PROFIT THROUGH PRODUCT QUALITY AND QUALITY SERVICE

by

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(ABSTRACT)

Many technical and business papers have been written proclaiming that companies which provide high quality products and high quality service will increase market share and profitability. Although the theory of the positive relationship between quality and profitibility (i.e. - higher product quality and service leads to higher profits) is commonly accepted, few studies have attempted to quantitatively justify this theory. The overall goal of this report is to present a quantitative framework that supports this commonly accepted positive relationship.

Two major difficulties arise when attempting to assess this relationship quantitatively. First, the relationships which link product quality and service to profitability are interdisciplinary and often imprecise. These relationships involve the social behavior and feelings of customers, the competitive marketing environment, the service policies and

technical competence of the producer, and of course the economic evaluation of improvements to quality and service.

Second, to accurately assess the impact of product quality and service on profitability the assessment must be done over time. This is very important, because the improvements in product quality and service are strategic policies for improving long-term profitibility. Evaluation methods which measure the short-term effects and/or the static effects of product quality and service on profitibility will be inaccurate.

To overcome these difficulties, first an extensive review of the literature on product quality, service and customer satisfaction was performed. This research led to the development of the many interdisciplinary cause-and-effect relationships which link product quality and service to profitibility. Then the interaction of these causal relationships was evaluated by using a dynamic modeling language (DYNAMO III).

The model results support the literature, indicating that companies providing both high quality products and high quality service will reap higher profits. Furthermore, the model provides a framework which, if further refined, could be used to help optimize the design of specific products.

ACKNOWLEDGEMENTS

I would like to acknowledge Digital Equipment Corporation and particularly the administrators of the Graduate Engineering Education Program (GEEP) without whom the last 16 months would not have been possible.

My thanks to the members of my faculty advisory committee for their guidance and support throughout this project.

Special thanks to my wife Donna for her tireless support of my work during the completion of this project and my other degree requirements.

DEDICATION

This project is dedicated to the loving memory of my grandfather, Edmond J. Picard (October 4, 1910 - July 2, 1991), whose constant dedication to quality in his own business as a floor layer is an inspiring example of the concepts discussed throughout this project. His dedication to quality and service allowed his business to thrive for over forty years, solely through positive word-of-mouth.

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I. INTRODUCTION

"Running a company by profit alone is like driving a car by looking in the rearview mirror. It tells you where you've been, not where you are going."

- W. Edwards Deming

At the onset of World War II, the focus on quality in United States industries was virtually non-existent. During the war, "crash" programs in quality were developed and the quality of products from U.S. industries improved dramatically.[1] Unfortunately, at the end of the war these improvements in quality were soon forgotten. The workers and their supervisors instructed in the "crash" quality programs during the war were not in a position to drive the decisions made by their companies.

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[1] Rafael Aguayo, Dr. Deming, The American who Taught the Japanese about Quality (New York: Carol Publishing Group, 1990), p. 237.

Management in these industries began to focus on production levels with quality as a secondary concern. A company that could produce in high quantity, regardless of quality, while keeping costs to a bare minimum seemed to be the company that would reap the best profits.[2] This management style, often referred to as financial results or visible numbers only (VNO)[3] management, has dominated U.S. business schools and U.S. businesses since World War II.

1.1 The Mystique of U.S. Management

The VNO management style has been utilized by most U.S. companies since the end of World War II. The basic management process involves determining how much profit the company needs to make and then examining the financial reports of the past to determine what costs must be cut and how much sales must be increased to realize the profit. For example, if a VNO manager wants to increase profit by 12 percent he might look at production costs and determine that a 10 percent reduction in production staff would result in a 6 percent cost savings. Then to realize the 12 percent profit goal he will just have to increase sales by 6 percent.

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[2] Rafael Aguayo, p. 237.
[3] Rafael Aguayo, p. 10.

If the VNO manager is successful his company looks healthy to the business world and the company's stock price will rise. This method of increasing profits without any focus on providing product quality and quality service will result in only short-term profit. The pressure on production to produce more with less workers and the pressure on the sales force to constantly produce more sales will result in a work force focussed on pushing product out the door regardless of quality. Customers will not be fooled by the company's positive financial results, the shoddy merchandise will result in lost customers and negative word-of-mouth. If the company does not take actions to stop this negative impression, its decline will be quite rapid.

One of the most prevalent examples of the failure of the VNO management style is the decline of ITT in the late 1970s. Between 1961 and 1977 under the VNO management style of Harold Geneen, ITT increased its earnings from $29 million to $562 million and absorbed some 350 different businesses on its rise to the ninth largest corporation in the Fortune 500.[4] In the late 1970s, the firm started to lose its credibility as the products and services of ITT and its many subsidiaries were criticized for their poor

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[4] Harold Geneen and Alvin Moscow, Managing (New York: Avon Books, 1985), p. 2,3.

quality. The company declined to a fraction of its former size.[5]

An analogy written by Rafael Aguayo, a student of W. Edwards Deming for over seven years, summarizes nicely what is wrong with using the VNO approach to management. Aguayo writes:

> "To navigate the oceans of the world, we need to know about longitude and latitude... In business we need at least two sets of numbers to operate properly. We need to know about the financial numbers, such as profit, and we need to know about quality."

1.2 Quality as a Pressing Business Concern

With the failure of VNO management in U.S. companies such as ITT and less dramatically in other companies, some U.S. companies have searched for new management styles. During the search for new management methods the U.S. has invariably turned to Japan where the worldwide desirability of Japanese products has allowed Japanese companies to dominate many markets, including consumer electronics, integrated circuits, cameras and automobiles. Japanese goods were not always so desirable. In the 1950s, Japan had a reputation for shoddy consumer goods and the nation as a whole had a negative net worth.[6]

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[5] Rafael Aguayo, p. 24.

[6] W. Edwards Deming, Out of the Crisis. (Cambridge Massachusetts: M.I.T. Center for Advanced Study, 1986), p. 5.

Surprisingly, the man that the Japanese credit with starting them towards becoming worldwide economic leaders is an American, W. Edwards Deming. Deming, a worldwide renown statistician and quality expert, was invited to Japan by the Japanese Union of Scientists and Engineers (JUSE) after World War II. During many days, he spoke to top management of Japanese firms about his beliefs that management commitment to improve quality would make Japan economically competitive, worldwide, within five years.[7]

Deming taught management the relationships between quality and profit, quality and productivity and quality and competitive market position. Figure 1 shows this chain reaction. Using Figure 2, Deming explained that the consumer must be considered as an integral part of the production line.

The management style, presented to the Japanese over 40 years ago by Deming is being adopted and recognized as the key to success by more and more U.S. companies every year. The companies which continue to ignore the benefits of product quality and quality service will find themselves unable to compete in the marketplace.

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[7] Rafael Aguayo, p. 6.

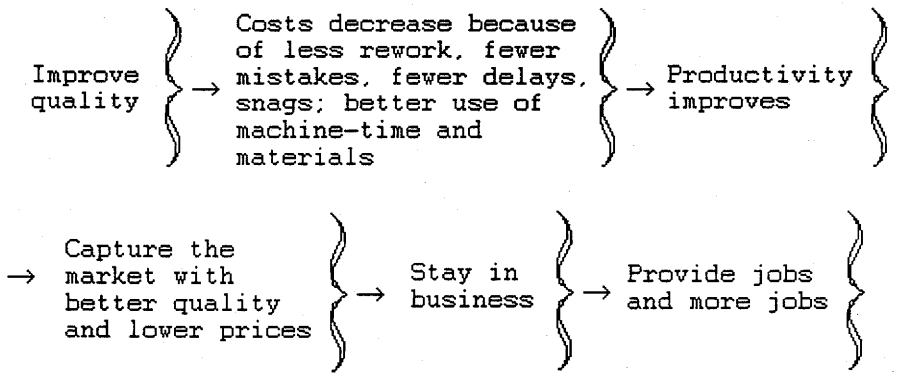

Figure 1 - Quality Improvement Chain Reaction
(Deming, 1986)

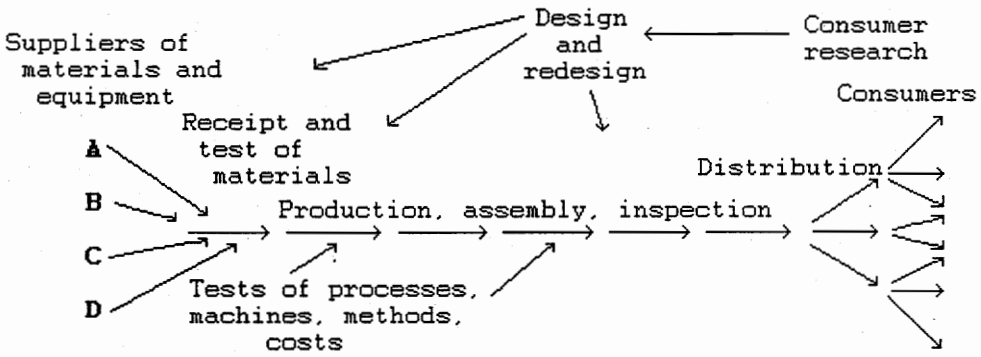

Figure 2 - Consumer Included in Production Flow (Deming, 1986)

1.3 Project Overview

A recent survey by Business International (BI) of over 400 CEOs, worldwide, verified that customer satisfaction through product quality and quality service is becoming the most important strategic direction of companies. In the BI report entitled "Maximizing Customer Satisfaction: Meeting the Demands of the Global Marketplace", over half of the 400 CEOs interviewed cited customer satisfaction as their number one objective. The CEOs believe that their efforts to increase customer satisfaction will lead to increased market share, customer loyalty and profitability. The chain reaction which Deming impressed upon the Japanese after World War II has finally reached worldwide popularity.

The purpose of this project is to examine the causal relationships between product quality, quality service and profit. Through the development of a simulation model of these causal relationships a more quantitative understanding of the chain reaction discussed by Deming and other quality consultants will be developed. The model will focus on companies which produce and service durable goods.

Before development of the model is discussed their will be some background material presented on product quality, customer expectations of service, creating loyal customers, and the importance of customer complaints.

II. WHAT IS PRODUCT QUALITY?

"Quality, of course, is a fuzzy concept. It's almost like a work of art --difficult to define because it means radically different things to different people."

- Lee Iacocca

2.1 The Many Definitions of Quality

With the acknowledgment of product quality and quality service as a pressing business concern, many people from varying disciplines have considered the subject. These different disciplines which include philosophy, economics, marketing, and operations management (manufacturing and engineering) have all derived definitions for quality. These different disciplines have taken various approaches to the subject of quality. These approaches include: (1) the Transcendent approach of philosophy; (2) the Product-based approach of economics; (3) the User-based approach of economics, marketing and operations management; and (4) the Manufacturing-based and (5) Value-based approaches of operations management.[8] A summary of how quality is defined in each approach is presented in Table 1.

Although these many definitions create the potential for conflict among the members of the product team, they are

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[8] David A. Garvin. "What Does "Product Quality" Really Mean?" Sloan Management Review. (Fall1984), p. 25.

Table 1 - Definitions of Quality
(Adapted from Garvin, 1984)

Approach	**Definition** (Source)
Transcendent	"...it is hard to identify or measure quality, but the absence of it stands out like Bermuda shorts worn to a black tie affair." (Rafael Aguayo, Dr. Deming, The American who Taught the Japanese about Quality. p. 35.)
Product-based	"Differences in quality amount to differences in the quantity of some desired ingredient or attribute." (L. Abbott, Quality and Competition. pp. 126-127.)
User-based	"Quality is the degree to which a specific product satisfies the wants of a specific consumer." (Joseph M. Juran, Editor in Chief, Quality Control Handbook. pp. 1-2.)
Manufacturing-based	"Quality [means] conformance to requirements." (Philip B. Crosby, Quality is Free. p. 15.)
Value-based	"Quality is the degree of excellence at an acceptable price and the control of variability at an acceptable cost." (R.A. Broh, Managing Quality for Higher Profits. p.3.)

all essential to the development of a high quality product.[9] Initially in the development stages, the marketing people must determine what the customers want; then these attributes must be translated into product attributes within the economic constraints of the project; and finally, manufacturing must ensure conformance to design requirements. Failure in any one of these development stages will result in sub-optimal product quality.

2.2 The Eight Point Concept of Product Quality

One of the most intriguing breakdowns of product quality in the present literature is presented by David A. Garvin in "What Does "Product Quality" Really Mean?". Garvin presents an eight dimension framework for product quality. Each dimension with an abridged description is presented in Table 2.

These dimensions reinforce the need for various disciplines to work together when developing a high quality product. Performance, Features, Aesthetics and Perceived Quality are all highly subjective characteristics and should be defined through marketing research and carefully designed into the product by engineering. Reliability, Conformance, Durability, and Serviceability also require an

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[9] David A. Garvin, p. 29.

Table 2 - The Eight Dimensions of Product Quality

Dimension	**Description**
1) Performance	The primary operating characteristics of the product.
2) Features	The "bells and whistles" of products. Secondary characteristics that supplement the product's basic functions.
3) Reliability	The probability that a product will operate for a specified period of time under specified operating conditions.
4) Conformance	The degree to which the manufactured product meets the specified design standards.
5) Durability	The amount of use one gets from a product before replacement is considered economically preferable to continued repair.
6) Serviceability	The ease, accuracy, safety and economy with which service can be performed.
7) Aesthetics	How the product looks, feels, sounds, tastes or smells.
8) Perceived Quality	Indirect quality measure through comparison to similar products.

interdisciplinary effort including marketing, engineering, and manufacturing personnel. Throughout the development, economic constraints must also be considered.

All the effort to understand the factors and methods which influence product quality are driven by the belief that higher quality yields higher profits.

2.3 Quality and Profitability

Perhaps the greatest practical support for the positive link between quality and profit (i.e. - as quality improves so does profit) resides in the data base of the Profit Impact Strategies (PIMS) program. As of 1980 over 200 corporations were involved in the PIMS project which is conducted by the Strategic Planning Institute in Cambridge, Massachusetts.[10] Each company provides financial, market and competitive information on their products. The reports developed from this information provide companies with present performance data in their respective industries from which future strategic plans can be developed.

One of the key strategic relationships which has been investigated using the PIMS data base is the quality and profit relationship. According to Schoeffler, Buzzell and Heany, in an investigation of businesses with less than 12

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[10] Robert D. Buzzell and Frederik D. Wiersema, "Succesful Share Building Strategies" Harvard Business Review. (January-February 1981): 135-144.

percent of the market, those with inferior product quality averaged a return on investment of 4.5 percent, those with adequate product quality averaged an ROI of 10.4 percent and those with superior product quality averaged an ROI of 17.4 percent. Also, from PIMS data, Buzzell and Wiersema found that increases in product quality led to increases in market share as shown in Table 3.

2.4 Management's Responsibility

With empirical evidence, that higher quality means higher profits many companies have turned to quality consultants for advice on how to improve quality. It is by no mistake that the leading quality consultants, such as Phil Crosby and W. Edwards Deming, emphasize management reform when discussing quality improvement.

Management must openly embrace and live the quality message if product quality and quality service are the goal. There will be no quality if management emphasizes production quotas over production quality; if management cuts training costs to improve profit margins; if management treats quality as something to be inspected into, instead of designed into the product; if management creates barriers between internal departments of the company; etc.

Table 3 - Change in Quality vs. Change in Market Share
(Adapted from Buzzell, Wiersema, 1981)

Change in relative quality	**Consumer products**	**Raw materials**	**Industrial products**
Reduced	+2.1 %	-0.9 %	+0.7 %
No change	+0.1 %	+0.8 %	+2.5 %
Increased	+4.0 %	+2.1 %	+4.3 %

* Note - Table entries signify percentage of market gain

Management is the key driving factor which determines whether or not quality will succeed. As W. Edwards Deming once said, "Quality is made in the boardroom".

III. CUSTOMER EXPECTATIONS OF SERVICE

"Nobody talks about "good" service"

- Jerry R. Wilson

Recently, as shown in the 1991 report by Business International entitled "Maximizing Customer Satisfaction: Meeting the Demands of the New Global Marketplace", customers are choosing companies not only for the quality of their products, but also for the quality of their service. Defining the level of quality service has been as difficult as defining product quality. However, a common belief in all level-of-service definitions, is that the level of service depends on the customer's expectations.

3.1 Level of Service Defined by Customer Expectations

Customer expectations divide level of service into three ranges; poor, adequate (good) and excellent. The boundary between poor and adequate is marked by the minimum customer expectations and the boundary between adequate and excellent is marked by the maximum customer expectations. Figure 3 gives a pictorial representation of this concept.

Depending on the type of product or type of customer the ranges of poor, adequate and excellent will vary. The key strategy for companies is to understand the customer

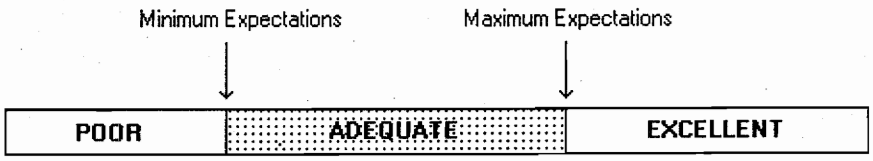

Figure 3 - Level of Service Determined by Customer Expectations (Adapted from Wilson, 1991)

expectations and develop strategies to exceed the customer's maximum expectations. If they succeed, the company's service will be perceived as excellent by the customer and customer loyalty and positive word-of-mouth will follow. If they settle for adequate service no one will talk positively, and if they slump into poor service customers will soon be lost customers that will create negative word-of-mouth.

3.2 Using the Service Process Dimensions

One of the most plausible strategies for exceeding customer expectations of service is presented by Parasuraman, Berry and Zeithaml in their paper entitled "Understanding Customer Expectations of Service". Parasuraman, Berry and Zeithmal breakdown service into five dimensions as presented in Table 4. They refer to the last four dimensions (Tangibles, Responsiveness, Assurance and Empathy) as the process dimensions and the "key" to exceeding customer expectations. Although Reliability is the most important dimension required to meet customer expectations, the other dimensions are most important for exceeding customer expectations.

Tangibles, Responsiveness, Assurance and Empathy are referred to as the process dimensions, because they define

Table 4 - The Five Dimensions of Service
(Adapted from Parasuraman, Berry and Zeithaml, 1991)

Service Dimension	**Definition**
Reliability	The ability to perform the promised service dependably and accurately.
Tangibles	The appearance of physical facilities, equipment, personnel, and communication materials.
Responsiveness	The willingness to help customers and provide prompt service.
Assurance	The knowledge and courtesy of employees and their ability to convey trust and confidence.
Empathy	The caring, individualized attention provided to the customer.

the delivery of the service by the service personnel. Often exceeding in these areas is as simple as smiling as you serve a customer or providing true empathy as you try to resolve a customer problem.

Tom Peters and Nancy Austin point out in "A Passion for Excellence", that it is the little things which make the lasting impressions. In their interview with Don Burr, chairman of People's Express, Don said; "Coffee stains on the flip-down trays [in the airplane] mean [to the passengers] that we do our engine maintenance wrong". On the positive side they relate a story of an avid skier and his many friends who rave about the Kleenex box that one resort provides at the head of the lift line. Accumulating "Kleenex box" stories and avoiding the "coffee stain" stories can be the driving factor behind positive perceptions of service.

3.3 Management and Service Personnel

Providing excellent service requires excellent service people. However, all to often managers fall into what Shlesinger and Heskett refer to as the "Cycle of Failure" in their paper entitled "Breaking the Cycle of Failure in Service". This concept which involves interaction between service personnel, customers and resulting customer satisfaction is shown in Figure 4. To break this cycle,

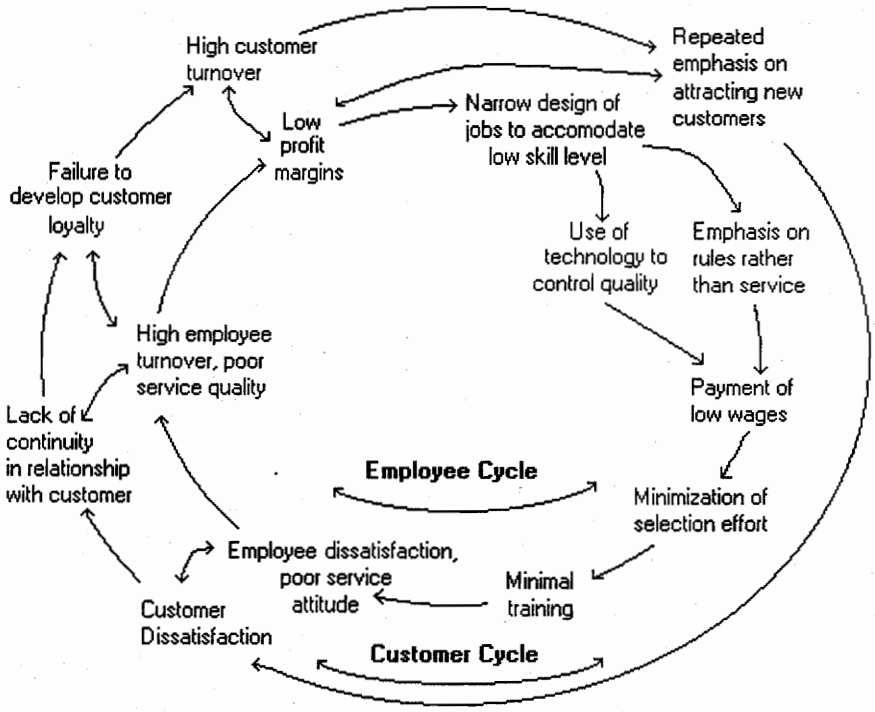

Figure 4 - The Cycle of Failure
(Adapted from Schlesinger and Heskett, 1991)

Schlesinger and Heskett urge managers to promote the "Cycle of Success" as shown in Figure 5.

As one can see, service as well as quality is very dependent upon management practices.

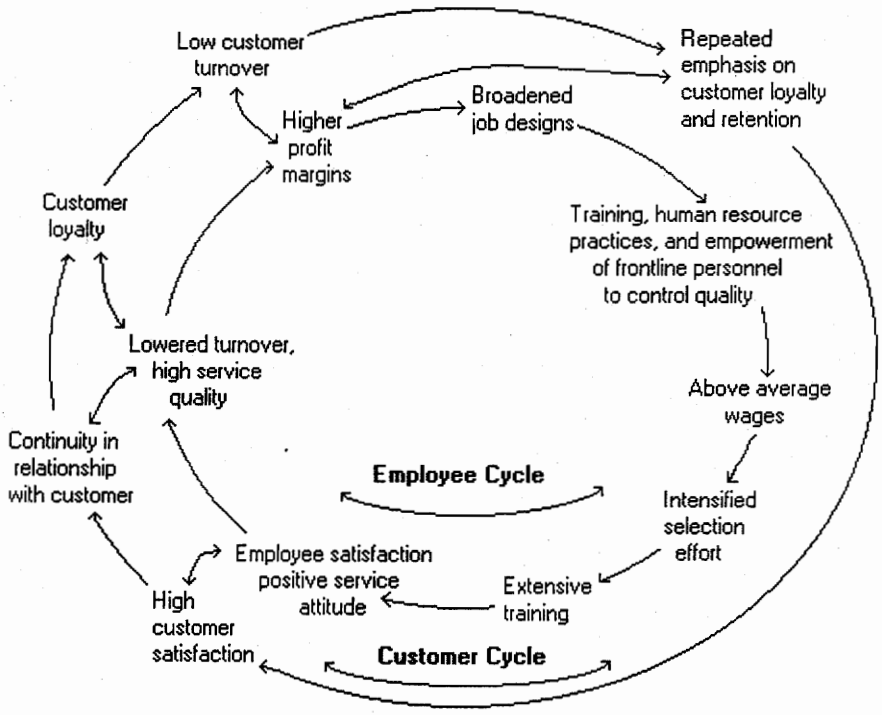

Figure 5 - The Cycle of Success
(Adapted from Schlesinger and Heskett, 1991)

IV. CREATING LOYAL CUSTOMERS

"The proof of the pudding is not in the tasting but in whether or not people return for a second helping"

- Bob Levoy, Consultant

High product quality and service can provide companies with increased profits and positive word-of-mouth leading to increased market share. The primary force which creates this atmosphere for the company with quality products and services is the increasing body of loyal customers it creates. To create and keep loyal customers the company must understand the different levels that customers must progress through to become loyal customers. They must also understand the affects of service and quality which cause the transitions between levels.

4.1 The Customer Pyramid

The levels which customers progress through on their way to becoming loyal customers is often presented in the form of a "customer pyramid" as shown in Figure 6. A brief definition of each group is shown in Table 5.

The movement of the customer from General Public to Loyal Customer and the causal effects of quality and service are the key to the model developed in section VI.

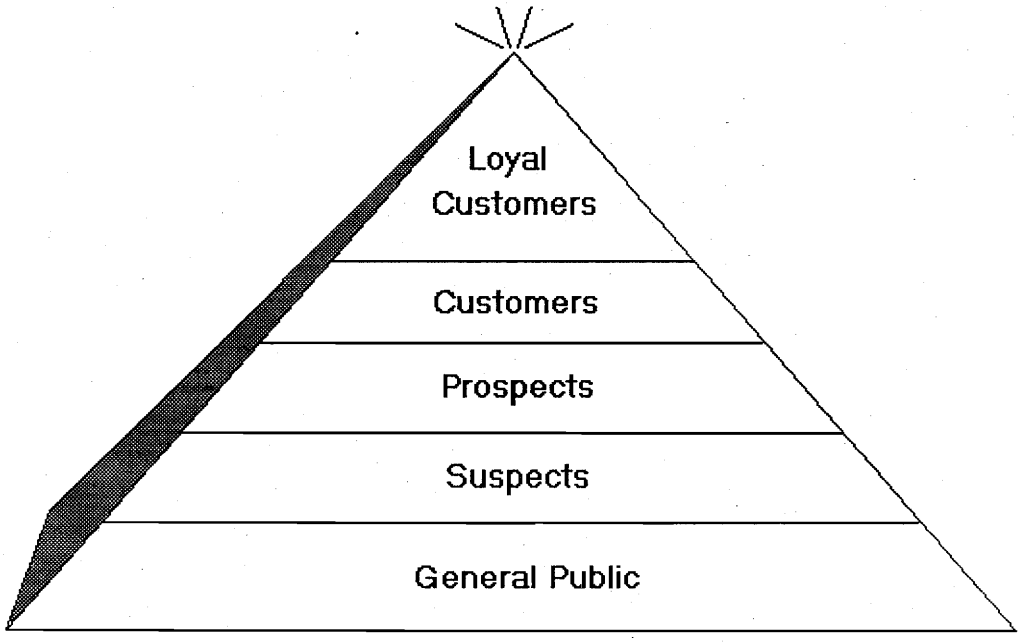

Figure 6 - The Customer Pyramid
(Adapted from Wilson, 1991)

Table 5 - Definitions of Customer Levels

Level	**Definition**
General Public	These are the potential people that your company could serve, but at the present time these people have no need for your company's products or services.
Suspects	These are the people who have identified a need for a product or service which your company offers, but may or may not know of your company.
Prospects	These are the people who have identified a need for a product or service which your company offers and have decided to consider your company.
Customers	These are the prospects who have decided to purchase products or services from your company.
Loyal Customers	These are the customers who would recommend your company to people and intend to or have made follow-on purchases with your company. Their expectations are constantly exceeded by your company.

4.2 The Profitability of Loyal Customers

Loyal Customers create more profit. Deming concludes that profit from loyal customers is six to eight times more than from other customers.[11] In a survey by Business International, 5 % increases in customer retention rates created profitability increases from 20 to 125 %.[12] This data is shown by industry in Figure 7.

Loyal customers are more profitable for the following reasons:

1) The cost of acquiring new customers can be substantial. Customer loyalty implies fewer customers need to be acquired.

2) Loyal customers tend to buy more.

3) Loyal customers place frequent, consistent orders, therefore, usually cost less to serve.

4) Loyal customers are often willing to pay premium prices to suppliers they trust.

5) Retaining customers makes market entry or gain difficult for competitors.

6) Loyal customers often refer new customers to the supplier.[13]

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[11] Rafael Aguayo, p. 8.

[12] Andrea Mackiewicz, Maximizing Customer Satisfaction. (New York: Business International Corporation, 1990), p. 10.

[13] Andrea Mackiewicz, p. 11.

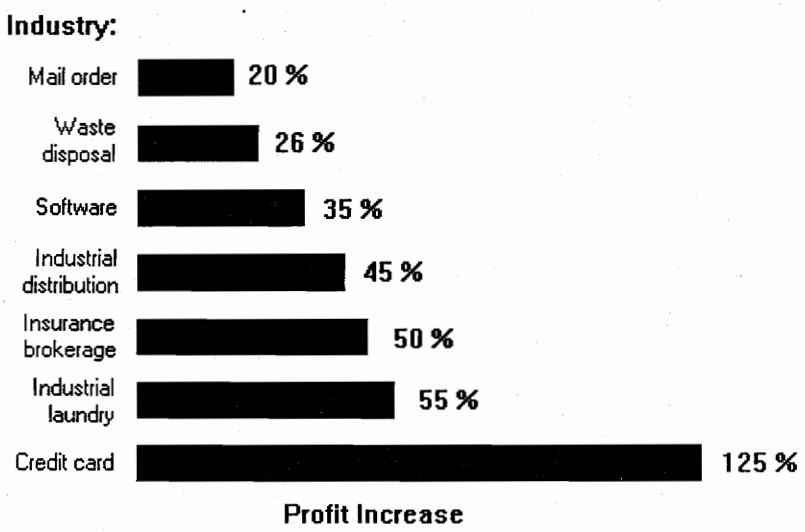

Figure 7 - Profit Increase from 5 % Increase in Customer Retention Rate (Mackiewicz, 1990)

4.3 Word-of-Mouth

Word-of-mouth, or the "talk factor" as Jerry Wilson calls it in his book "Word-of-Mouth Marketing" is a powerful influencing factor in the business world. Loyal customers will tell positive stories about your company, but more importantly, dissatisfied customers will tell negative stories about your company at a higher rate. In a Technical Assistance Research Progress Institute (TARP) study, sponsored by Coca-Cola USA, it was found that dissatisfied customers told a median of 10 people about their negative experience whereas satisfied customers told a median 4 people of their positive experience. In the automotive industry, dissatisfied customers related their negative stories to a median of 16 other people whereas satisfied customers told their positive stories to a median of 8 people.[14] These surveys support a talk factor of 2 bad stories for every good story, however, other researchers support the notion that this factor could be as high as 11 bad stories for every good story.[15]

The fact that people are more willing to relate negative experiences is not hard to believe. We have all been to dinner parties where after dinner conversations lead

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[14] Andrea Mackiewicz, p. 13.

[15] Jerry R. Wilson, Word-of-Mouth Marketing. (new York: John Wiley & Sons, 1991), p. 22.

to a variety of different horror stories about individual experiences.

The important thing for companies to do is silence the negative talk by continually satisfying their customers. If the company allows too many customers to become dissatisfied the negative word-of-mouth will dominate and the future of the company will be jeopardized.

V. THE IMPORTANCE OF CUSTOMER COMPLAINTS

"We have to find them [car owners with problems]. We have to actually solicit complaints. If we are able to do a good job of satisfying them the first time, we'll not only win them as customers but they'll tell their friends, neighbors and other people about their satisfactory experience."

- Lloyd Reuss, V.P. General Motors of Canada

An effective strategy for preventing customer dissatisfaction is to resolve customer complaints. In fact, data collected by TARP suggests customers whose complaints are resolved to their satisfaction are as likely, and often times more likely, to become loyal customers than customers with no complaints.[16] This makes good intuitive sense, because a company that has a record of resolving customer problems assures their customers that future problems will be resolved.

The biggest problem with this strategy of resolving customer problems is getting customers to complain. A recent consumer affairs survey reveals that most businesses can expect 96 % of all customers who have problems will NOT complain![17] An industry specific study by TARP (Figure 8)

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[16] Andrea Mackiewicz, p. 15.

[17] Joan Coob Cannie and Donald Caplin, Keeping Customers for Life. (New York: AMACOM, 1991), p. 16.

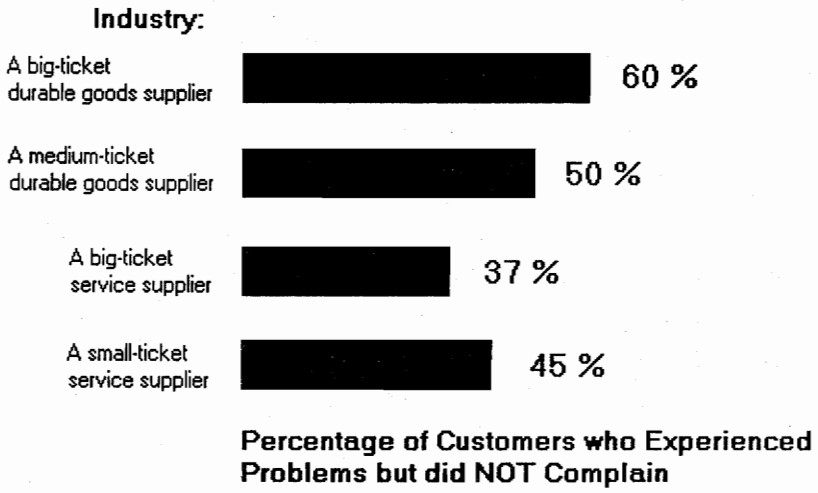

Figure 8 - Customers with Problems that do not Complain (Mackiewicz, 1990)

reveals more data regarding the probability that customers with problems will not complain. The reasons most often quoted by customers for not complaining are:

1) They believe it is not worth the time or trouble.
2) They don't know how to register a complaint.
3) They believe complaining will not do any good.[18]

The dilemma for companies is that the customers who do not complain not only become lost customers, but they spread negative word-of-mouth. This is why many companies solicit complaints through toll-free numbers, questionnaires, customer visits, etc. The recorded return on investment for corporate complaint-handling strategies is always very high and these calculations do not even consider the elimination of negative word-of-mouth.

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[18] Jerry R. Wilson, p. 121.

VI. MODEL DEVELOPMENT AND RESULTS

"Models are intellectual tools that help us distinguish what is possible from what is impossible and then, from the realm of the possible, to distinguish the better from the worse."

- J. A. Henize

The model development focuses on the progression of customers from General Public (GP) to Loyal Customers (LYCU) or Lost Customers (LCU) in a fictitious company. The progressions are driven by the causal effects of Relative Level Of Service (RLOS) and Relative Level Of Quality (RLOQ).

RLOQ is the level of product quality which the fictitious company provides. This level of quality is based upon the product attributes important to the customer, and how well the companies products provide these attributes. The important product attributes may be similar to those outlined in Table 2 or some other set of specific attributes.

RLOS is the level of service which the fictitious company provides. This level of service is based upon the service characteristics important to the customer, and how well the companies service delivers these characteristics. The important service characteristics may be similar to

those outlined in Table 4 or some other set of characteristics.

Monthly Profit (MPROF) is then determined by calculating estimated revenue from the company's Customers (CU) and Loyal Customers (LYCU) and subtracting the estimated Total Monthly Cost Of Service and Quality (TMCOSQ).

The model shows that a company must provide high levels of both service and product quality to continually develop loyal customers and high profits. If the company fails to provide adequate service and product quality, the negative word-of-mouth developed by their Lost Customers (LCU) will eventually destroy the company. The model also shows the beneficial results of soliciting customer complaints.

The following section contains a detailed verbal description of the model.

6.1 Verbal Description

In the model the company starts out with no customers (i.e. - new company) all of the population starts as General Public (GP). People in the General Public (GP) become Suspects (S) if they have a Need For the Product (NFP) sold by the company. The need is determined monthly and is dependent on the Probability of Need For the Product (PNFP), which is determined from normal marketing demand (*For the*

fictitious company portrayed by this model, PNFP is 0.0005). Suspects (S) become Prospects (P) if they Consider the Company (CC) portrayed by the model. Company Consideration (CC) is also determined monthly and is dependent upon the Probability of Company Consideration (PCC). The Probability of Company Consideration (PCC) is the sum of the General Public Positively Influenced by Marketing (GPPIM) and the General Public Positively Influenced by Word-of-Mouth (GPPIWM) divided by the Total Monthly Market (TMM) (*For the fictitious company portrayed by this model, GPPIM = 100,000 and TMM = 125,000*). Limits of zero and one are set on Probability of Company Consideration (PCC). Prospects (P) who decide to Purchase (PUR) from the company become Customers (CU). The decision to Purchase (P) is determined monthly and is dependent upon the Probability of Purchase (PPUR). The Probability of Purchase (PPUR) is determined statistically by the company (*For the fictitious company portrayed by this model, PPUR = 0.30*). Suspects Return to the General Public (SRTGP) if they do not consider the company and Prospects Return to the General Public (PRTGP) if they do not decide to purchase. It follows that No Purchase (NPUR) is equal to 1 - PUR and Probability of No Company Consideration (PNCC) is equal to 1 - CC.

Customers (CU) become Customers Without Problems (CUWOP) if they have a Good Experience With the Company

(GEWC). Good Experience With the Company (GEWC) depends on the Good Experience Factor (GEF) which is the difference between the Relative Level Of Service and Quality (RLOSQ) provided by the company and what the customer considers to be the Adequate Level Of Service and Quality (ALOSQ) (*For the fictitious company portrayed by this model, ALOSQ = 0.60*). This is shown in Figure 9. Customers (CU) become Customers With Problems (CUWP) if they have a Bad Experience With the Company (BEWC). Bad Experience With the Company (BEWC) depends on the Bad Experience Factor (BEF) which is the difference between the Excellent Level Of Service and Quality (ELOSQ) and the Relative Level of Service and Quality (RLOSQ) provided by the company (*For the fictitious company portrayed by this model, ELOSQ = 0.90*). This is also shown in Figure 9. A lower limit of zero is set for both the Good Experience Factor (GEF) and the Bad Experience Factor (BEF).

Customers (CU) become Lost To Competitors (LTC) each month due to customer perceptions of company mediocrity. The Customers Lost To Competitor Rate (CULTCR) is dependent upon Customers Lost to Mediocrity factor (CULTM) which is determined from the Relative Level Of Service and Quality (RLOSQ) as shown in Figure 10. This supports findings in research that customers will become disheartened, if the company is not exceeding their expectations, and find a new company.

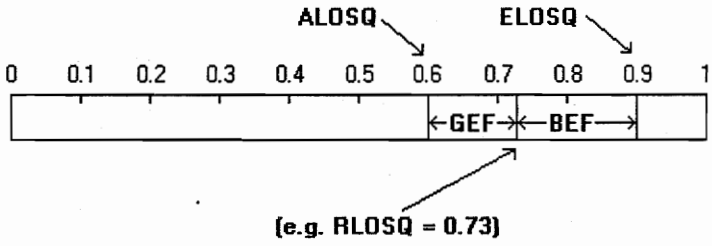

Figure 9 - Determination of Good Experience Factor (GEF) and Bad Experience Factor (BEF)

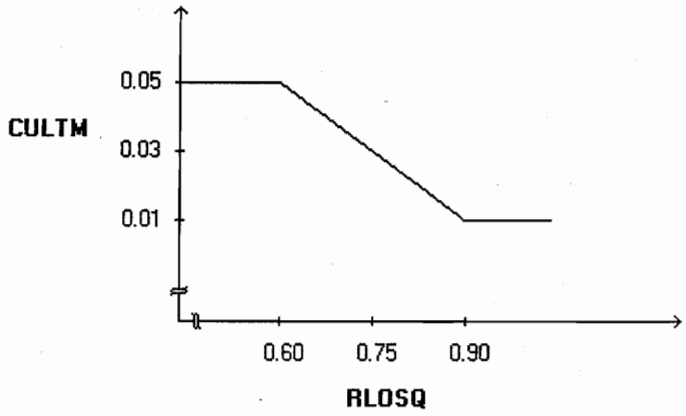

Figure 10 - Relative Level Of Service and Quality (RLOSQ) versus Customers Lost To Medeocrity (CULTM)

The Relative Level Of Service and Quality (RLOSQ) is the sum of the Relative Level of Service (RLOS) multiplied by the Service Factor (SF) and the Relative Level of Quality (RLOQ) multiplied by the Quality Factor (QF). The Service Factor (SF) and the Quality Factor (QF) can be used to put different weights on quality and service when determining the Relative Level Of Service and Quality (RLOSQ) (*For the fictitious company portrayed by this model, SF = 0.5 and QF = 0.5*).

Customers With Problems (CUWP) will become Non-complaining Customers (NCCU) if they do not complain about their problem. The Customer Non-complaining Rate (CUNCR) is determined monthly and is dependent upon the Probability of No customer Complaint (PONCUC). The Probability Of No Customer Complaint (PONCUC) is 1 - Probability Of Customer Complaint (POCUC), which is the sum of the Normal Probability Of Customer Complaint (NPOCUC) and the Extra Customer Complaints From Solicitation (ECUCFS) (*For the fictitious company portrayed by this model, NPOCUC = 0.60 and ECUCFS will be varied to determine the possible benefit*). Customers With Problems (CUWP) become Complaining Customers (CCU) if they complain about their problem. The Customer Complaint Rate (CUCR) is determined monthly and is dependent upon the Probability Of Customer Complaint (POCUC).

Complaining Customers (CCU) become Satisfied Complaining Customers (SCCU) if their problems are resolved

to their satisfaction. The Complaining Customer Satisfaction Rate (CCUSR) is dependent upon the Relative Level of Service (RLOS). Complaining Customers (CCU) become Lost Customers (LCU) if their problems are not resolved to their satisfaction. The Complaining Customer Dissatisfaction Rate (CCUDR) is dependent upon the Relative Level Of Bad Service (RLOBS) which is simply 1 - RLOS.

At this point there are three different groups of customers; Satisfied Complaining Customers (SCCU), Non-complaining Customers (NCCU) and Customers Without Problems (CUWOP). The customers in each of these groups will transition each month to either Lost Customers (LCU) or Loyal Customers (LYCU) dependent upon simple probabilities.

The Satisfied Complaining Customers Lost Rate (SCCULR) is dependent upon the Probability that a Satisfied Complaining Customer will become a Lost Customer (PSCLC). The Satisfied Complaining Customers Won Rate (SCCUWR) is dependent upon the Probability that a Satisfied Complaining Customer will become a Loyal Customer (PSCLYC) (*For the fictitious company portrayed by this model, PSCLC = 0.05 and PSCLYC = 0.95*).

The Non-complaining Customers Lost Rate (NCCULR) is dependent upon the Probability that a Non-complaining Customer will become a Lost Customer (PNCLC). The Non-complaining Customers Won Rate (NCCUWR) is dependent upon the Probability that a Non-complaining Customer will become

a Loyal Customer (PNCLYC) (*For the fictitious company portrayed by this model PNCLC=0.90 and PNCLYC = 0.10*).

The Customer Without Problem Lost Rate (CUWOLR) is dependent upon the Probability that a Customer Without a Problem will become a Lost Customer (PCWLC). The Customer Without Problem Won Rate (CUWOWR) is dependent upon the Probability that a Customer Without a Problem will become a Loyal Customer (PCWLYC) (*For the fictitious company portrayed by this model PCWLC = 0.15 and PCWLYC = 0.85*).

Loyal Customers (LYCU) can return to being just Customers (CU) if their expectations are not continually exceeded. The Expectations Not Exceeded Rate (ENER) is determined from the Probability of Expectations Not Exceeded (PENE), which is the difference between the Bad Experience Factor (BEF) and the Loyal Customer Forgiving Factor (LYCUFF). A minimum of zero is set for the Probability of Expectations Not Exceeded (PENE). The Loyal Customer Forgiving Factor (LYCUFF) is an arbitrary adjustment based on the fact that Loyal Customers (LYCU) will be slightly more tolerant with their company than normal Customers (CU) (*For the fictitious company portrayed by this model, LYCUFF = 0.10*).

The General Public Positively Influenced by Word-of-Mouth (GPPIWM) is the difference between the Loyal Customers (LYCU) multiplied by the Loyal Customers Talk Factor (LYCUTF) and the Lost Customers (LCU) multiplied by the Lost

Customers Talk Factor (LCUTF) (*For the fictitious company portrayed by this model, LYCUTF = 1 and LCUTF =2*).

The Monthly Revenue (MREV) created by the company is equal to the sum of the Customers (CU) multiplied by the Customer Revenue Factor (CURF) and the Loyal Customers (LYCU) multiplied by the Loyal Customer Revenue Factor (LYCURF) (*For the fictitious company portrayed by this model, CURF = $1000 and LYCURF = $2000*).

Total Monthly Cost Of Service and Quality (TMOSQ) is the sum of the Monthly Cost Of Individual Service (MCOIS), the Monthly Cost Of Individual Quality (MCOIQ), and the Monthly Cost Of Soliciting Complaints (MCOSC) multiplied by the Extra Customer Complaints From Solicitation (ECUCFS), all multiplied by the total number of Customers (CU) and Loyal Customers (LYCU). The Monthly Cost Of Individual Service (MCOIS) is dependent upon the Relative Level Of Service (RLOS) as shown in Figure 11 and the Monthly Cost Of Individual Quality (MCOIQ) is dependent upon the Relative Level Of Quality (RLOQ) as shown in Figure 12 (*The relationships in Figures 11 and 12 were arbitrarily determined for the fictitious company in this model*).

Monthly Profit (MPROF) is the difference between Monthly Revenue (MREV) and Total Monthly Cost Of Service and Quality (TMCOSQ).

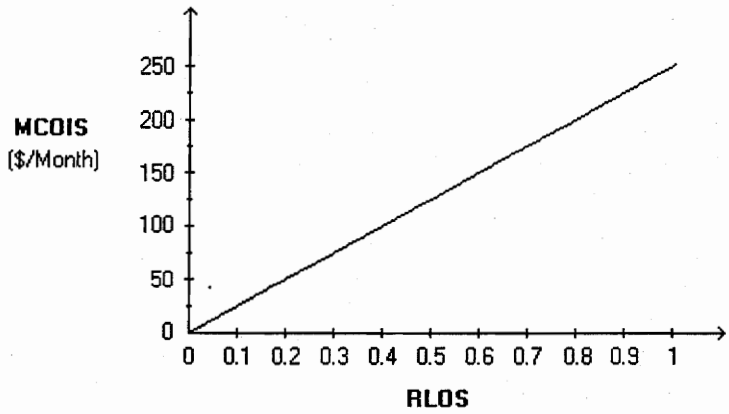

Figure 11 - Relative Level Of Service (RLOS) versus Monthly Cost Of Individual Service (MCOIS)

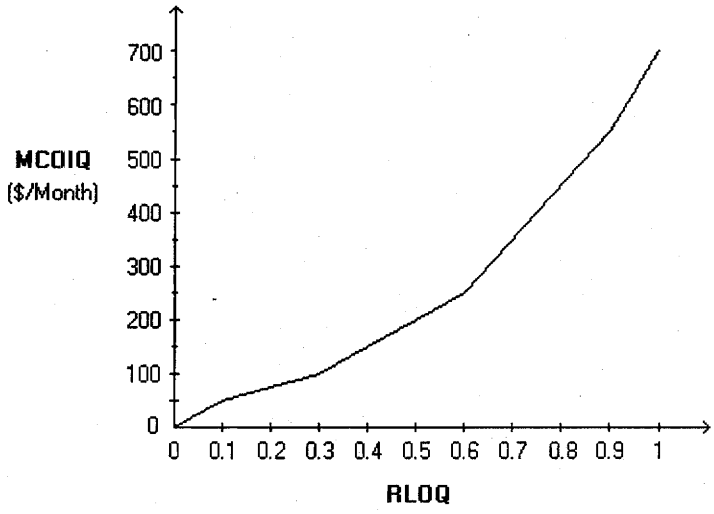

Figure 12 - Relative Level Of Quality (RLOQ) versus Monthly Cost Of Individual Quality (MCOIQ)

6.2 Causal Diagram

A causal diagram based on the verbal description in the previous section is shown in Figure 13.

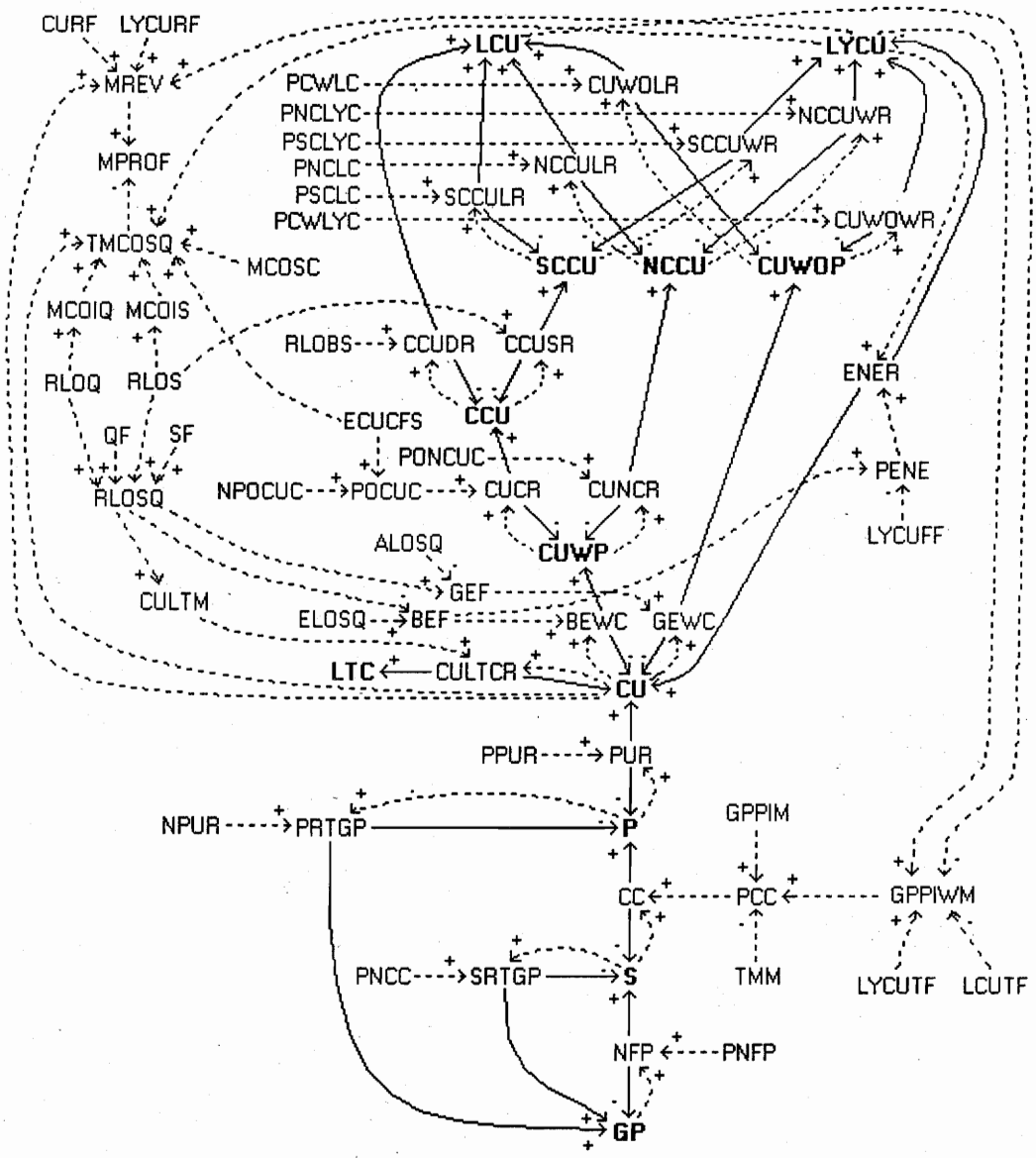

Figure 13 - Causal Diagram of Model

6.3 System Equations

The DYNAMO III equations for the model are presented in APPENDIX A. Variable units are given in the comments throughout the equations.

6.4 Model Results

Initially several simulation runs of the model were performed using various values for Relative Level Of Service (RLOS) and Relative Level Of Quality (RLOQ). In later simulation runs RLOS and RLOQ were held constant and the variable Extra Customer Complaints From Solicitation (ECUCFS), which remained at zero for the initial runs, was increased. All simulation runs were performed for a 120 month company lifetime.

From the initial runs where only RLOS and RLOQ were varied, it is possible to determine when the company continued to increase its profit and when the company reaped the maximum profit after the 120 months.

From some of the simulation runs where RLOS and RLOQ were low the company made some initial profits, but profits dropped quickly as the negative word-of-mouth from the lost customers took over. An example of this is shown in APPENDIX B where the plot of Monthly Revenue (MREV=R) and Monthly Profit (MPROF=$) versus time is shown for RLOS = 0.4 and RLOQ = 0.4. A plot of the Customers (CU=C), Loyal Customers (LYCU=Y), Lost Customers (LCU=L) and the Customers Lost To Competitors (LTC=T) versus time is also shown for these levels of quality and service in APPENDIX B.

The company starts to continually increase profits and loyal customers over the 120 month period when RLOS and RLOQ

are both increased to 0.8 as shown by the plots in APPENDIX C.

The company continually increases its loyal customers and maximizes its profits at approximately $4.8 billion over the 120 month period if RLOS = 1 and RLOQ = 0.6 as shown by the plots in APPENDIX D. For this fictitious company, increasing RLOQ any higher will result in more loyal customers after 120 months, but the cost will be such that profit will not be increased. This will obviously vary depending on the costs determined for service and quality.

On the final simulation runs, RLOS was held constant at 1, RLOQ was held constant at 0.4 and ECUCFS was increased from 0 to 0.4. In these runs, one can see a beneficial effect from soliciting complaints. When ECUCFS = 0 the ending profit after 120 months was approximately $150 million whereas when ECUCFS = 0.4 the ending profit after 120 months was approximately $1.5 billion. This is shown by the plots in APPENDIX E. Unfortunately even with the increased profit, after 120 months the profits are still on a downturn from previous years. This emphasizes that companies must work on both service and quality to continually increase profits.

VII. SUMMARY AND RECOMMENDATIONS

"Problems should be viewed in the context of larger problems before taking them apart."

- Dr. Donald R. Drew

7.1 Project and Report Summary

Based on the model results in the previous section, one can see that unless a company provides both product quality and quality service, as determined by their customers, their profits will eventually diminish. However, depending on the costs of delivering the quality and service that is required to exceed customer expectations, profit maximization may not occur when quality and service are at their highest levels. This is evident from the fictitious company represented in the model, where profit maximization occurs at RLOS = 1 and RLOQ = 0.6.

The model results also reinforce that the driving force which creates continuous profit increase is the development of loyal customers or the avoidance of lost customers. Loyal customers create more revenue for the company and they bring in more new customers through their positive word-of-mouth.

Complaint soliciting, as shown by the model results will also help companies to resolve more customer complaints

thereby creating more loyal customers. This strategy is particularly helpful if the company's service level is high. However, this strategy alone will not allow the company with poor quality or service to overcome these deficiencies.

Figure 13 provides a simplified view of the causal relationships which link product quality and service to profit.

7.2 Future Research

The model presented in this report is a good solid framework for evaluating the dynamic effects which quality and service have on company profit. The model is presented at a fairly macroscopic level, evaluating a generic durable goods producer and their overall policies toward quality and service. Improvements should focus on developing the model to be used in a specific industry for a specific product.

By focussing on specific industry, some of the characteristics in the model could be further developed. Industry Marketing data could be used to determine Probability of Need For Product (PNFP), General Public Positively Influenced by Marketing (GPPIM), Probability of Purchase (PPUR), Loyal Customer Talk Factor (LYCUTF) and Lost Customer Talk Factor (LCUTF). Competitive marketing data and customer surveys could be used to more accurately

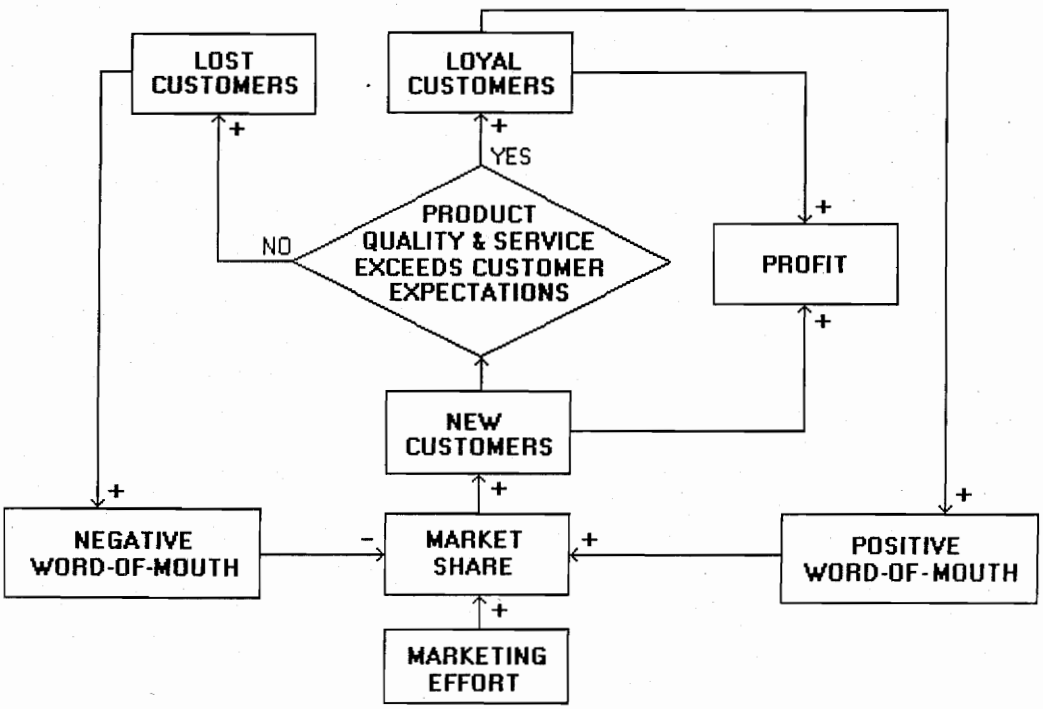

Figure 14 - Simplified View of Causal Relationships

assess Adequate Level Of Service and Quality (ALOSQ) and Excellent Level Of Service and Quality (ELOSQ).

Also, by focussong on a specific product, Quality Function Deployment (QFD) or some other method could be used to determine the specific product and service features which influence the customer's expectations of quality and service. These specific features could then be added into the model to provide a more detailed assessment of the Relative Level Of Service and Quality (RLOSQ).

Industry research might also help to quantify the six probabilities in the model which cause the final transitions to either Lost Customers (LCU) or Loyal Customers (LYCU).

The possibilities are really endless for the model if applied in an actual industrial environment.

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APPENDIX A - System Equations

The DYNAMO III equations for the model are presented on the following pages with the variable units given in the comments throughout the equations. The simulation was done on VM1 (IBM 3090) at Virginia Tech.

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          NOTE     ****************************************************************
          NOTE     *  QUALITY AND SERVICE VS. PROFIT MODEL                        *
          NOTE     *  DANIEL J. FIELD      PROJECT AND REPORT        8/1/91        *
          NOTE     ****************************************************************
          NOTE
          NOTE     GP - GENERAL PUBLIC  (PEOPLE)
          L GP.K=GP.J+(DT)(PRTGP.JK+SRTGP.JK-NFP.JK)
          N GP=GPN
          N GPN=250000000
          NOTE     NFP - NEED FOR PRODUCT (PEOPLE/MONTH)
          R NFP.KL=GP.K*PNFP
          NOTE     PNFP - PROBABILITY NEED FOR PRODUCT  (PER MONTH)
          C PNFP=0.0005
          NOTE     SRTGP - SUSPECTS RETURN TO GENERAL PUBLIC  (PEOPLE/MONTH)
          R SRTGP.KL=S.K*PNCC.K
          NOTE     S - SUSECTS  (PEOPLE)
          L S.K=S.J+(DT)(NFP.JK-SRTGP.JK-CC.JK)
          N S=SN
          N SN=0
          NOTE     CC - COMPANY CONSIDERATION  (PEOPLE/MONTH)
          R CC.KL=S.K*PCC.K
          NOTE     PCC - PROBABILITY OF COMPANY CONSIDERATION  (PER MONTH)
          A PCC.K=MAX(0,MIN(1,((GPPIM+GPPIWM.K)/TMM)))
          NOTE     TMM - TOTAL MONTHTLY MARKET  (PEOPLE)
          C TMM=125000
          NOTE     PNCC - PROBABILITY OF NOT CONSIDERING COMPANY  (PER MONTH)
          A PNCC.K=1-PCC.K
          NOTE     P -  PROSPECTS  (PEOPLE)
          L P.K=P.J+(DT)(CC.JK-PUR.JK-PRTGP.JK)
          N P=PN
          N PN=0
          NOTE     PRTGP - PROSPECTS RETURN TO GENERAL PUBLIC  (PEOPLE/MONTH)
          R PRTGP.KL=P.K*NPUR.K
          NOTE     PUR - PURCHASE  (PEOPLE/MONTH)
          R PUR.KL=P.K*PPUR
          NOTE     PPUR - PROBABILITY OF PURCHASE  (PER MOTNH)
          C PPUR=0.3
          NOTE     NPUR - PROBABILITY OF NO PURCHASE  (PER MONTH)
          A NPUR.K=1-PPUR
          NOTE     CU - CUSTOMERS  (PEOPLE)
          L CU.K=CU.J+(DT)(PUR.JK+ENER.JK-BEWC.JK-GEWC.JK-CULTCR.JK)
          N CU=CUN
          N CUN=0
          NOTE     BEWC - BAD EXPERIENCE WITH COMPANY  (PEOPLE/MONTH)
          R BEWC.KL=CU.K*BEF.K
          NOTE     BEF - BAD EXPERIENCE FACTOR  (PER MONTH)
          A BEF.K=MAX(0,ELOSQ-RLOSQ.K)
          NOTE     ALOSQ - ADEQUATE LEVEL OF SERVICE AND QUALITY  (PER MONTH)
          C ALOSQ=0.60
          NOTE     RLOSQ - RELATIVE LEVEL OF SERVICE AND QUALITY  (PER MONTH)
          A RLOSQ.K=(RLOS*SF)+(RLOQ*QF)
          NOTE     RLOS - RELATIVE LEVEL OF SERVICE  (PER MONTH)
          C RLOS=0.4
```

```
NOTE    SF - SERVICE FACTOR  (DIMENSIONLESS)
C SF=0.5
NOTE    RLOQ - RELATIVE LEVEL OF QUALITY  (PER MONTH)
C RLOQ=0.4
NOTE    QF - QUALITY FACTOR  (DIMENSIONLESS)
C QF=0.5
NOTE    GEWC - GOOD EXPERIENCE WITH COMPANY  (PEOPLE/MONTH)
R GEWC.KL=CU.K*GEF.K
NOTE    GEF - GOOD EXPERIENCE FACTOR  (PER MONTH)
A GEF.K=MAX(0,RLOSQ.K-ALOSQ)
NOTE    ELOSQ - EXCELLENT LEVEL OF SERVICE AND QUALITY  (PER MONTH)
C ELOSQ=0.90
NOTE    CUWP - CUSTOMER WITH PROBLEM  (PEOPLE)
L CUWP.K=CUWP.J+(DT)(BEWC.JK-CUCR.JK-CUNCR.JK)
N CUWP=CUWPN
N CUWPN=0
NOTE    CUCR - CUSTOMER COMPLAINT RATE  (PEOPLE/MONTH)
R CUCR.KL=CUWP.K*POCUC.K
NOTE    POCUC - PROBABILITY OF CUSTOMER COMPLAINT  (PER MONTH)
A POCUC.K=NPOCUC+ECUCFS
NOTE    NPOCUC - NORMAL PROBABILITY OF CUSTOMER COMPLAINT  (PER MONTH)
C NPOCUC=0.6
NOTE    ECUCFS - EXTRA CUSTOMER COMPLAINTS FROM SOLICITATION  (PER MONTH)
C ECUCFS=0
NOTE    CUNCR - CUSTOMER NO COMPLAINT RATE  (PEOPLE/MONTH)
R CUNCR.KL=CUWP.K*PONCUC.K
NOTE    PONCUC - PROBABILITY OF NO CUSTOMER COMPLAINT (PER MONTH)
A PONCUC.K=1-POCUC.K
NOTE    CCU - COMPLAINING CUSTOMERS  (PEOPLE)
L CCU.K=CCU.J+(DT)(CUCR.JK-CCUDR.JK-CCUSR.JK)
N CCU=CCUN
N CCUN=0
NOTE    CCUDR - COMPLAINING CUSTOMER DISSATISFACTION RATE  (PEOPLE/MONTH)
R CCUDR.KL=CCU.K*RLOBS.K
NOTE    RLOBS - RELATIVE LEVEL OF BAD SERVICE  (PER MONTH)
A RLOBS.K=1-RLOS
NOTE    CCUSR - COMPLAINING CUSTOMER SATISFACTION RATE  (PEOPLE/MONTH)
R CCUSR.KL=CCU.K*RLOS
NOTE    SCCU - SATISFIED COMPLAINING CUSTOMERS  (PEOPLE)
1PAGE 2 FILE:PROJECTF    8/15/91 09:58

L SCCU.K=SCCU.J+(DT)(CCUSR.JK-SCCULR.JK-SCCUWR.JK)
N SCCU=SCCUN
N SCCUN=0
NOTE    SCCULR - SATISFIED COMPLAINING CUSTOMER LOST RATE  (PEOPLE/MONTH)
R SCCULR.KL=SCCU.K*PSCLC
NOTE    PSCLC - PROBABILITY SATISFIED COMPLAINING CUSTOMER WILL BECOME
NOTE            A LOST CUSTOMER  (PER MONTH)
C PSCLC=0.05
NOTE    SCCUWR - SATISFIED COMPLAINING CUSTOMER WON RATE  (PEOPLE/MONTH)
R SCCUWR.KL=SCCU.K*PSCLYC.K
NOTE    PSCLYC - PROBABILITY SATISFIED COMPLAINING COSTOMER WILL BECOME
NOTE             A LOYAL CUSTOMER  (PER MONTH)
A PSCLYC.K=1-PSCLC
NOTE    NCCU - NONCOMPLAINING CUSTOMERS  (PEOPLE)
```

```
L NCCU.K=NCCU.J+(DT)(CUNCR.JK-NCCULR.JK-NCCUWR.JK)
N NCCU=NCCUN
N NCCUN=0
NOTE     NCCULR - NONCOMPLAINING CUSTOMER LOST RATE  (PEOPLE/MONTH)
R NCCULR.KL=NCCU.K*PNCLC
NOTE     PNCLC - PROBABILITY NONCOMPLAINING CUSTOMER WILL BECOME A LOST
NOTE             CUSTOMER  (PER MONTH)
C PNCLC=0.90
NOTE     NCCUWR - NONCOMPLAINING CUSTOMER WON RATE  (PEOPLE/MONTH)
R NCCUWR.KL=NCCU.K*PNCLYC.K
NOTE     PNCLYC - PROBABILITY NONCOMPLAINING CUSTOMER WILL BECOME A
NOTE              LOYAL CUSTOMER  (PER MONTH)
A PNCLYC.K=1-PNCLC
NOTE     CUWOP - CUSTOMERS WITHOUT PROBLEM  (PEOPLE)
L CUWOP.K=CUWOP.J+(DT)(GEWC.JK-CUWOLR.JK-CUWOWR.JK)
N CUWOP=CUWOPN
N CUWOPN=0
NOTE     CUWOLR - CUSTOMERS WITHOUT PROBLEMS LOSS RATE  (PEOPLE/MONTH)
R CUWOLR.KL=CUWOP.K*PCWLC
NOTE     PCWLC - PROBABILITY CUSTOMERS WITHOUT PROBLEMS WILL BECOME A
NOTE             LOST CUSTOMER  (PER MONTH)
C PCWLC=0.15
NOTE     CUWOWR - CUSTOMERS WITHOUT PROBLEMS WON RATE  (PEOPLE/MONTH)
R CUWOWR.KL=CUWOP.K*PCWLYC.K
NOTE     PCWLYC - PROBABILITY CUSTOMERS WITHOUT PROBLEMS WILL BECOME A
NOTE              LOYAL CUSTOMER  (PER MONTH)
A PCWLYC.K=1-PCWLC
NOTE     LCU - LOST CUSTOMERS  (PEOPLE)
L LCU.K=LCU.J+(DT)(CCUDR.JK+SCCULR.JK+NCCULR.JK+CUWOLR.JK)
N LCU=LCUN
N LCUN=0
NOTE     LYCU - LOYAL CUSTOMERS  (PEOPLE)
L LYCU.K=LYCU.J+(DT)(SCCUWR.JK+NCCUWR.JK+CUWOWR.JK-ENER.JK)
N LYCU=LYCUN
N LYCUN=0
NOTE     ENER - EXPECTATIONS NOT EXCEEDED RATE  (PEOPLE/MONTH)
R ENER.KL=LYCU.K*PENE.K
NOTE     PENE - PROBABILITY EXPECTATIONS NOT EXCEEDED  (PER MONTH)
A PENE.K=MAX(0,(BEF.K-LYCUFF))
NOTE     LYCUFF - LOYAL CUSTOMER FORGIVING FACTOR  (PER MONTH)
C LYCUFF=0.1
NOTE     GPPIWM - GENERAL PUBLIC POSITIVELY INFLUENCED BY WORD-OF-MOUTH
NOTE              (PEOPLE/MONTH)
A GPPIWM.K=(LYCU.K*LYCUTF)-(LCU.K*LCUTF)
NOTE     LCUTF - LOST CUSTOMER TALK FACTOR  (PER MONTH)
C LCUTF=2
NOTE     LYCUTF - LOYAL CUSTOMER TALK FACTOR  (PER MONTH)
C LYCUTF=1
NOTE     GPPIM - GENERAL PUBLIC POSITIVELY INFLUENCED BY MARKETING
NOTE             (PEOPLE/MONTH)
C GPPIM=100000
NOTE     LTC - CUSTOMERS LOST TO COMPETITORS  (PEOPLE)
L LTC.K=LTC.J+(DT)(CULTCR.JK)
N LTC=LTCN
N LTCN=0
```

```
NOTE    CULTCR - CUSTOMERS LOST TO COMPETITORS RATE (PEOPLE/MONTH)
R CULTCR.KL=CU.K*CULTM.K
NOTE    CULTM - CUSTOMERS LOST DUE TO MEDIOCRITY  (PER MONTH)
A CULTM.K=TABHL(CULTMT,RLOSQ.K,0.6,0.9,0.15)
T CULTMT=0.05/0.03/0.01
NOTE    MREV - MONTHLY REVENUE  (DOLLARS/MONTH)
A MREV.K=(CU.K*CURF)+(LYCU.K*LYCURF)
NOTE    CURF - CUSTOMER REVENUE FACTOR  (DOLLARS/PERSON-MONTH)
C CURF=1000
NOTE    LYCURF - LOYAL COSTOMER REVENUE FACTOR  (DOLLARS/PERSON-MONTH)
C LYCURF=2000
NOTE    MCOIS - MONTHLY COST OF INDIVIDUAL SERVICE (DOLLARS/PERSON-MONTH)
A MCOIS.K=TABLE(MCOIST,RLOS,0,1,0.1)
T MCOIST=0/25/50/75/100/125/150/175/200/225/250
NOTE    MCOIQ - MONTHLY COST OF INDIVIDUAL QUALITY (DOLLARS/PERSON-MONTH)
A MCOIQ.K=TABLE(MCOIQT,RLOQ,0,1,0.1)
T MCOIQT=0/50/75/100/150/200/250/350/450/550/700
NOTE    TMCOSQ - TOTAL MONTHLY COST OF SERVICE AND QUALITY
NOTE              (DOLLARS/MONTH)
A TMCOSQ.K=(CU.K+LYCU.K)*(MCOIS.K+MCOIQ.K+ECUCFS*MCOSC)
NOTE    MCOSC - MONTHLY COST OF SOLICITING COMPLAINTS  (DOLLARS/PERSON)
C MCOSC=20
NOTE    MPROF - MONTHLY PROFIT  (DOLLARS/MONTH)
1PAGE 3 FILE:PROJECTF    8/15/91 09:58

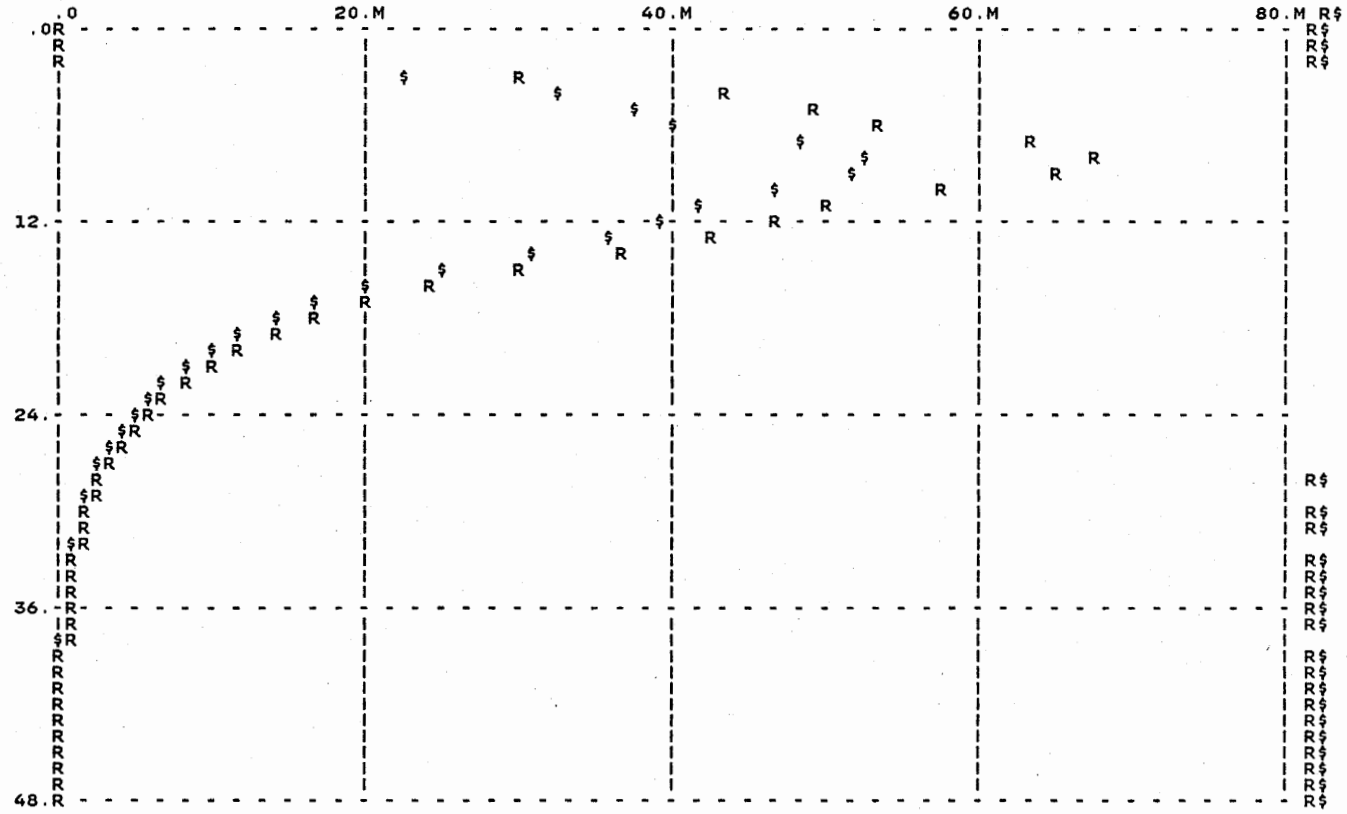
A MPROF.K=MREV.K-TMCOSQ.K
PLOT MREV=R,MPROF=$
PLOT CU=C,LYCU=Y,LCU=L,LTC=T
SPEC DT=1/PRTPER=1/PLTPER=1/LENGTH=120
RUN
```

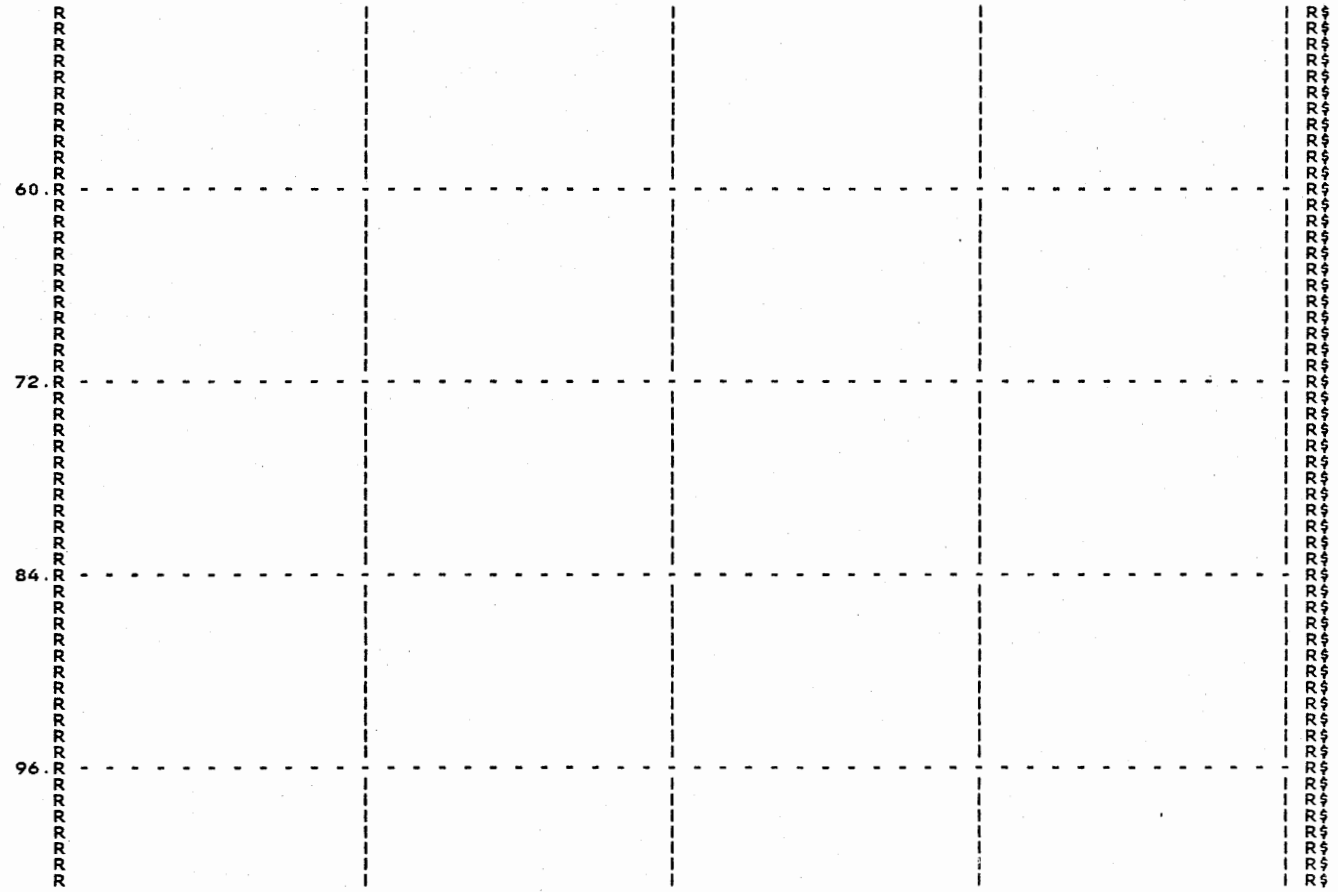
APPENDIX B - Results of Poor Service and Quality

This Appendix contains results from a simulation run where RLOS = 0.4 and RLOQ = 0.4. This simulation run provides a good example of what happens to long-term profit when the levels of quality and service are low. A plot of Monthly Revenue (MREV=R) and Monthly Profit (MPROF=$) versus time shows that profit increases at first, but then declines rapidly. A plot of the Customers (CU=C), Loyal Customers (LYCU=Y), Lost Customers (LCU=L) and the Customers Lost To Competitors (LTC=T) versus time shows that lost customers increase and loyal customers decrease quite rapidly.

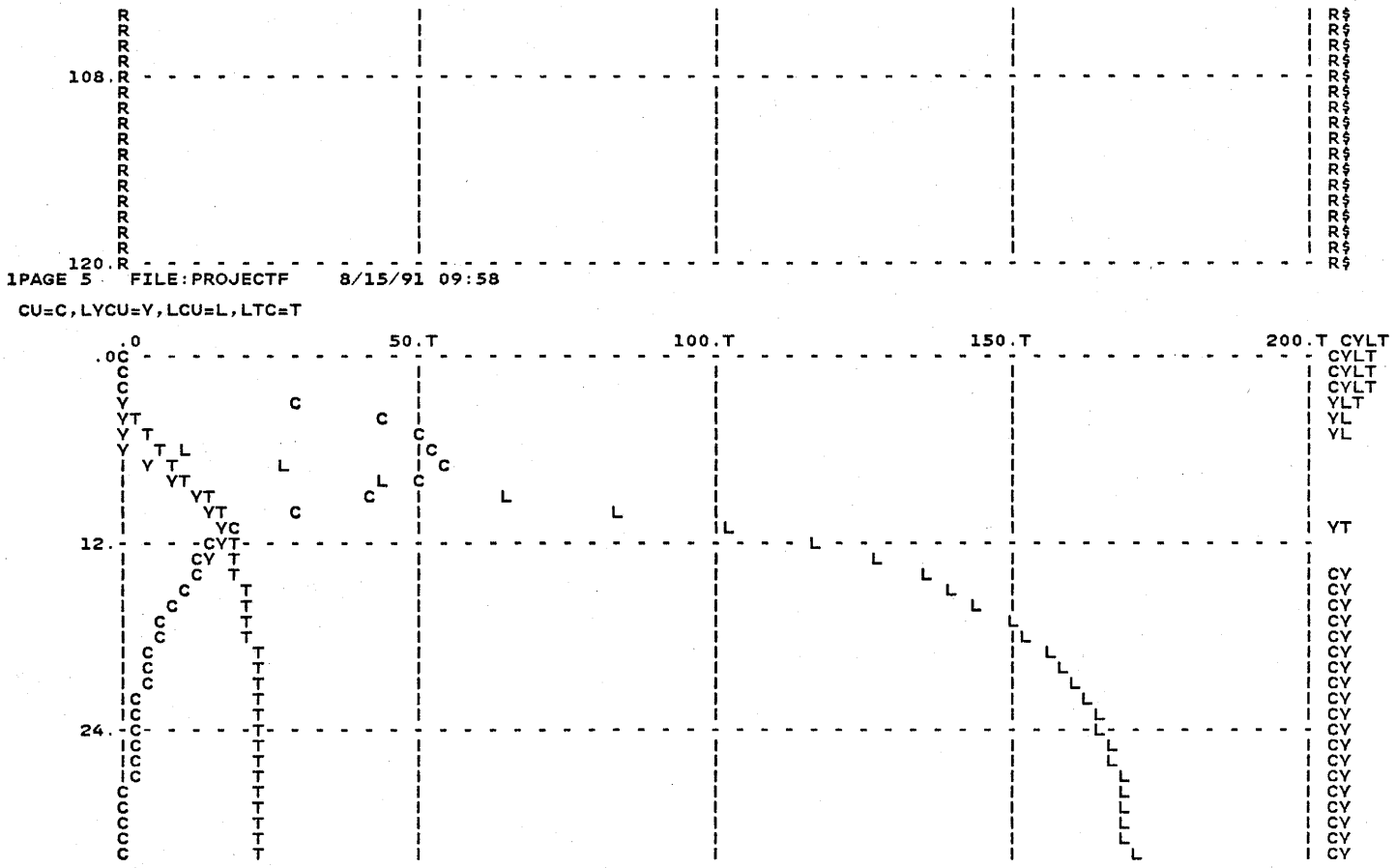
```
PLOT4    OUTPUT   A1 08/15/91 10:07   V 112   253 RECS 08/15/91 10:08 PAGE      1

0         104 SYMBOL TABLE ENTRIES
1PAGE 4   FILE:PROJECTF     8/15/91 09:58
 MREV=R,MPROF=$
```




60.
72.
84.
96.

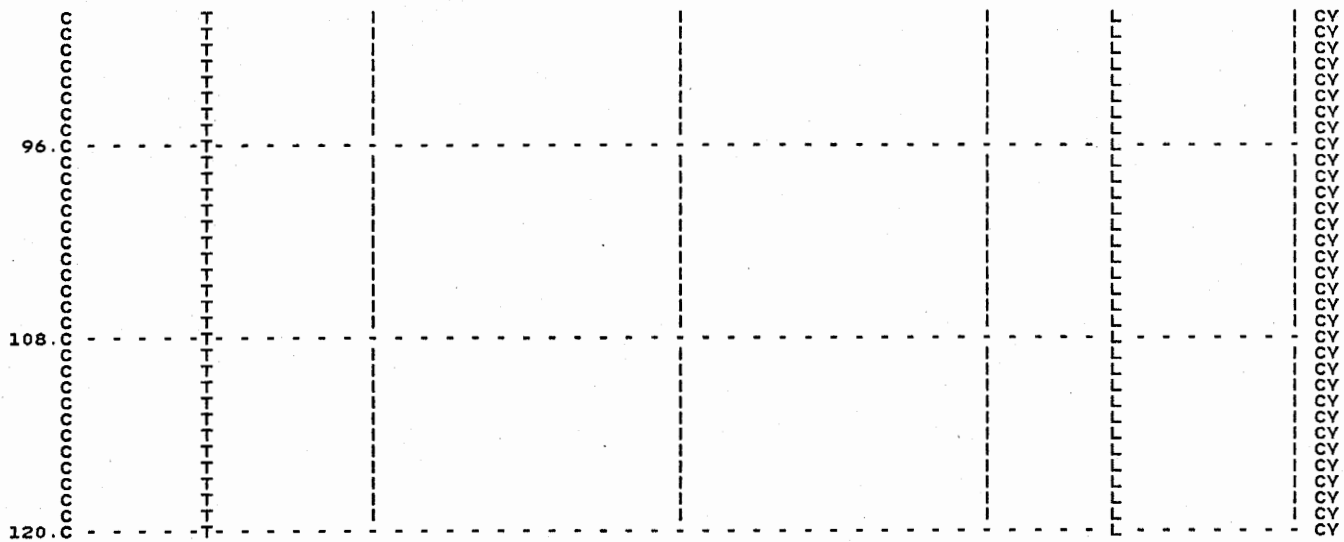
PLOT4 OUTPUT A1 08/15/91 10:07 V 112 253 RECS 08/15/91 10:08 PAGE 3



1PAGE 5 FILE:PROJECTF 8/15/91 09:58

CU=C,LYCU=Y,LCU=L,LTC=T

```
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
 36.C - - - - -T- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - L - - - - - - - - - CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
 48.C - - - - -T- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - L - - - - - - - - - CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
 60.C - - - - -T- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - L - - - - - - - - - CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
 72.C - - - - -T- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - L - - - - - - - - - CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
 84.C - - - - -T- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - L - - - - - - - - - CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
    C         T          |                    |                    |         L           | CY
```


96.
108.
120.

APPENDIX C - Service and Quality for Continual Profit Increase

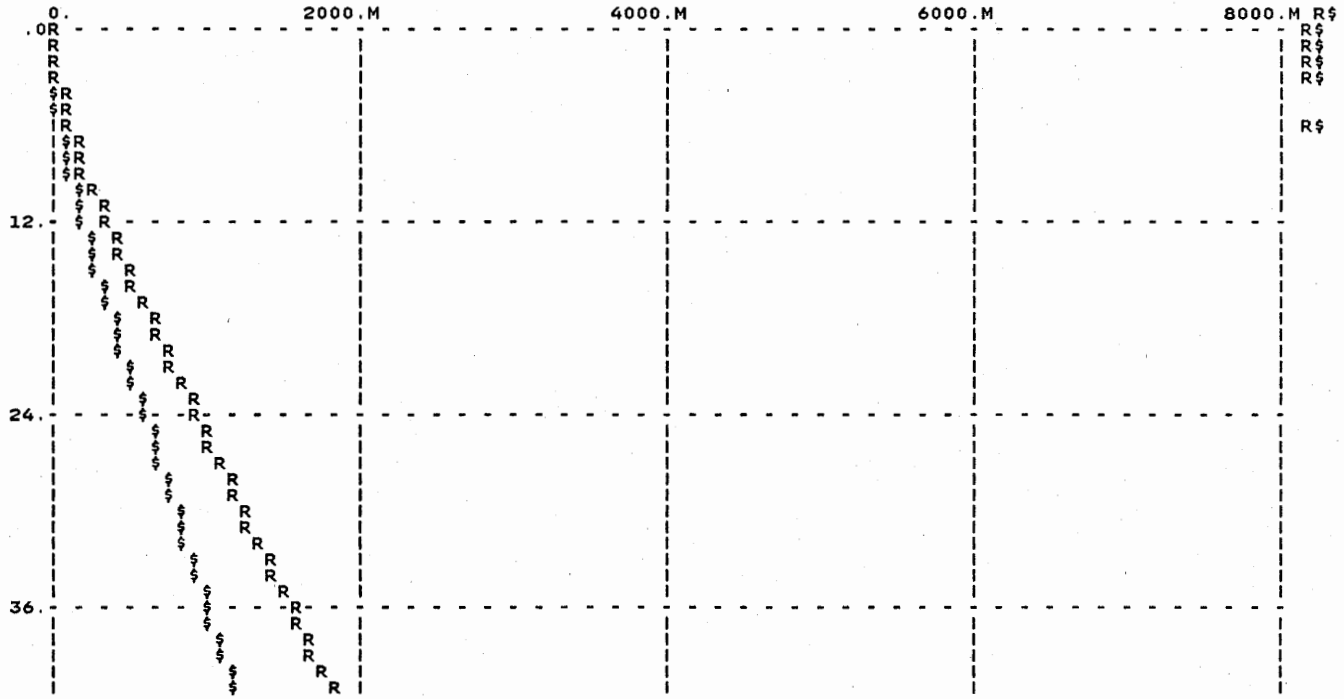
This Appendix contains results from a simulation run where RLOS, RLOQ are set just large enough to maintain a continual profit increase over the 120 month period. A plot of Monthly Revenue (MREV=R) and Monthly Profit (MPROF=$) versus time shows that profit continues to increase for the 120 month period. A plot of the Customers (CU=C), Loyal Customers (LYCU=Y), Lost Customers (LCU=L) and the Customers Lost To Competitors (LTC=T) versus time shows that loyal customers also continually increase over the 120 month period.

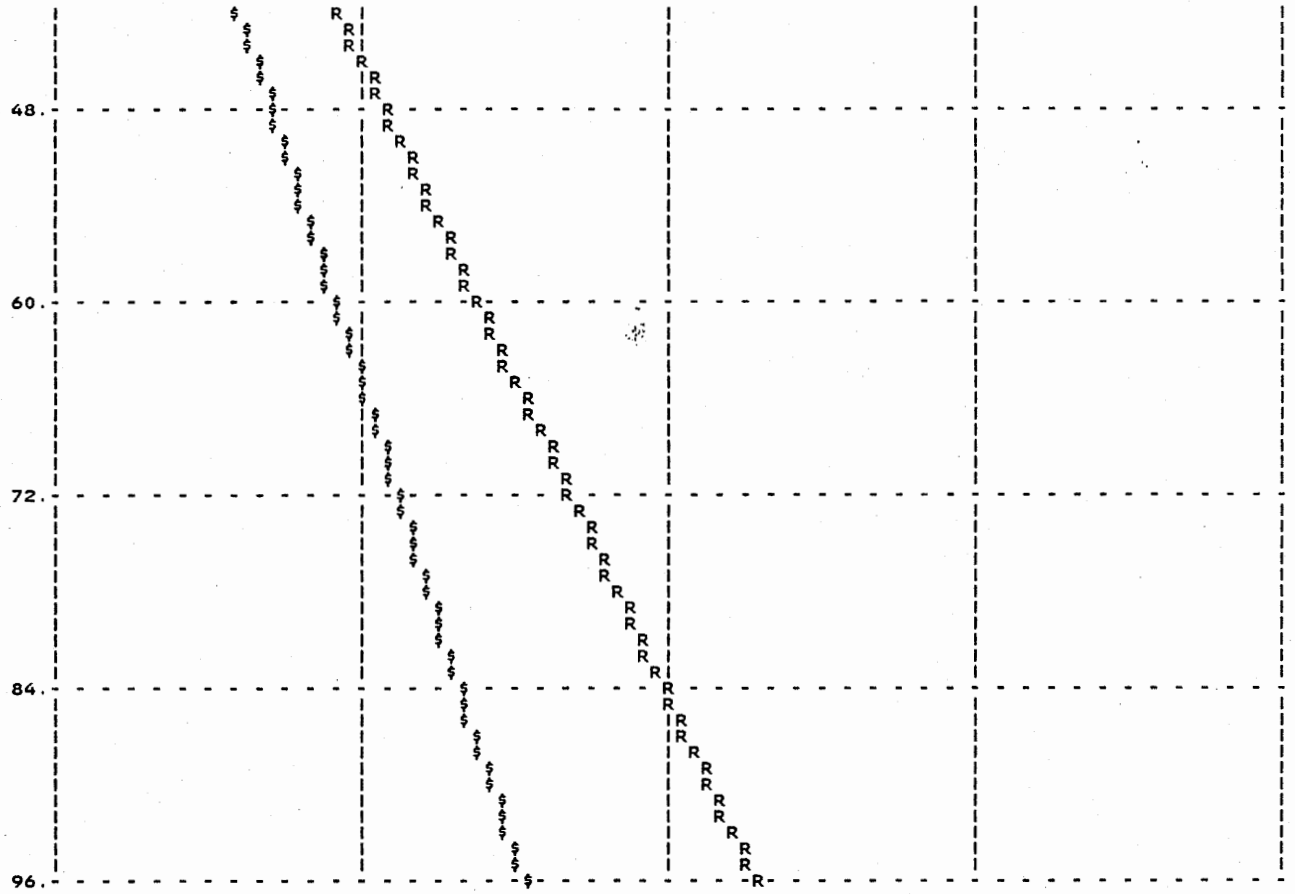
```
PLOT8    OUTPUT   A1 08/15/91 10:10   V 112   260 RECS 08/15/91 10:10 PAGE      1

1PAGE 6   FILE:PROJECTF    8/15/91 09:58

          C RLOS=0.8
          C RLOQ=0.8
          RUN
0            RLOQ     RLOS
  PRESENT      .8       .8
 ORIGINAL      .4       .4
1PAGE 7   FILE:PROJECTF    8/15/91 09:58

 MREV=R,MPROF=$
```

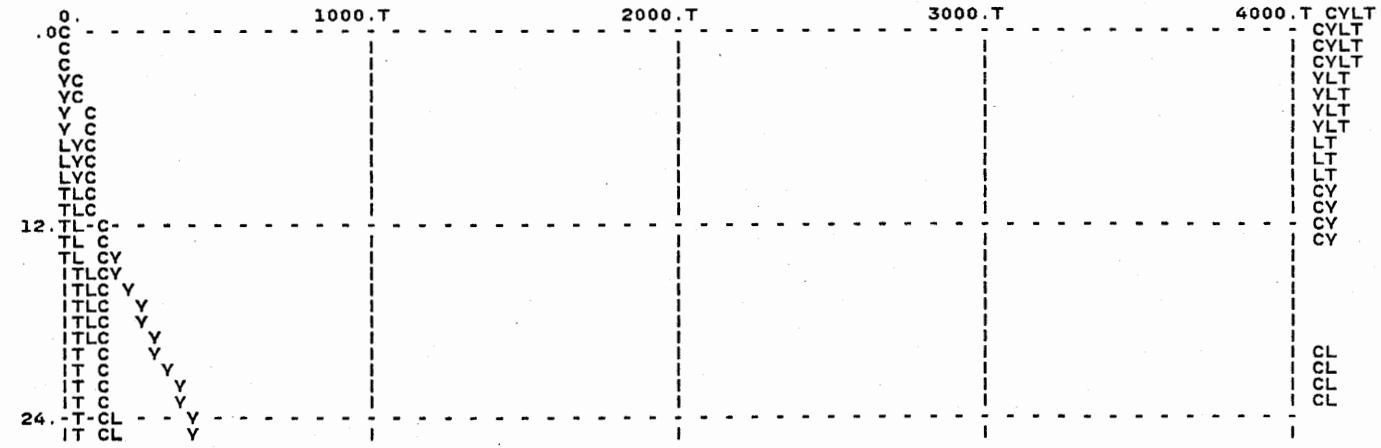



48.
60.
72.
84.
96.

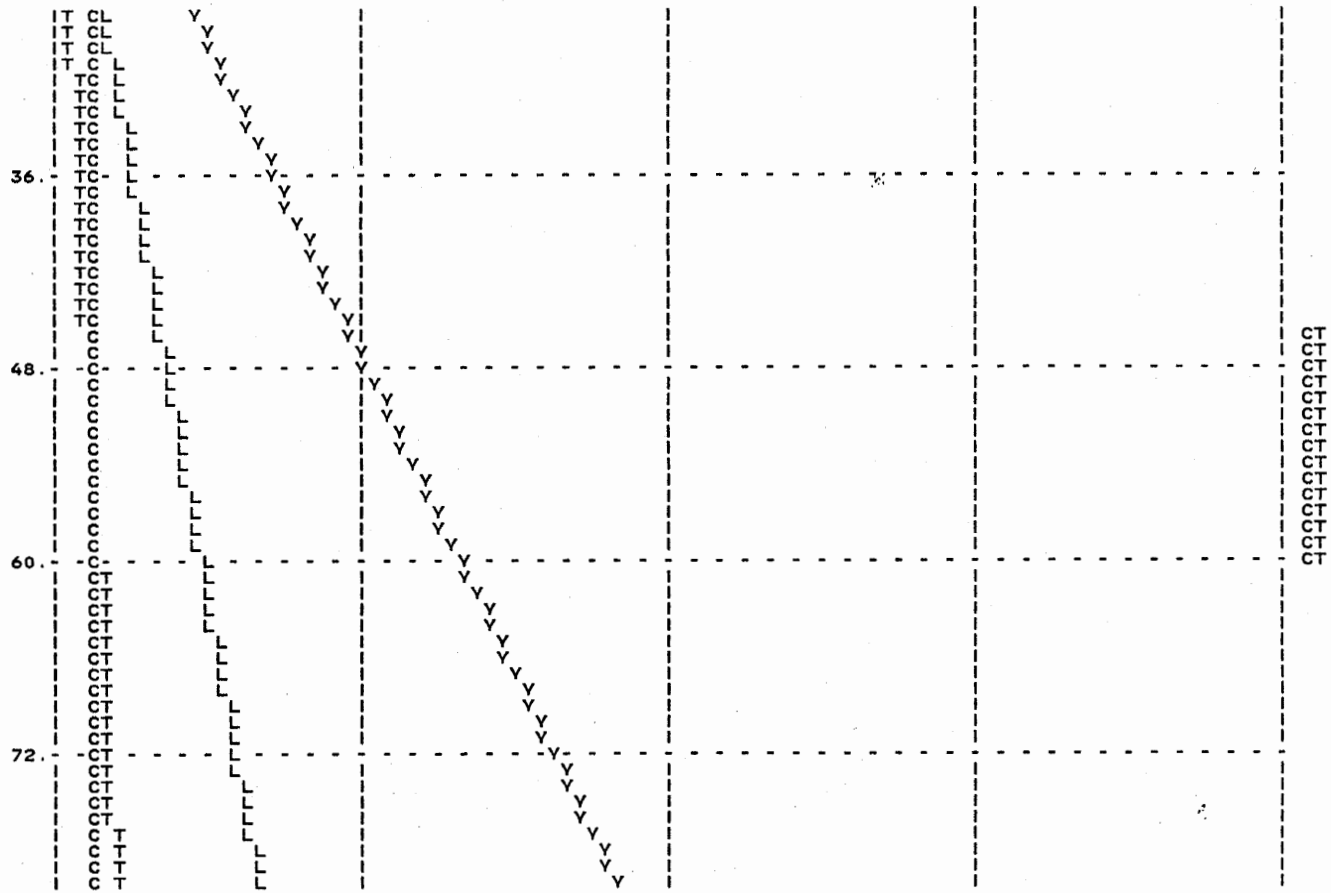
PLOT8 OUTPUT A1 08/15/91 10:10 V 112 260 RECS 08/15/91 10:10 PAGE 3

1PAGE 8 FILE:PROJECTF 8/15/91 09:58

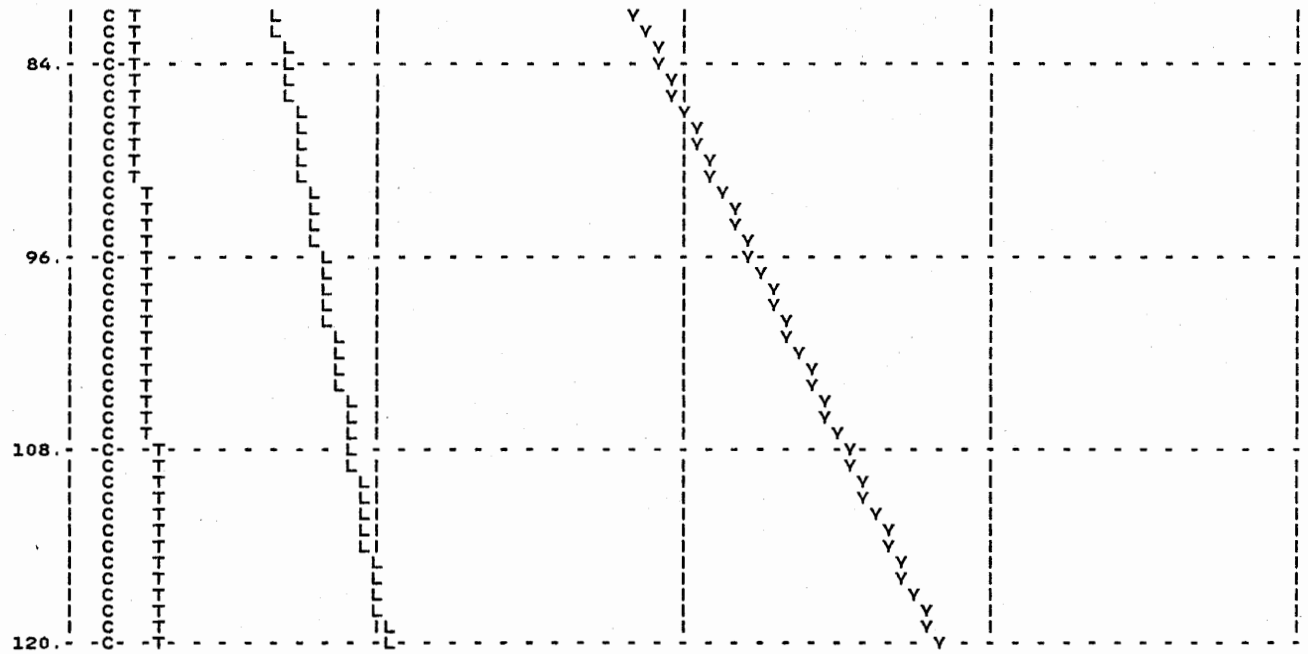
CU=C,LYCU=Y,LCU=L,LTC=T



PLOT8 OUTPUT A1 08/15/91 10:10 V 112 260 RECS 08/15/91 10:10 PAGE 4



PLOT8 OUTPUT A1 08/15/91 10:10 V 112 260 RECS 08/15/91 10:10 PAGE 5



APPENDIX D - Service and Quality for Maximum Profit

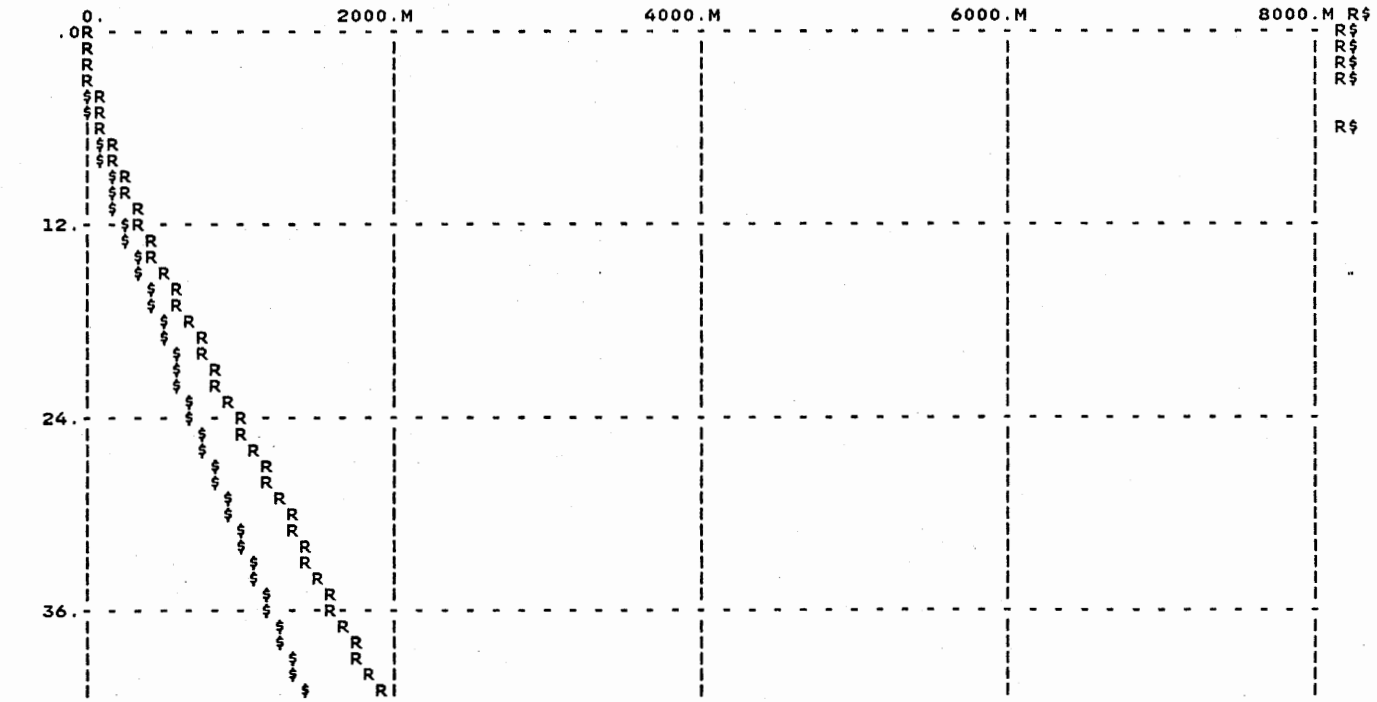
This Appendix contains results from a simulation run where RLOS, RLOQ are set to maximize profit at the end of the 120 month period. A plot of Monthly Revenue (MREV=R) and Monthly Profit (MPROF=$) versus time shows that profit continues to increase for the 120 month period and comparison to other simulation runs showed that this was the maximum profit at the end of the 120 month period. A plot of the Customers (CU=C), Loyal Customers (LYCU=Y), Lost Customers (LCU=L) and the Customers Lost To Competitors (LTC=T) versus time shows that loyal customers continually increase over the 120 month period.

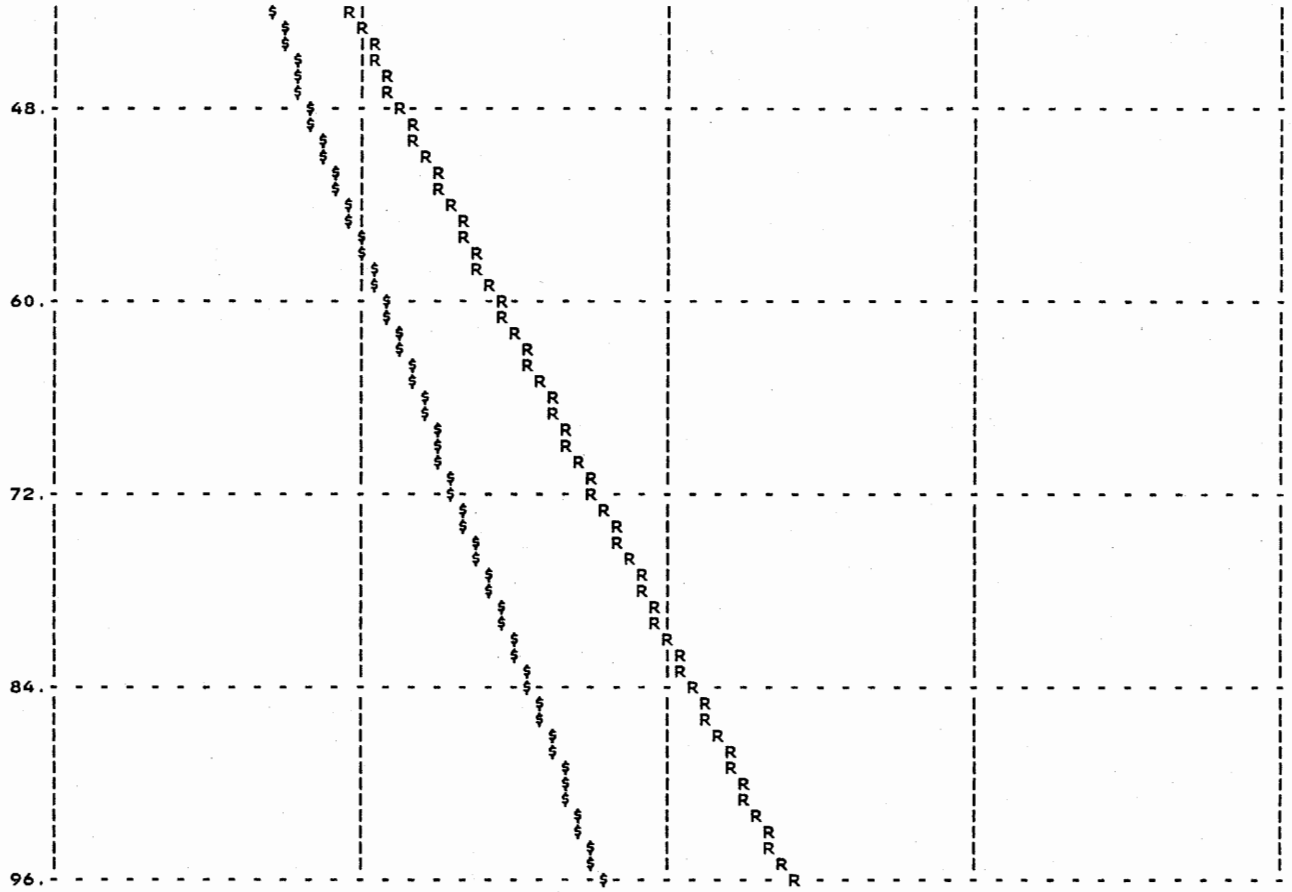
```
PLOTMAX  OUTPUT   A1 08/15/91 10:13   V 112   260 RECS 08/15/91 10:14 PAGE      1

1PAGE 9   FILE:PROJECTF    8/15/91 09:58

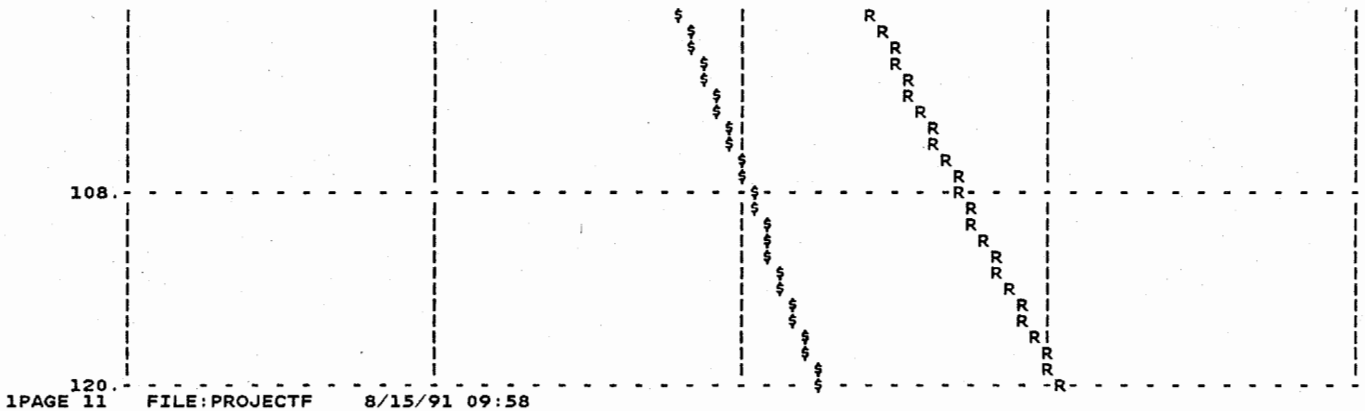
          C RLOS=1
          C RLOQ=0.6
          RUN
0            RLOQ     RLOS
  PRESENT      .6       1.
 ORIGINAL      .4       .4
1PAGE 10   FILE:PROJECTF    8/15/91 09:58

 MREV=R,MPROF=$
```



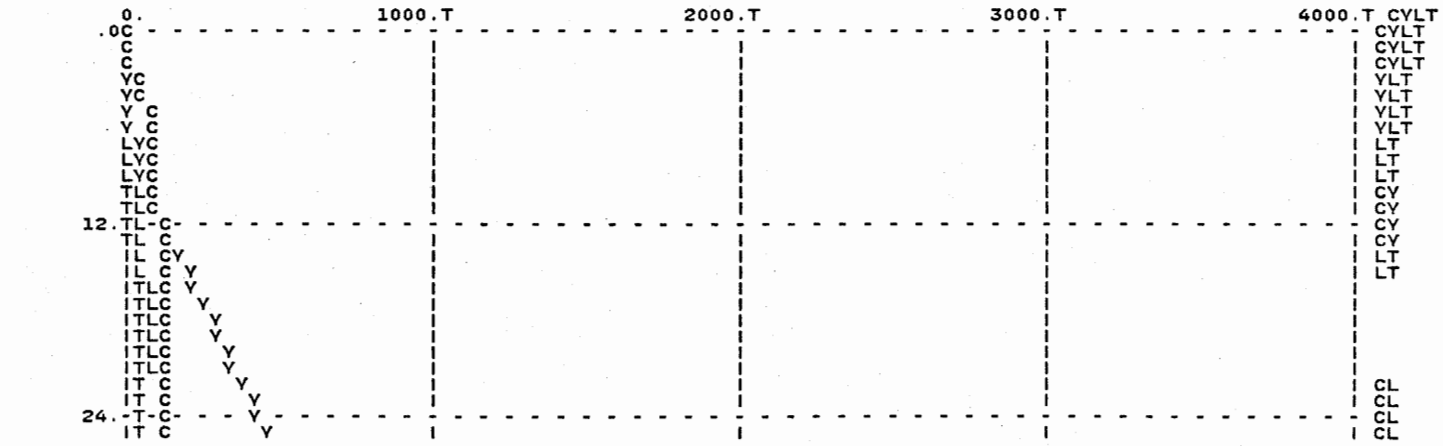

48.
60.
72.
84.
96.

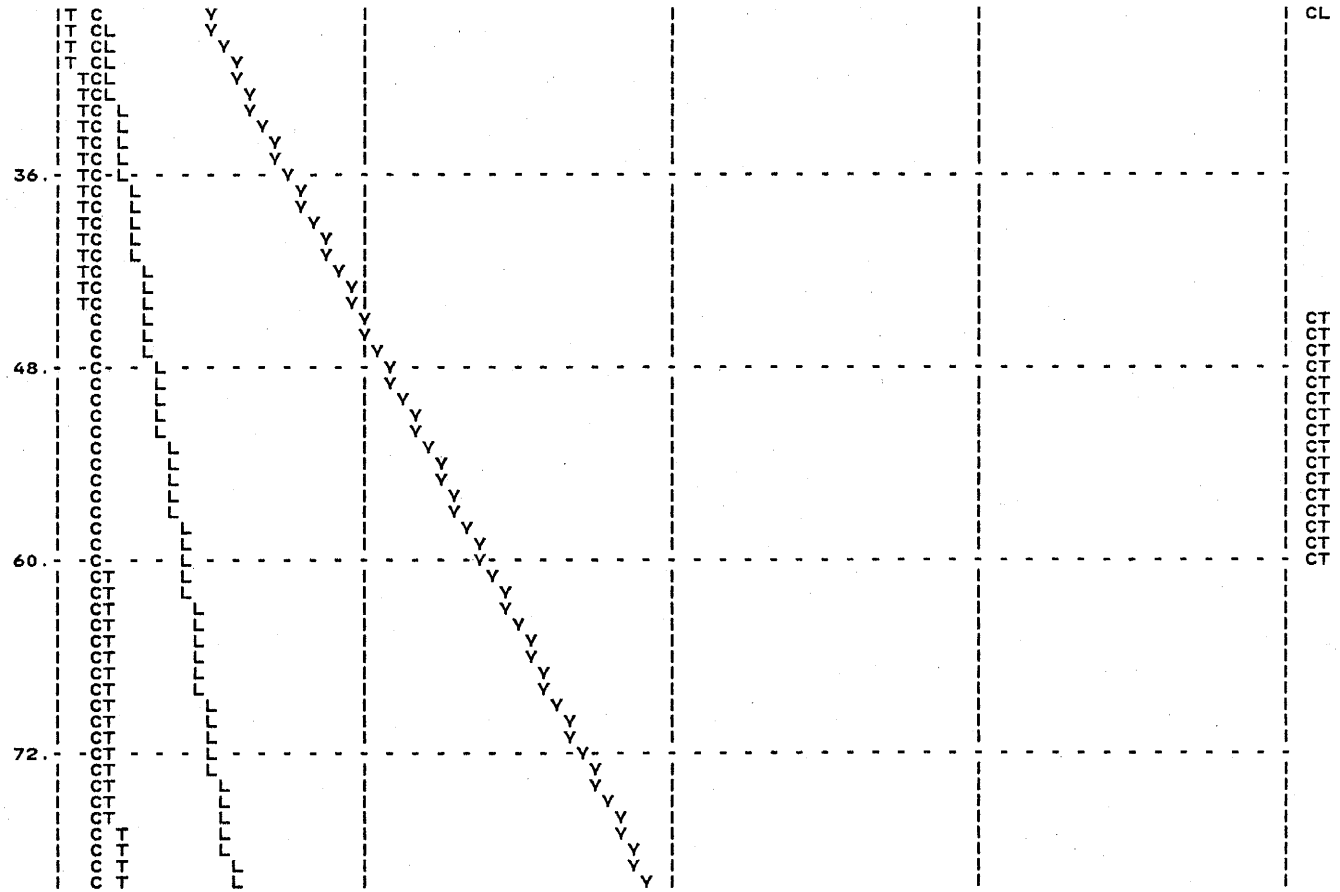
PLOTMAX OUTPUT A1 08/15/91 10:13 V 112 260 RECS 08/15/91 10:14 PAGE 3



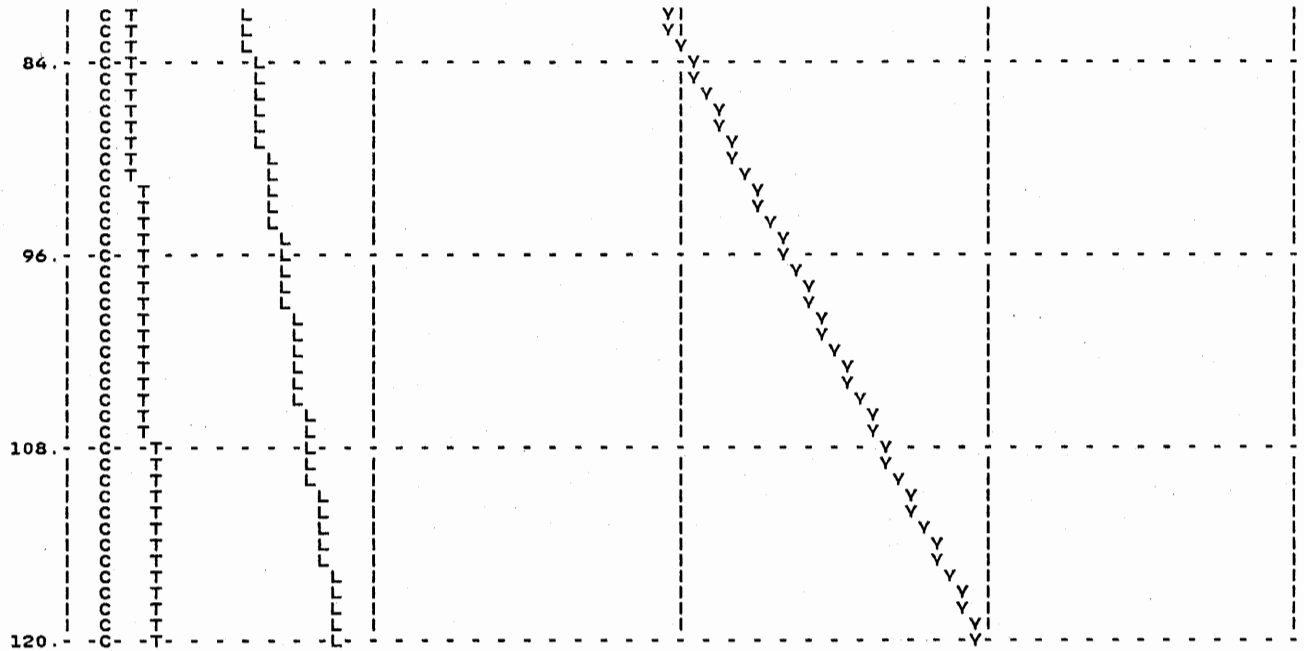
1PAGE 11 FILE:PROJECTF 8/15/91 09:58

CU=C,LYCU=Y,LCU=L,LTC=T




36.
48.
60.
72.
CL
CT

PLOTMAX OUTPUT A1 08/15/91 10:13 V 112 260 RECS 08/15/91 10:14 PAGE 5



APPENDIX E - The Effect of Complaint Soliciting on Profit

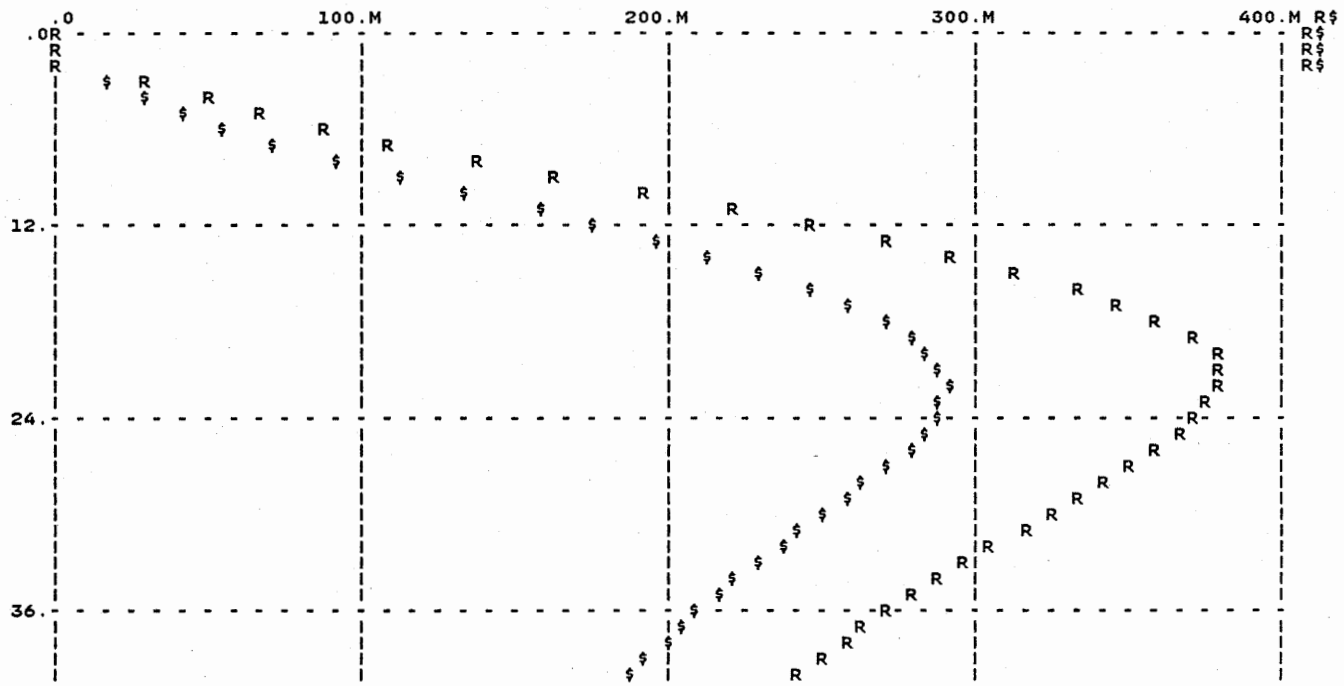
This Appendix shows results from some of the final simulation runs, where RLOS was held constant at 1, RLOQ was held constant at 0.4 and ECUCFS was increased from 0 to 0.4. From the plots of Monthly Profit (MREV=R) and Monthly Profit (MPROF=$) one can see the beneficial effect from soliciting complaints. When ECUCFS = 0 the ending profit after 120 months was approximately $150 million whereas when ECUCFS = 0.4 the ending profit after 120 months was approximately $1.5 billion.

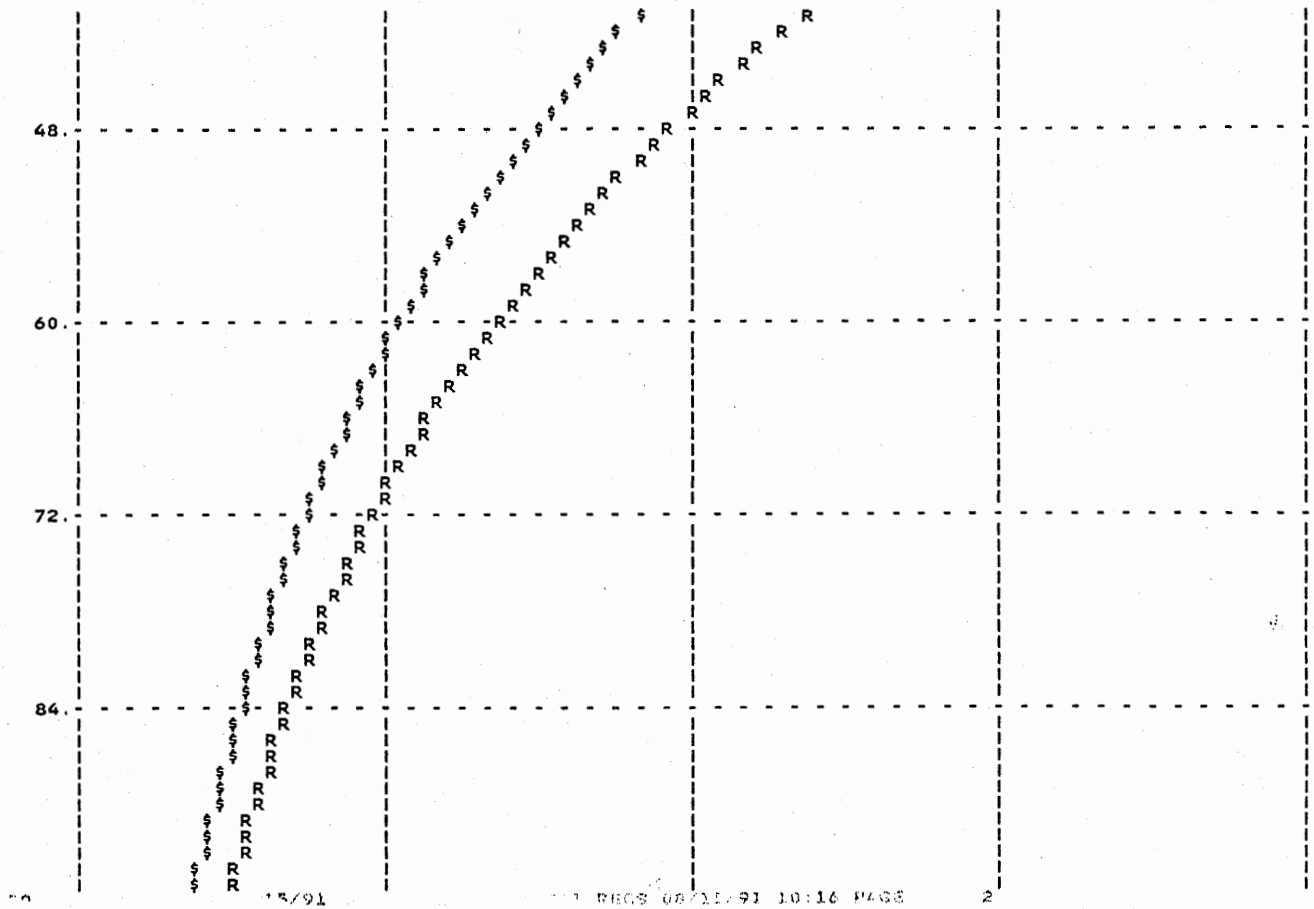
```
PLOTS0   OUTPUT   A1 08/15/91 10:16   V 112   261 RECS 08/15/91 10:16 PAGE      1

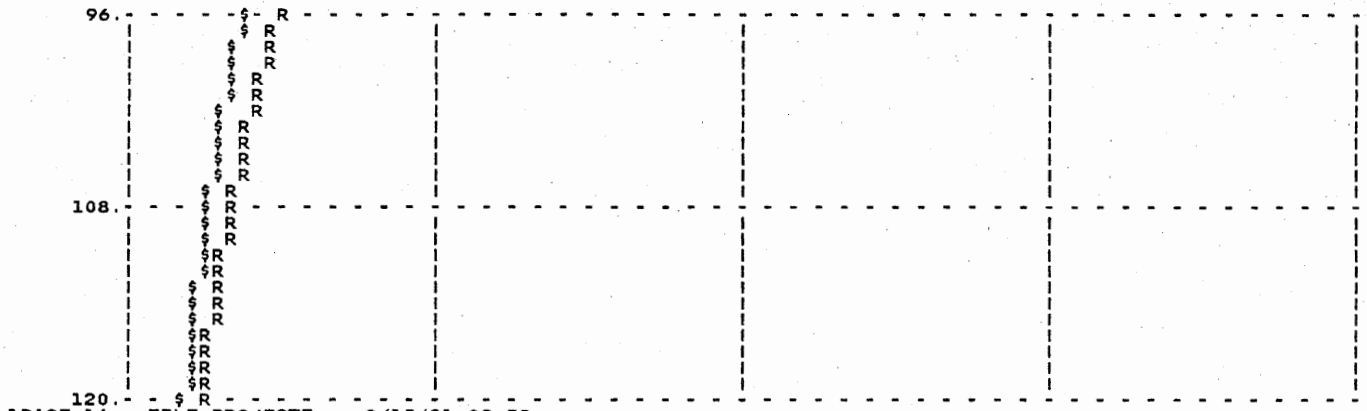
1PAGE 12   FILE:PROJECTF    8/15/91 09:58

          C RLOS=1
          C RLOQ=0.4
          C ECUCFS=0
          RUN
0          ECUCFS     RLOQ     RLOS
  PRESENT      0.       .4       1.
 ORIGINAL      0.       .4       .4
1PAGE 13   FILE:PROJECTF    8/15/91 09:58

 MREV=R,MPROF=$
```

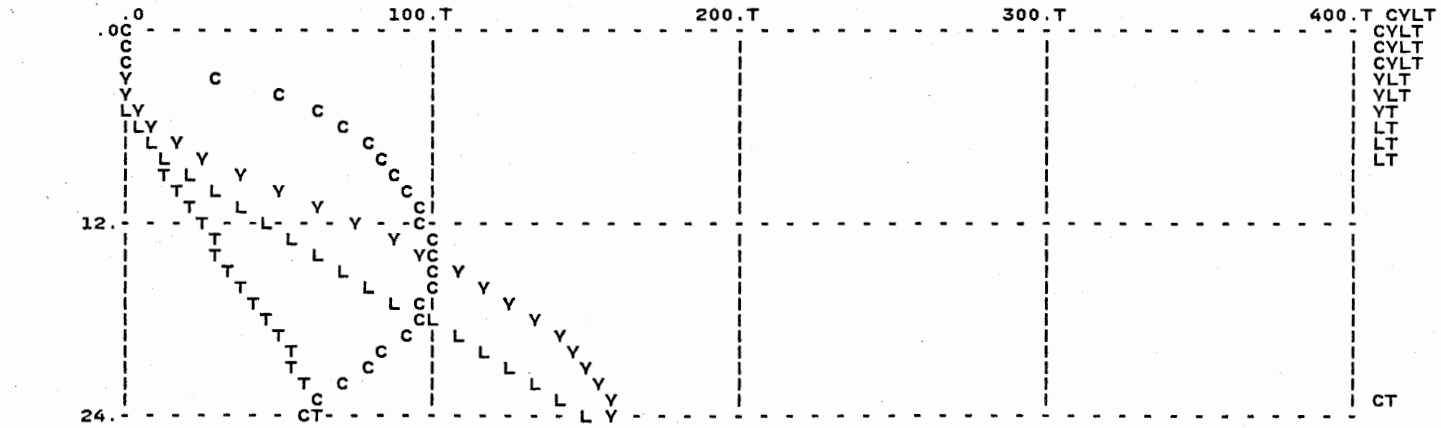


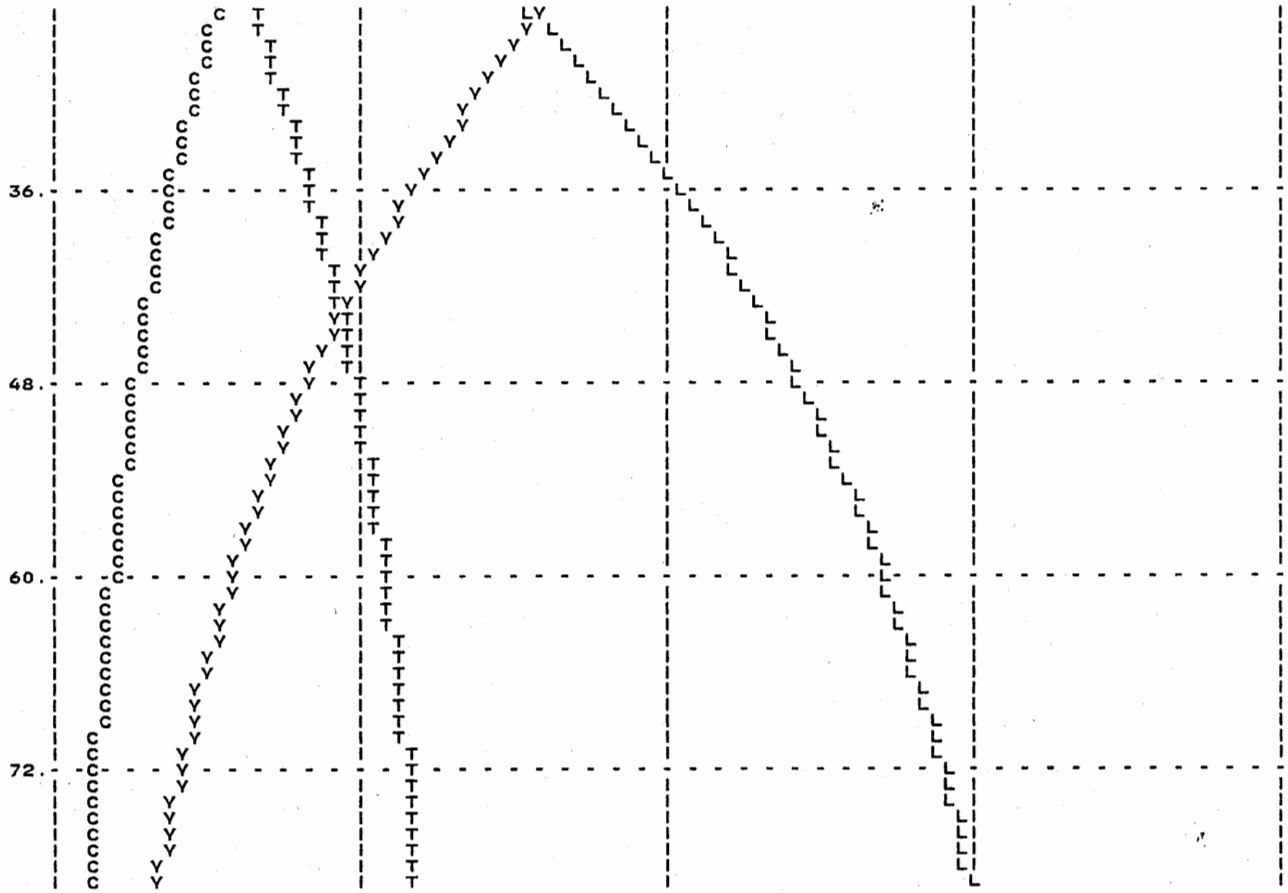

48.
60.
72.
84.

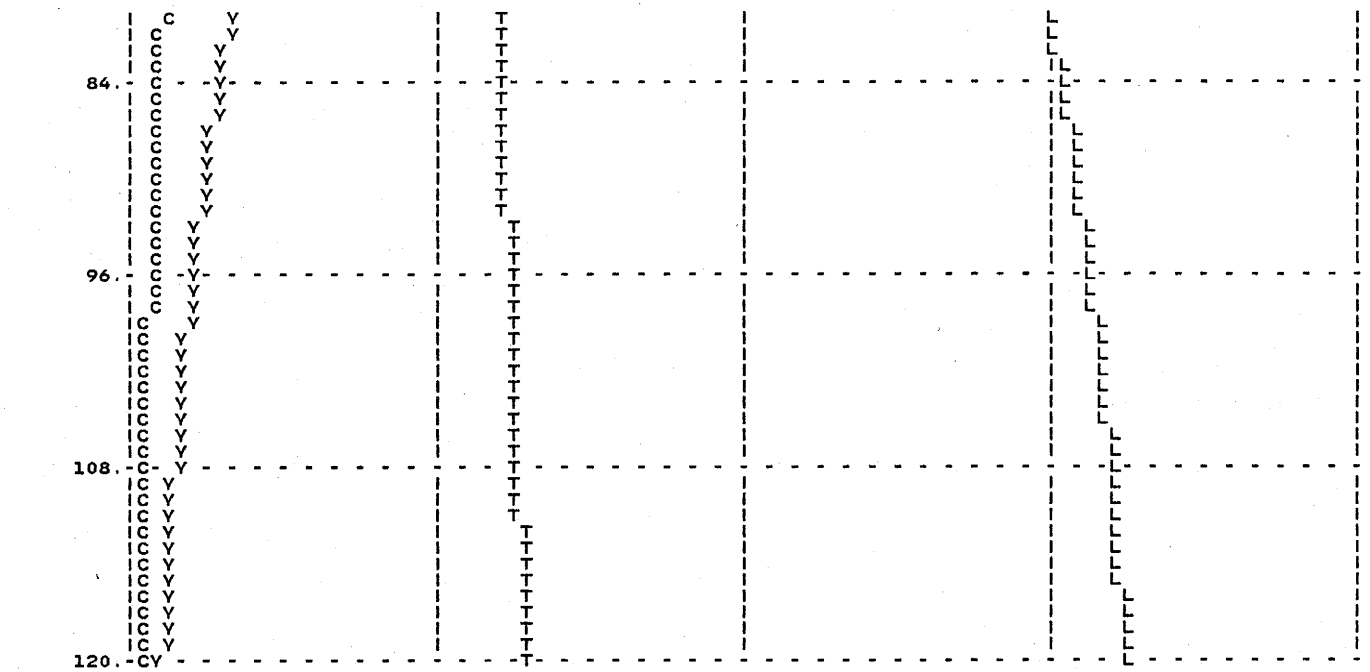


1PAGE 14 FILE:PROJECTF 8/15/91 09:58

CU=C,LYCU=Y,LCU=L,LTC=T




36.
48.
60.
72.

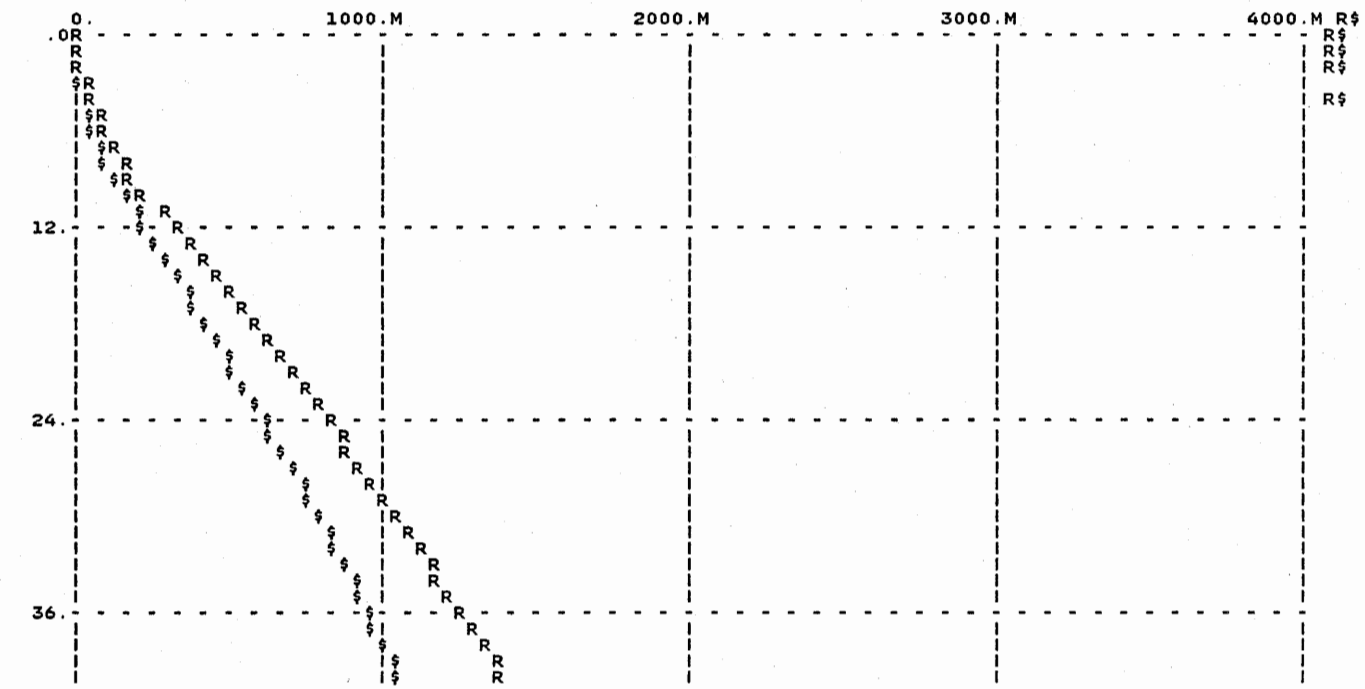

84.
96.
108.
120.

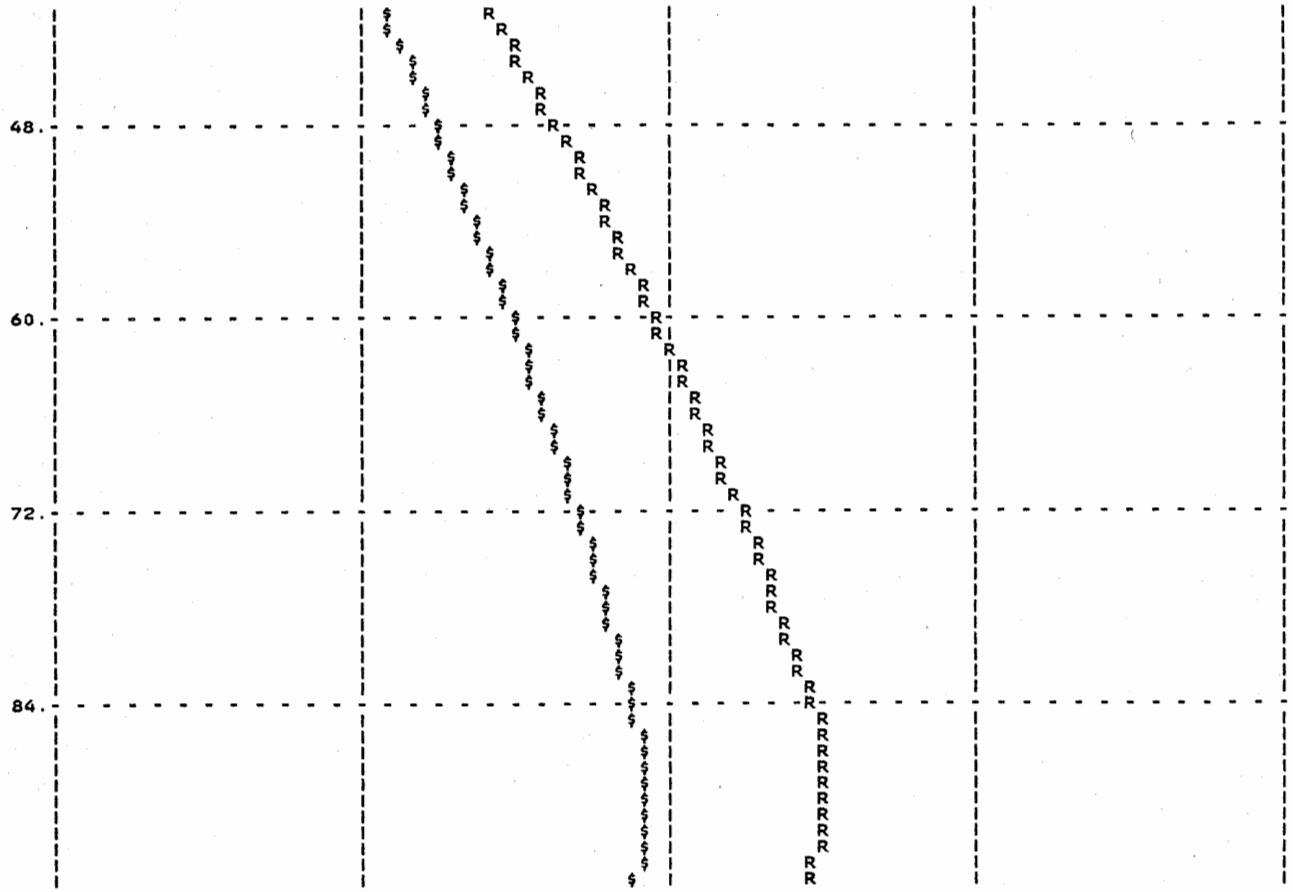
```
PLOTS4   OUTPUT   A1 08/15/91 10:18   V 112   261 RECS 08/15/91 10:19 PAGE      1

1PAGE 15   FILE:PROJECTF    8/15/91 09:58

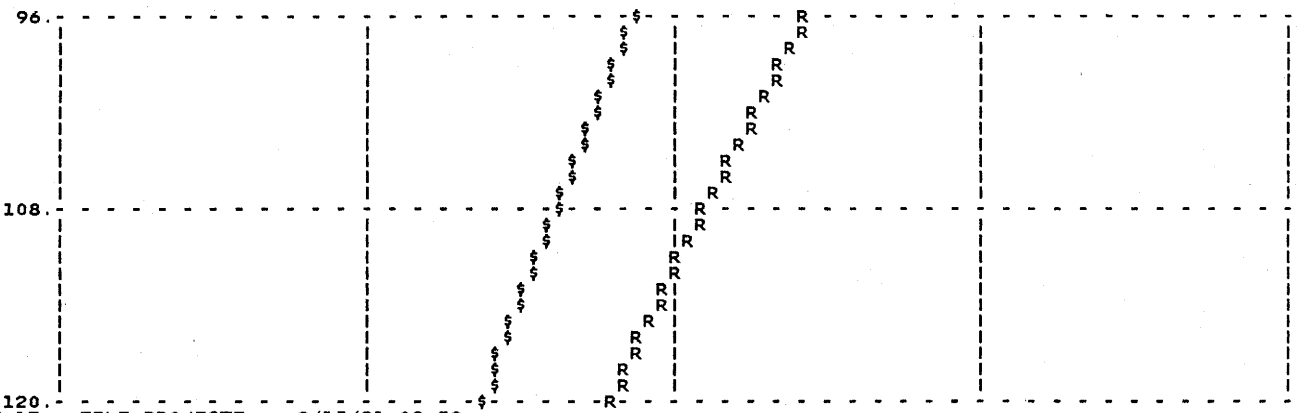
          C RLOS=1
          C RLOQ=0.4
          C ECUCFS=0.4
          RUN
0          ECUCFS     RLOQ     RLOS
  PRESENT      .4       .4       1.
 ORIGINAL      0.       .4       .4
1PAGE 16   FILE:PROJECTF    8/15/91 09:58

 MREV=R,MPROF=$
```



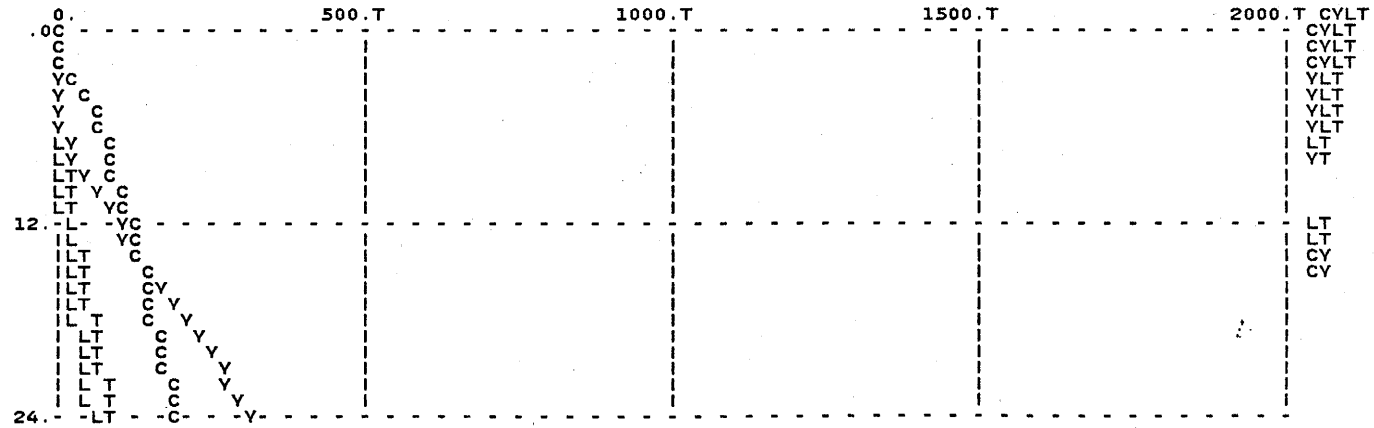

48.
60.
72.
84.

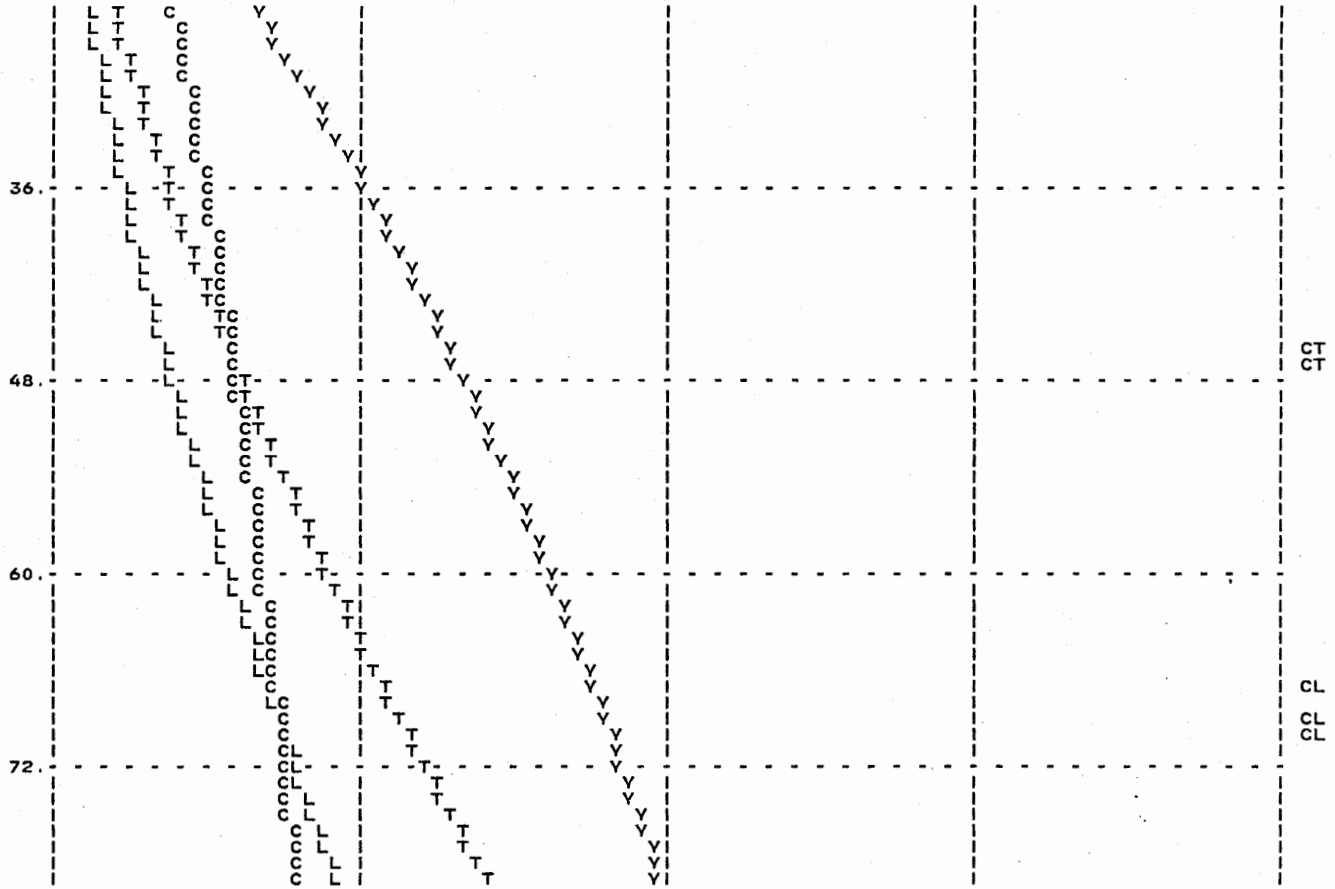
PLOTS4 OUTPUT A1 08/15/91 10:18 V 112 261 RECS 08/15/91 10:19 PAGE 3



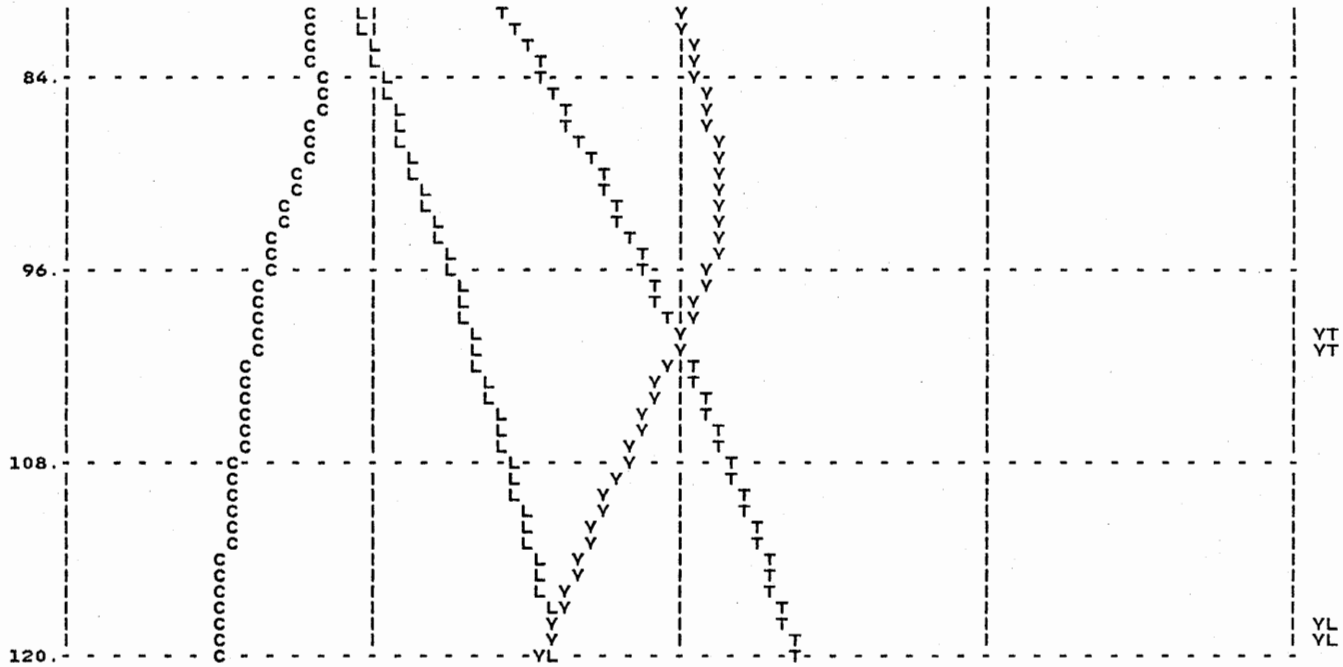
1PAGE 17 FILE:PROJECTF 8/15/91 09:58

CU=C,LYCU=Y,LCU=L,LTC=T




36.
48.
60.
72.
CT
CT
CL
CL
CL

PLOTS4 OUTPUT A1 08/15/91 10:18 V 112 261 RECS 08/15/91 10:19 PAGE 5



GRADUATE PROGRAM OF STUL

SYSTEMS ENGINEERING:

ENGR 5004 - The Systems Engineering Process (Fall 199
ENGR 5104 - Applied Systems Engineering (Spring 1991)
ENGR 5974 - Independent Study: Systems Engineering Tools Assessment (Spring 1991)
ENGR 5904 - Project and Report: Profit through Product Quality and Quality Service (Fall 1991)

ELECTRICAL ENGINEERING:

EE 4504 - Computer Organization (Spring 1991)
EE 5515 - Computer Architecture (Fall 1991)

INDUSTRIAL AND SYSTEMS ENGINEERING:

ISE 4424 - Logistics Engineering (Fall 1990)
ISE 5414 - Random Processes (Fall 1990)
ISE 5405 - Linear Programming (Fall 1990)
ISE 5154 - Applied Human Factors Engineering (Spring 1991)
ISE 5434 - Economic Evaluation of Industrial Projects (Fall 1991)
ISE 5204 - Manufacturing Systems Engineering (Fall 1991)

STATISTICS:

STAT 5615 - Statistics in Research (Fall 1991)

VITA

Daniel James Field was born on May 11, 1965 in Foxborough, Massachusetts. He graduated from Foxborough High School in 1983. He completed his Bachelor of Science Degree in Electrical Engineering in 1987. After graduating he went to work for Digital Equipment Corporation (DEC) in Marlboro, Massachusetts as a semiconductor packaging engineer. In 1988, he changed jobs within DEC becoming a product support engineer for DECs lineprinter product family in Merrimack, New Hampshire.

He was married to his wife Donna in March of 1990, accepted to DEC's Graduate Engineering Education Program (GEEP) in April of 1990 and began graduate studies at Virginia Polytechnic Institute and State University in August of 1990. His studies have been focussed on the application of quality, reliability, maintainability and Systems Engineering to the development of computer products. Following graduation in December of 1991 he will return to DEC in Merrimack, New Hampshire to work as a project engineer.

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