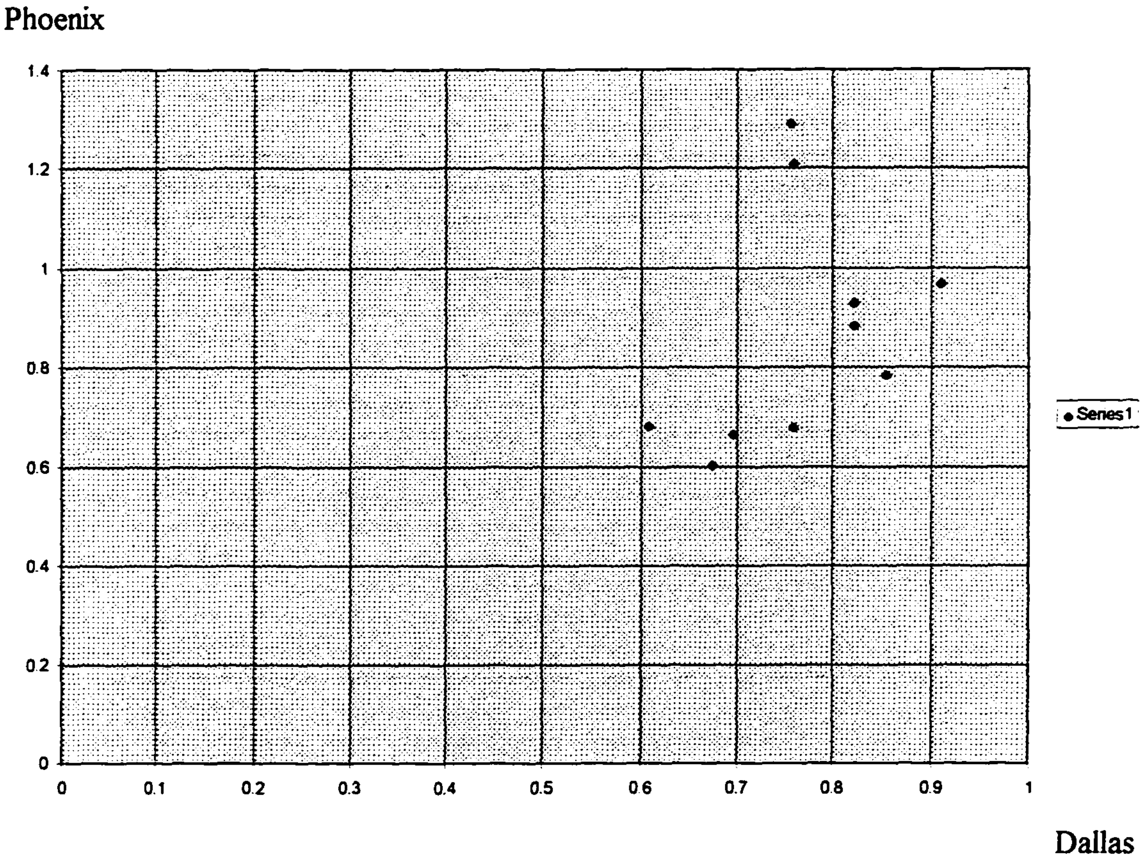


Figure 10. Sample linear correlation

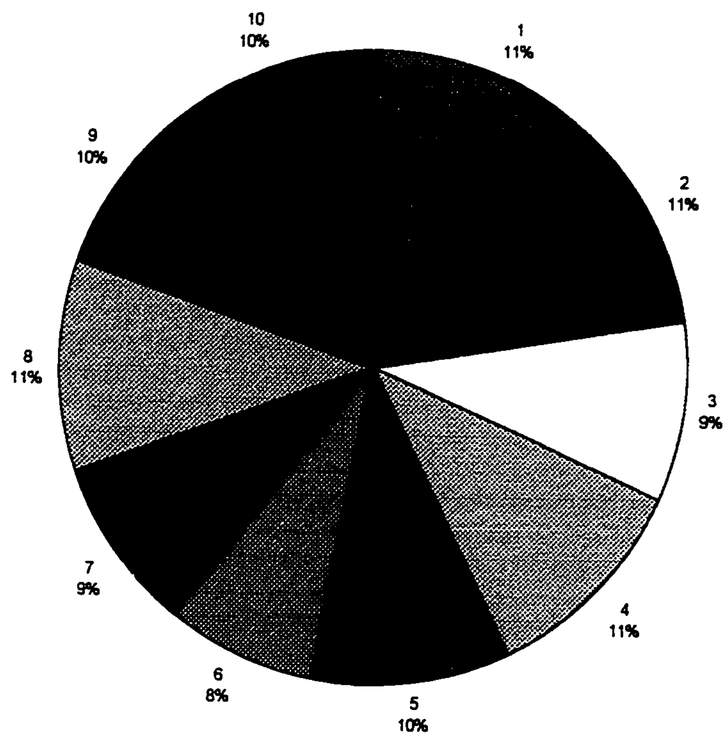


Figure 11. Pie chart of time/cost

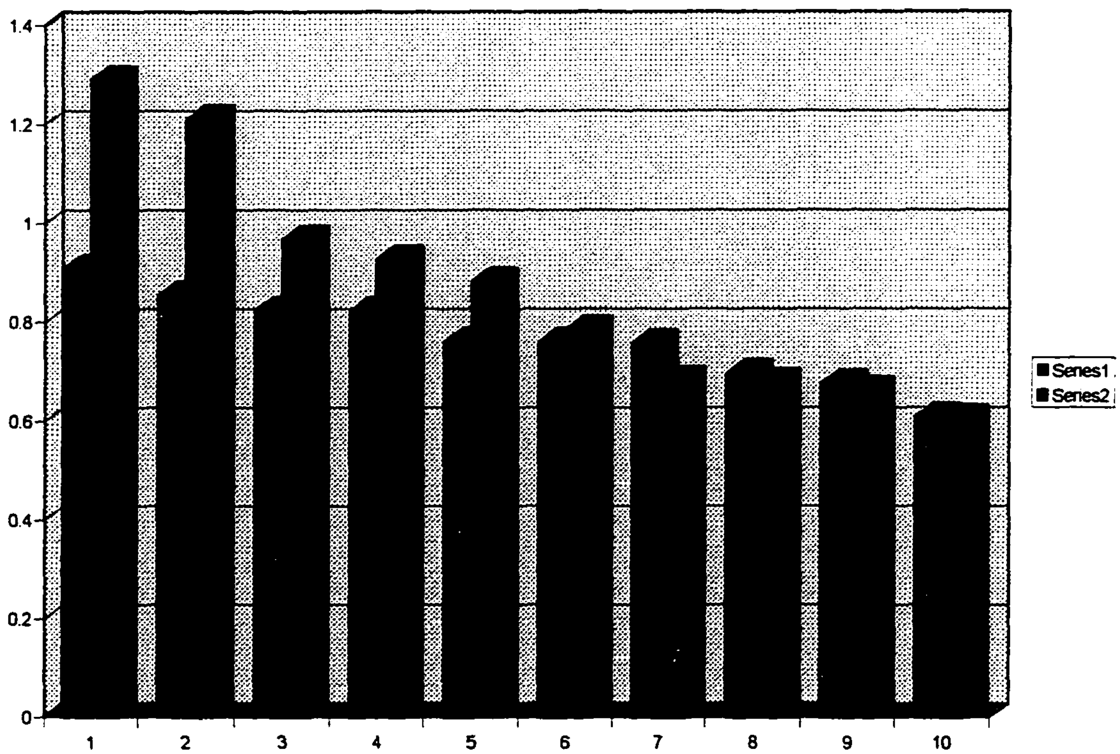


Figure 12. Time/cost

CHAPTER 5

CONCLUSIONS & RECOMMENDATIONS

The science of Industrial engineering is widely open to cover any aspect in any organization. This study made to test the application of I.E. tools in the flied of the airline industry, and with the limited support the author got for this subject still it became possible to come up the following conclusions.

1. Departments within the same company should be related to each other for the best optimal schedule.
2. Maintenance and overhauling must be made within the company maintenance for more cost reduction.
3. Operate same type of airplanes with the most efficient in fuel consumption, and less maintenance.
4. Using same kind of aircraft has positive effect toward cost reduction concerning spare part, training, and operation
5. Finding minimum cost for fuel tankering in the serviced cities, or suppliers. Planning flight fueling policy according to the fuel cost and the routing of each aircraft.
6. Considering hubbing as strategy for ultimate possible connection.
7. Hubbing can reduce the cost to operate, increase load factor, and more efficient.
8. Forecasting lead for better planning and more adequate schedule.
9. Change the flight schedule for seasonal variation and occasional events to met with market demand.
10. Fares reduction will increase demand.
11. Short range flying is more profitable than long one's.
12. Flying high effective hours will have direct impact on capital and operational cost.
13. Flying between major cities is essential for best maximum connection among the servicing map.
14. Using statistical analysis and operation research for most optimal results.
15. Establishing an industrial engineering department to maintain supervision and control over the whole operation.
16. Statistical analysis is important for updating any new information for future changes.
17. Using operation optimization to generate the largest profit factor.
18. Using transportation models will help in more efficient routing.

19. Flight simulation for compliance with airworthiness regulation, safety, reliability, economy, and comfort.
20. Maintenance department down sized up to 36%.
21. Maintenance schedule was improved by using Ghant chart.
22. Operation hours became more efficient by using line balancing
23. Rates must based on statistical analysis

BIBLIOGRAPHY

1. Bernard A., Schriever, and Seifert Willam W., "Air Transportation 1975 and Beyond: a system approach", *Massachusetts Institute of Technology*, 1969.
2. Blomquist, A.E, "Outline of Air Transport Practice", *Pitman Publishing Corporation*, 1941.
3. Boisseau Charles, "Heavy Stakes on flying Lite", *Houston Chronicale*,pp. f1, Aug,28,1994.
4. Burke Linda, "Touch act to Follow", *Dallas Time Herald*, October 5,1991.
5. Chakravarty Subrata N., "A Model of Superb Management: Hit 'Em hardest With The Mostest", *Forbes*, pp.48-51, September 16, 1991.
6. Chandler J. Greer, "Love Lost", *Frequent Flyer*, pp. 32-63, October, 1992.
7. Douglas George W., and Miller James C., "Economic Regulation of Air Transport", *The Booking Institution*, 1974.
8. Elsworth Peter, "Southwest Airlines New Push West", *The New York Time*, June 16, 1991.
9. Frederick S. Hillier, and Lieberman Gerald J., "Introduction to Operation Research", *Mc Graw Hill*, 1990.
10. Hansen Mark, and Kanafani Adib, "Hubbing and Airline Costs", *Journal of Transportation Engineering*, Vol.115, No 6, pp.581-590, Nov,1989.
11. Jeffrey L. Ethell, "Fuel Economy In Aviation", *NASA*, 1983.
12. Kpopf Gene, "Air Traffic Procedures", *Mc Graw Hill*, 1949.
13. Lee Alic M., "Applied Queuing Theory", *St Martin Press*, 1968.
14. Loockyer K.G., "An Introduction to Critical Path Analysis", *Sir Isaac Pitman and Sons LTD.*, 1969.
15. Masao Iri, Network Flow, "Transportation and Scheduling", *Academic Press*, 1969.
16. Maxon Terry, "Rising From Other's Ashes", *Dallas Morning News*, February 2, 1992.
17. Mierzejewski A. Edward, and Jackson Timothy, "Computerized Transportation Planning Models for site Impact analysis", *ASCE*, PP.128-132, 1992.
18. Mize Joe H., White Charles R., and Brooks George H., "Operation Planning and Control", *Prentice Hall*, INC., 1971.
19. O'Brian Bridget, "Flying on The Cheap", *The wall Street Journal*, October 26, 1992.
20. O'Brien James J., "Scheduling Handbook", *McGraw Hill*, 1969.
21. Ogburn William F., "The Social Effects Of Aviation", *The Riberide Press*, 1946.

22. Phillps Edward H., "Lower Costs Key to Airline's Survival", *Aviation Week & Space Technology*, pp.66-69, March 13,1995, and pp. 40-42 October 31, 1994.

23. R.R. Tadi, and Khasnabis S., "A Tool For Selecting Travel Demand Models", *Mathematical and computer Modeling*, Vol 12 No12, pp. 1465-1471, 1989.

24. Sanchez Jesus, "Just Plane Profitable", *Los Angles Time*, November 23, 1992.

25. Stevens James d., "Techniques For Construction Network Scheduling", *McGraw Hill*, 1990.

26. Straszhelm Mahlon R., "The International Airline Industry", *The Booking Institution*, 1969.

27. Stratford Alan H., "Air Transport Economics in the Supersonic Era", *Mac Millan st. Mattine Press*, 1973.

28. Stroup John S., and Wollmer Richard D., "Fuel management Model for The Airline Industry", *Operation Reseach*, Vol.40, No 2, pp.229-237, March 1992.

29. Tompkins James A., and White John A., "Facilities Planning", *John Wiley and Sons*, 1984.

30. Tsukiyama Makoto, and Ksazuyuki Mori, "Advanced Hybrid Scheduling System for Manufacturing", *Publication of IECON*, pp. 75-80, 1991.

31. Vardeman Stephen B., "Statistics for Engineering Problem Solving", *PWS Publishing*, 1994.

32. Walter Hamilton, "High Flier", *Los Angles Daily News*, October 11, 1992.

33. Weimin Yang, Zhu Yaun, Qingci Tu, and Yixing Sheng, "Simulation of Commercial Aircraft Reliability", *System Engineering Department*, Jan 29-31, 1991.

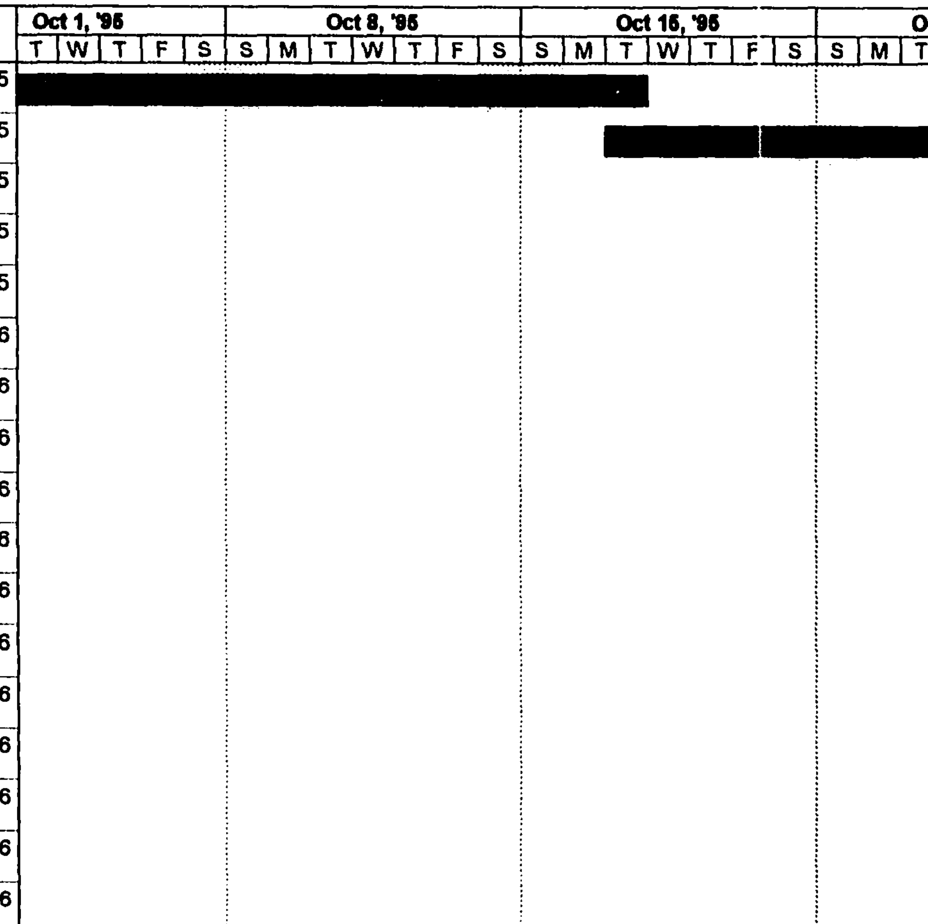
34. Weintraub Richard, "The Southwest Revolution", *The Washington Post*, September 12, 1993. Walter Hamilton, "High Flier", *Los Angles Daily News*, October 11, 1992.

35. Woodbury Richard, "Prince of Midair", *Time*, January 25, 1993.

APPENDIX

Ghant chart for maintenance schedule

ID	Task Name	Duration	Start	Finish
1	a check	11d	10/3/95	10/17/95
2	a check	11d	10/17/95	10/31/95
3	3a check	33d	10/31/95	12/14/95
4	a check	12d	11/14/95	11/29/95
5	a check	12d	11/29/95	12/14/95
6	b check	66d	12/14/95	3/13/96
7	a check	11d	12/29/95	1/12/96
8	a check	12d	1/13/96	1/29/96
9	3a check	33d	1/30/96	3/14/96
10	a check	11d	2/14/96	2/28/96
11	a check	12d	2/28/96	3/14/96
12	b ckeck	66d	3/15/96	6/13/96
13	a check	12d	3/30/96	4/15/96
14	a check	11d	4/16/96	4/30/96
15	3a check	33d	4/30/96	6/13/96
16	a check	12d	5/14/96	5/29/96
17	a check	11d	5/30/96	6/13/96



Project:
Date: 4/2/96

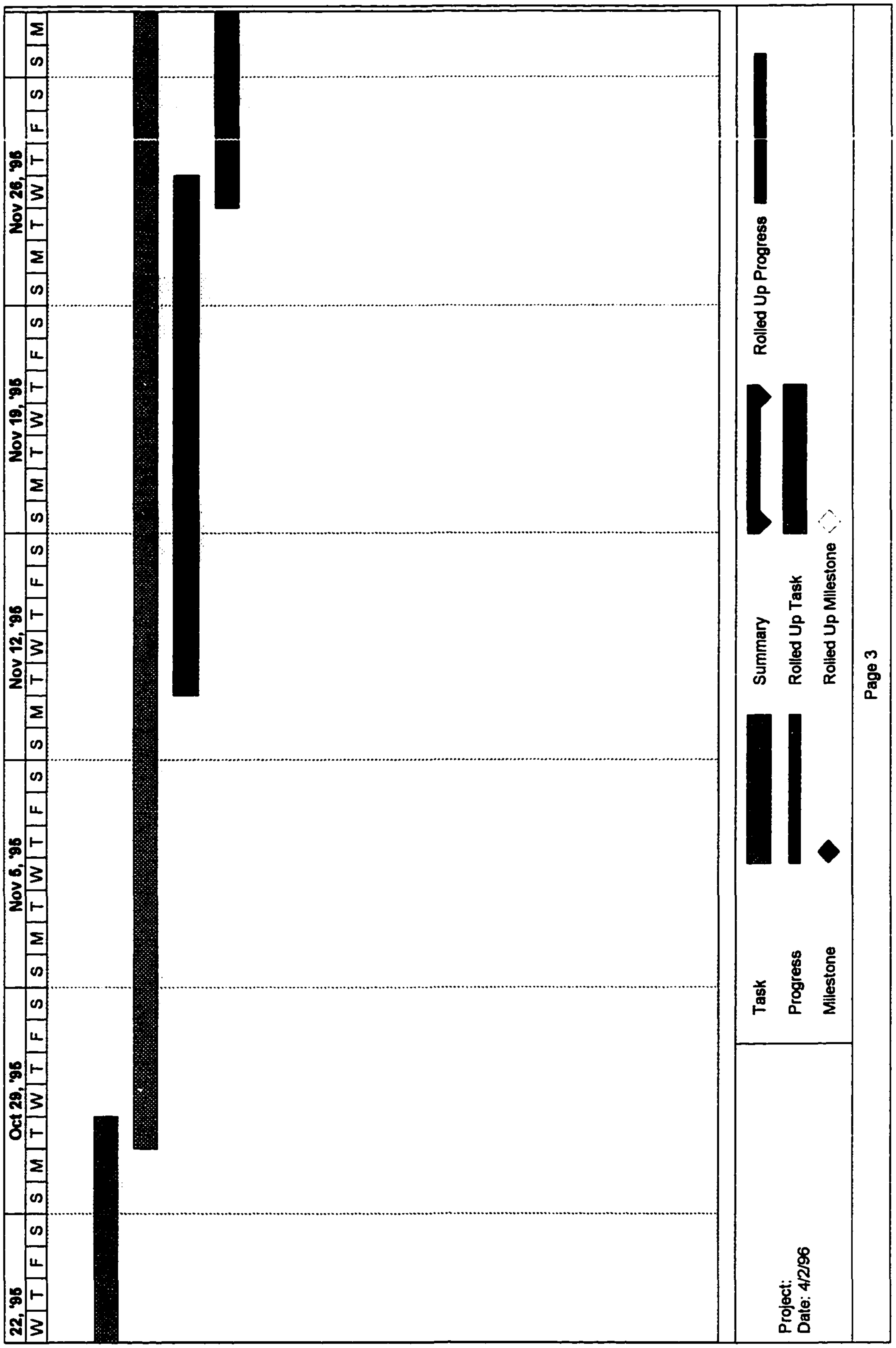
Task — Summary — Rolled Up Progress
Progress — Rolled Up Task
Milestone — Rolled Up Milestone

ID	Task Name	Duration	Start	Finish
18	b check	66d	6/14/96	9/12/96
19	a check	12d	6/29/96	7/15/96
20	a check	11d	7/16/96	7/30/96
21	3a check	33d	7/30/96	9/12/96
22	a check	12d	8/14/96	8/29/96
23	a check	11d	8/29/96	9/12/96

Oct 1, '95					Oct 8, '95							Oct 15, '95							Oc		
T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T

Project:
Date: 4/2/96

Task		Summary		Rolled Up Progress	
Progress		Rolled Up Task			
Milestone		Rolled Up Milestone			


22, '95
Oct 29, '95
Nov 5, '95
Nov 12, '95
Nov 19, '95
Nov 26, '95
W T F S S M T W T F S S M T W T F S S M T W T F S S M T W T F S S M T W T F S S M
Project:
Date: 4/2/96
Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress
Page 3

22, '95				Oct 29, '95							Nov 5, '95							Nov 12, '95							Nov 19, '95							Nov 26, '95								
W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M

Project:
Date: 4/2/96

Task

Progress

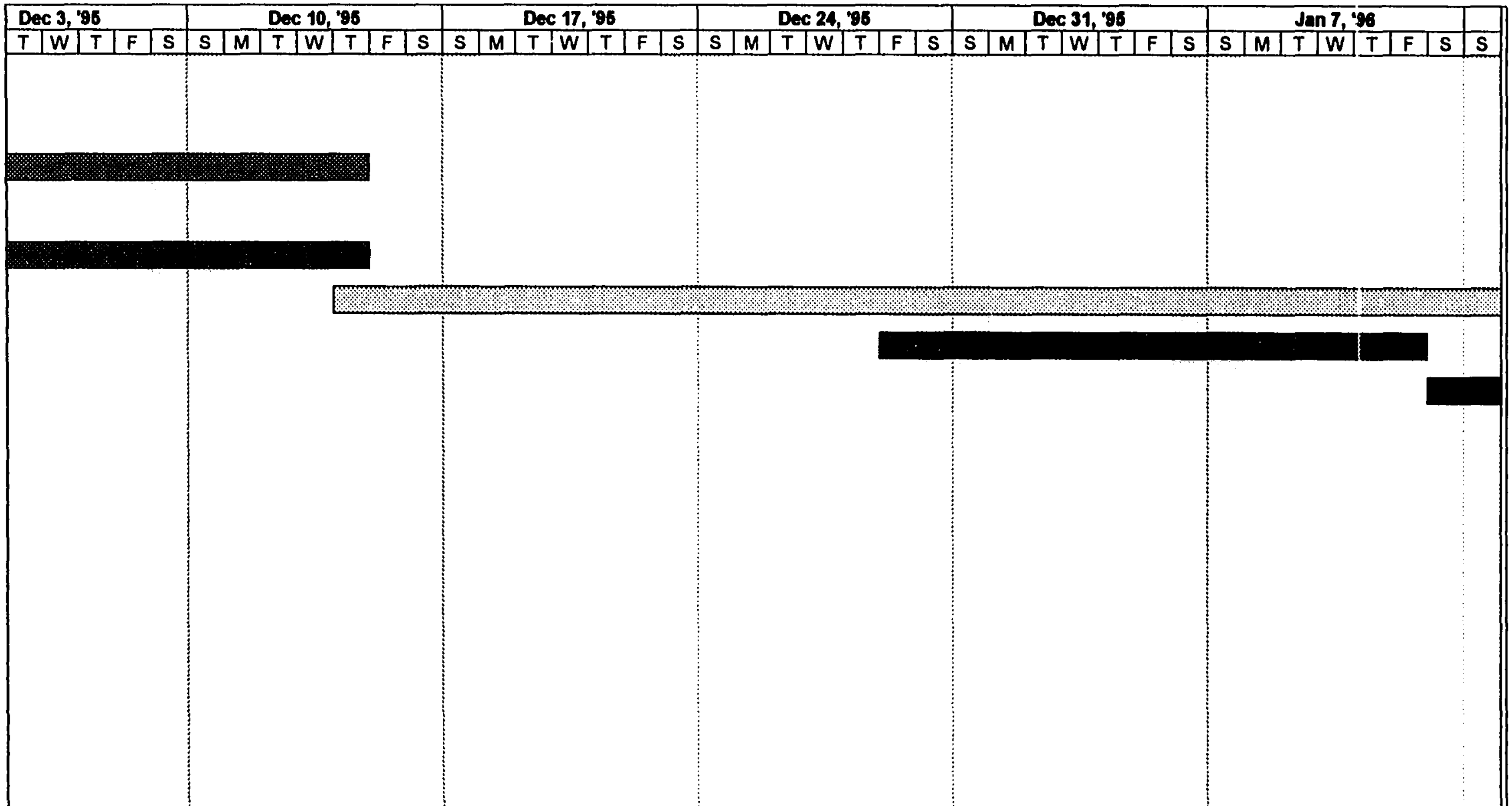
Milestone

Summary

Rolled Up Task

Rolled Up Milestone

Rolled Up Progress



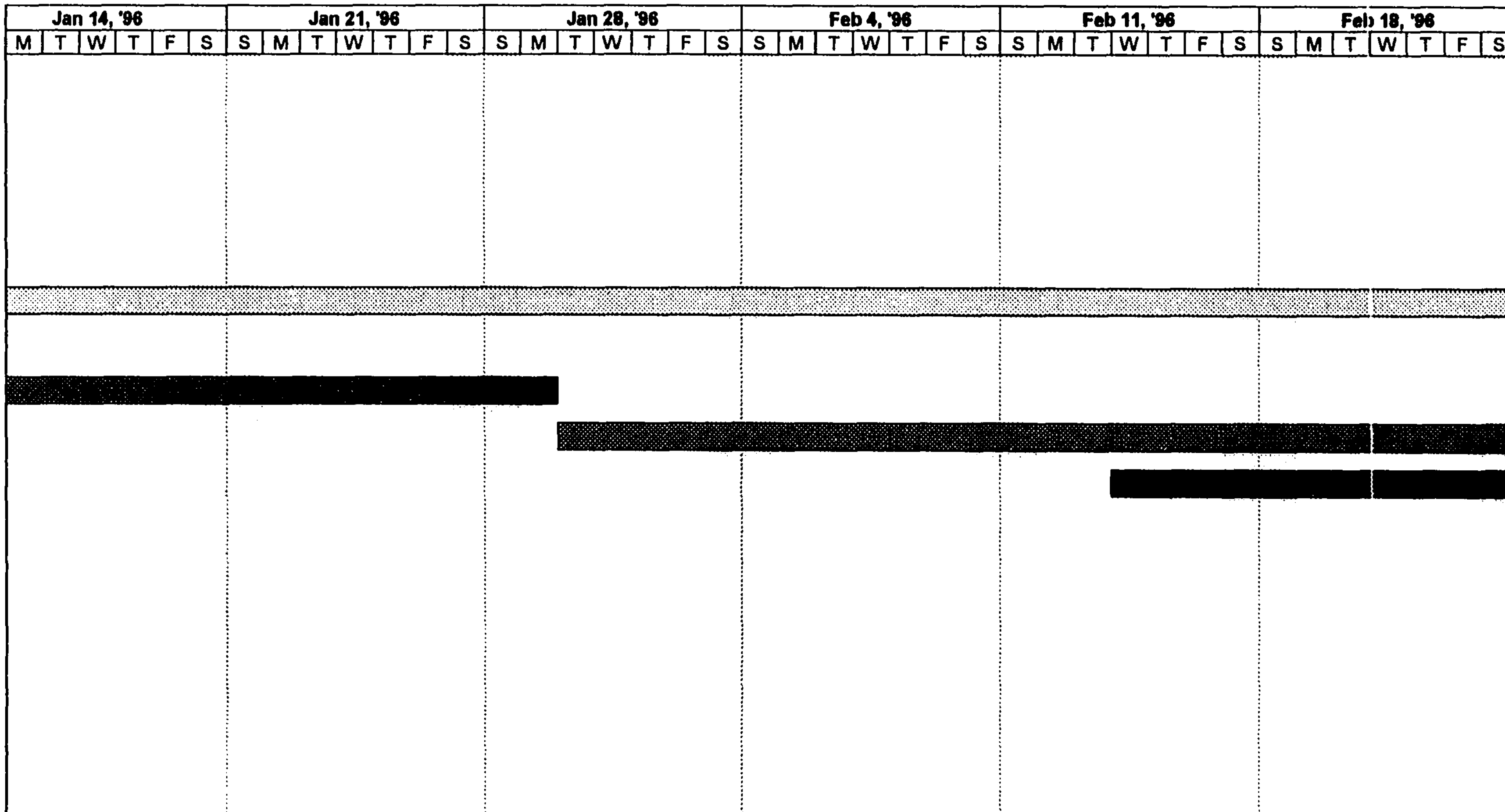
Project:
Date: 4/2/96

Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress

Dec 3, '95					Dec 10, '95							Dec 17, '95							Dec 24, '95							Dec 31, '95							Jan 7, '96							
T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S

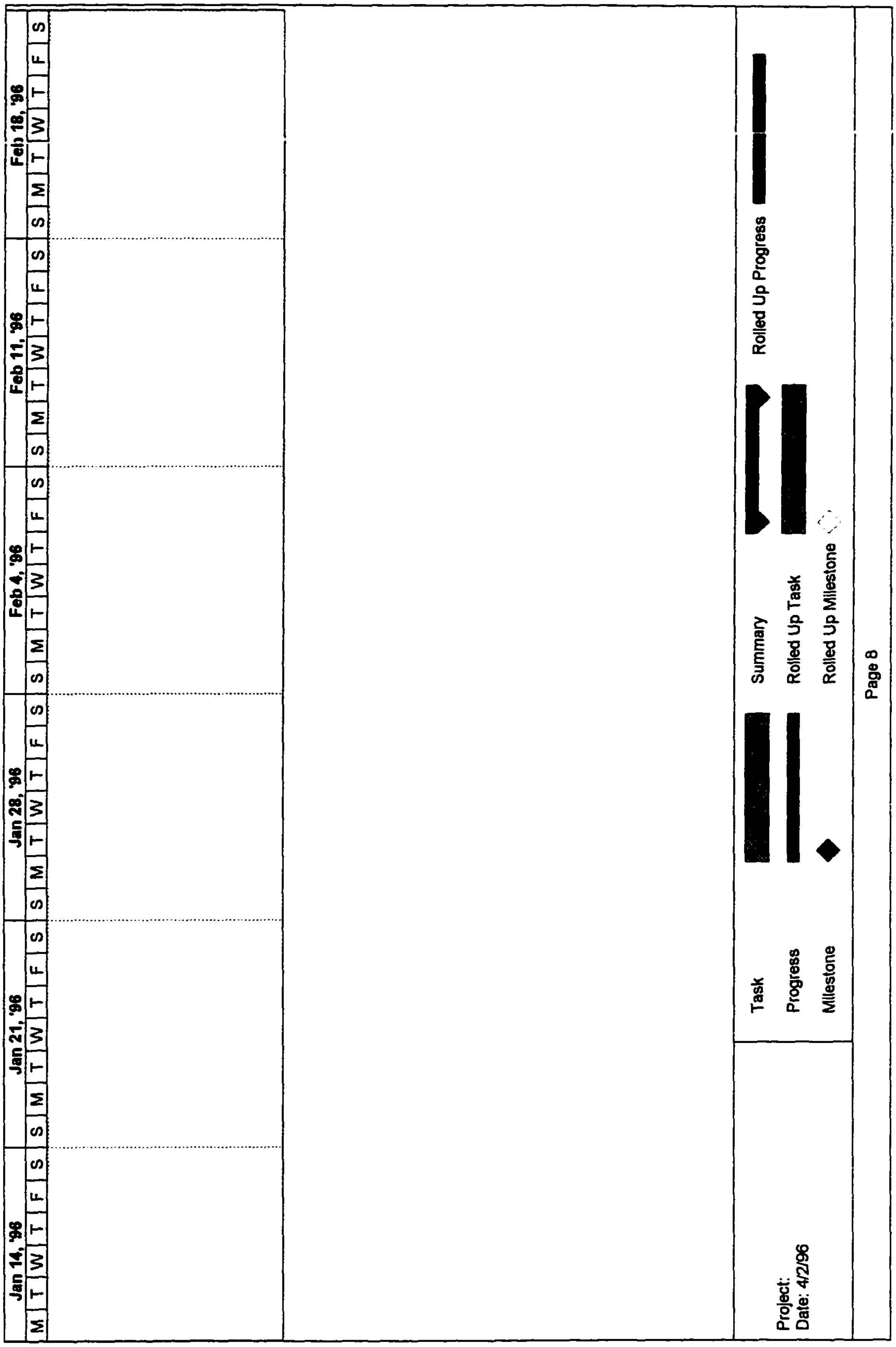
Project:
Date: 4/2/96

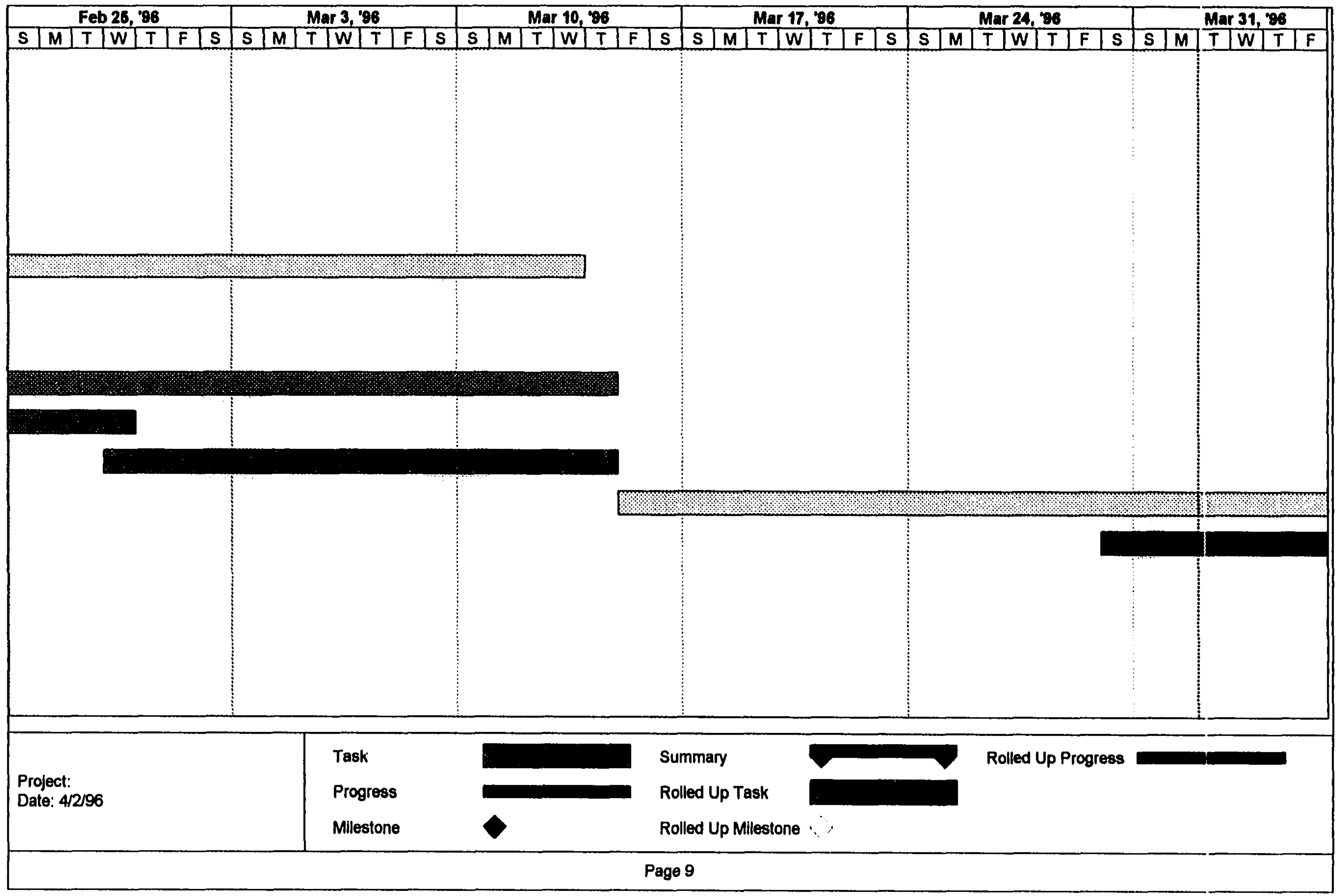
Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress



Project:
Date: 4/2/96

Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress


Jan 14, '96
M T W T F S
Jan 21, '96
S M T W T F S
Jan 28, '96
S M T W T F S
Feb 4, '96
S M T W T F S
Feb 11, '96
S M T W T F S
Feb 18, '96
S M T W T F S
Project:
Date: 4/2/96
Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress
Page 8


Feb 25, '96
Mar 3, '96
Mar 10, '96
Mar 17, '96
Mar 24, '96
Mar 31, '96
S M T W T F S
Project:
Date: 4/2/96
Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress
Page 9

Feb 25, '96							Mar 3, '96							Mar 10, '96							Mar 17, '96							Mar 24, '96							Mar 31, '96					
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F

Project: Date: 4/2/96	Task	Summary	Rolled Up Progress
	Progress	Rolled Up Task	
	Milestone	Rolled Up Milestone	

Project:
Date: 4/2/96

Task Summary Rolled Up Progress
Progress Rolled Up Task
Milestone Rolled Up Milestone

	Apr 7, '96							Apr 14, '96							Apr 21, '96							Apr 28, '96							May 5, '96							May 12, '96				
S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T

Project:
Date: 4/2/96

Task

Progress

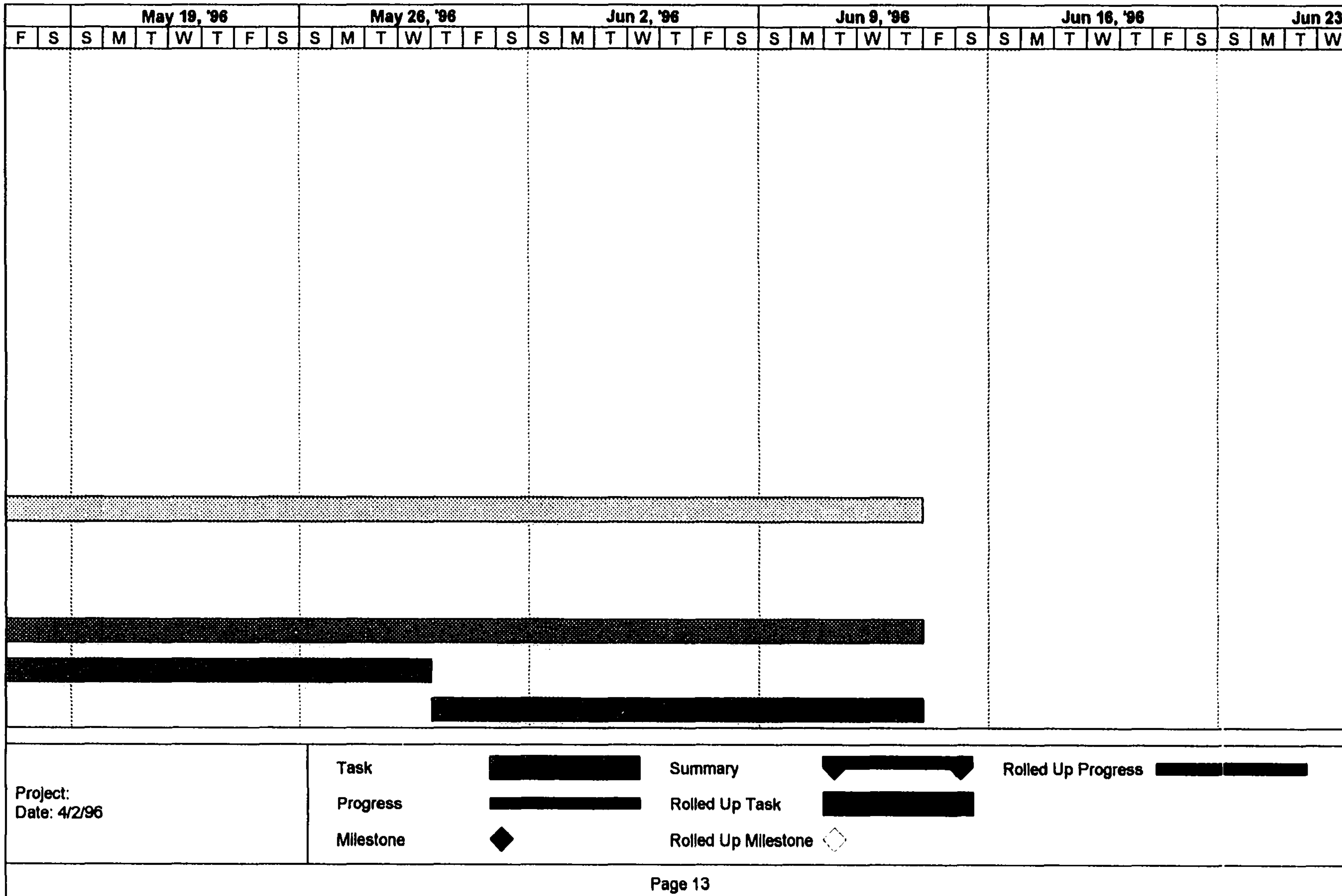
Milestone

Summary

Rolled Up Task

Rolled Up Milestone

Rolled Up Progress


May 19, '96
May 26, '96
Jun 2, '96
Jun 9, '96
Jun 16, '96
Jun 23,
F S S M T W T F S S M T W T F S S M T W T F S S M T W T F S S M T W T F S S M T W
Project:
Date: 4/2/96
Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress
Page 13

		May 19, '96							May 26, '96							Jun 2, '96							Jun 9, '96							Jun 16, '96							Jun 23,			
F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W

Project:
Date: 4/2/96

Task

Progress

Milestone

Summary

Rolled Up Task

Rolled Up Milestone

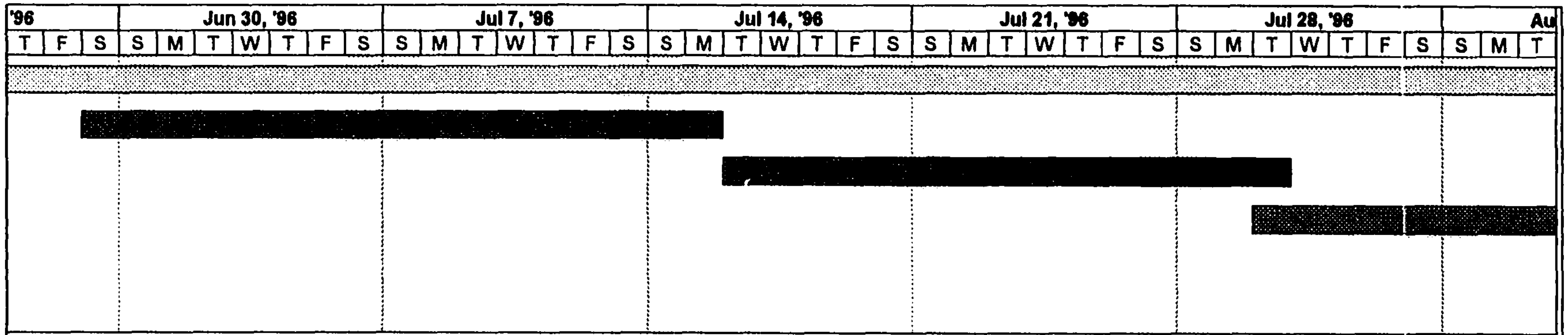
Rolled Up Progress

'96			Jun 30, '96							Jul 7, '96							Jul 14, '96							Jul 21, '96							Jul 28, '96							Au		
T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T

Project:
Date: 4/2/96

Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress

Page 15

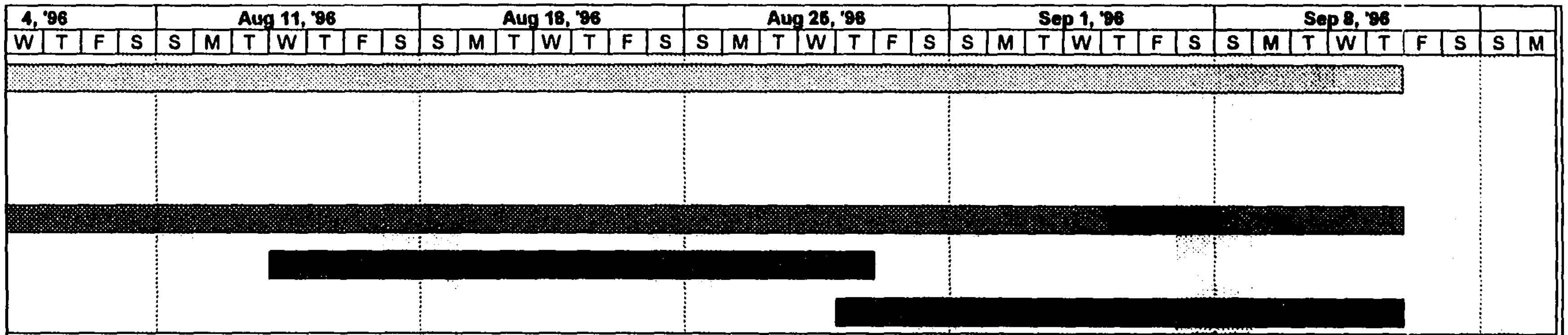


Project: Date: 4/2/96	Task		Summary		Rolled Up Progress
	Progress		Rolled Up Task		
	Milestone		Rolled Up Milestone		

4, '96				Aug 11, '96							Aug 18, '96							Aug 25, '96							Sep 1, '96							Sep 8, '96								
W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M

Project:
Date: 4/2/96

Task		Summary		Rolled Up Progress	
Progress		Rolled Up Task			
Milestone		Rolled Up Milestone			



Project:
Date: 4/2/96

Task
Summary
Rolled Up Progress
Progress
Rolled Up Task
Milestone
Rolled Up Milestone

VITA

Alaa Ahmed Elkodwa was born on July 23, 1968, in Damascus, Syria. After having the preliminary school, Alaa moved to Tunis, In 1985 graduated from the Iraqi high school in Tunisia, Tunis.

In December of 1985, Alaa joined Pakistan International Airline for three years, to graduate with Diploma in Aircraft Maintenance Engineering. In 1989 Alaa worked with some African airline as a maintenance engineer.

In September of 1990 Alaa attended Parks College of Saint Louis University, pursuing a B.S. in Aeronautical Engineering to graduate in July 1992.

Alaa commenced his graduate school in January 1993 in Texas A&M University Kingsville, and his due to acquire an M.S. Industrial Engineering on may 1996.

Mailing address is

P.O. box 572642

Houston TX 77257