Reconstruction of Operating Facilities,
A Model for Project Management

By

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A thesis
presented to the University of Waterloo
in fulfilment of the
thesis requirement for the degree of
Doctor of Philosophy
in
Civil Engineering

Waterloo, Ontario, Canada, 1999

0-612-51176-6

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ABSTRACT

The construction industry is the largest industry in Canada and worldwide. In recent years, a larger proportion of all construction investment has been spent on reconstruction projects. In spite of their increasing importance, however, little useable information was found in the literature to facilitate the management of reconstruction projects. The objective of this research, therefore, is to develop a model for the management and control of projects that involve reconstruction of operating facilities. The research has been motivated by the higher level of cost overrun, schedule overrun and quality problems associated with reconstruction projects, as compared to new construction. A model for the management and control of reconstruction projects is therefore needed.

Based on a comprehensive literature review and a survey among construction professionals, information was obtained related to fifty-four case studies of reconstruction projects, in addition to useful information regarding the reasons behind cost and schedule overruns and poor quality problems. Every case study included information about the specific techniques used for time, cost, and quality control, in addition to the actual performance outcomes. Based on the information obtained, thirty-six factors were identified to have direct impact on the overall performance of reconstruction projects. Based on a preliminary statistical investigation of these thirty-six factors, eighteen factors were identified as the most significant.

In order to develop an efficient predictive model of the performance in reconstruction projects, two techniques were used and their resulting models compared: Statistical Analysis, and Artificial Neural Networks. Forty-five project cases were used for model development and nine cases were used for validation and testing purposes. Based on the results obtained, the two models performed acceptably with the neural network model being advantageous due to its consideration of a larger number of factors. The predictive models consider the different tools available to the project manager for controlling the time, cost, and quality of a new project. Accordingly, the model provides a prediction of an overall project performance factor. Further experimentation with the model involved developing a spreadsheet user interface and a MontCarlo-based Sensitivity Analysis to address the user's uncertainty in his/her assessment of the input data on the performance prediction. Guidelines towards improving the management of reconstruction projects are then provided to enable managers better to plan this type of projects. This study contributes to a better understanding of the factors that governs the performance of reconstruction projects and provides a decision support tool to facilitate the efficient management of reconstruction projects.

DEDICATION

To my wife and my children.

Their patience and support gave me the strength to complete this work.

ACKNOWLEDGMENTS

(In the Name of God, The Most Merciful, The Most Compassionate)

I would like to express my gratitude and appreciation to the many individuals who have helped to make this thesis possible and contributed to its value. I am thankful to Dr. Archibald Sherbourne for his help and valuable input into this research. I am also very appreciative to Dr. Ralph Haas and Dr. Park Reilly for their help and valuable support during my research..

I am particularly grateful to my advisor, Dr. Tarek Hegazy for his guidance, understanding and valuable input in this work. Dr Hegazy has generously given his knowledge and time. His technical insight and support have been greatly appreciated.

I am also grateful to Dr. Robert McKim for his help and support during the preparation period of my program.

I would also like to express my sincere appreciation for the support of my colleagues and superiors at the Toronto District School Board. I owe special thanks to Ms. Sheila Penny, General Manager of the Technical Services Division and Mr. Frank Coppinger, General Manager of the Operations Division.

My greatest debt of gratitude goes to my wife Rafaa, my daughter Rana and my sons Ahmed and Omar. They have made many sacrifices throughout the compilation of this thesis and have always shown love, patience and understanding.

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CHAPTER 1 INTRODUCTION

1.1 GENERAL

The primary consideration for all parties in the construction industry (owner, contractor and engineer) is the completion of projects as efficiently as possible. Unfortunately, many projects fail to meet their cost, time and quality objectives. The cause of these failures in many of these projects is rooted to the use of an inadequate management and control system. Because of the wide diversity of the construction industry, there is not one project management system that is adequate for all projects. An adequate project management and control system for a given project should bring together many proven control factors to meet the unique needs of the project and its specific construction environment. This research focuses on the basic environment of reconstruction of operating facilities.

Construction projects are usually challenging because virtually every project is unique. Notwithstanding the similarity of experience that is transferable from one job to another, the complexity of each project makes it difficult to predict the outcome of the schedule, economics, and quality of construction with a high degree of confidence. This situation becomes more complicated in the case of reconstruction projects due to different constraints that cause it to be much more unpredictable than a new project [Krizek et al., 1996]. These constraints may include limited space, safety, and coordination and communication constraints.

Definition of Reconstruction Projects

Statistics Canada defines new construction projects as being any construction project that includes new construction, addition, renovation or conversion. Unlike the definition of Statistics Canada, in this work reconstruction projects will be defined as "the modification, conversion or phased complete replacement of an existing facility" [McKim and Attalla, 1998]. Modification may involve expansions, additions, interior renovation or upgrading the functional performance of the facility. Conversion includes changing the type of the facility to perform a different function or provide a different service. Phased replacement is a complete replacement. However, because the building is occupied and the owners can not shut down the building during construction, both demolition of the existing facility and the construction of the new facility have to proceed in phases. As such, running both the existing facility and the construction of the new facility adds substantial complications to the project and creates a different environment. Fig. 1.1 to Fig. 1.6 shows examples of reconstruction projects.

New construction projects significantly outperform reconstruction projects. Also reconstruction projects are becoming increasingly important and are driven by different factors. Furthermore, large sums of money are being invested in reconstruction projects.

Fig. 1.2 Asbestos Removal During Interior Renovation

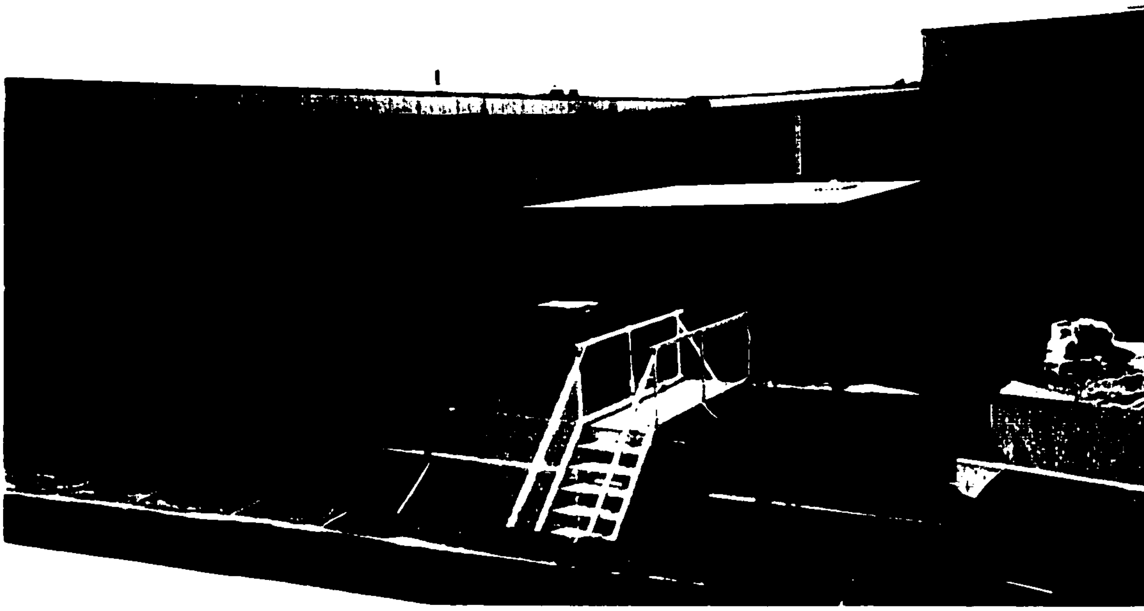

Fig. 1.3 Fire Escape rout in a Reconstruction Project

Fig. 1.4 Demolition and Protection of the Existing Facility

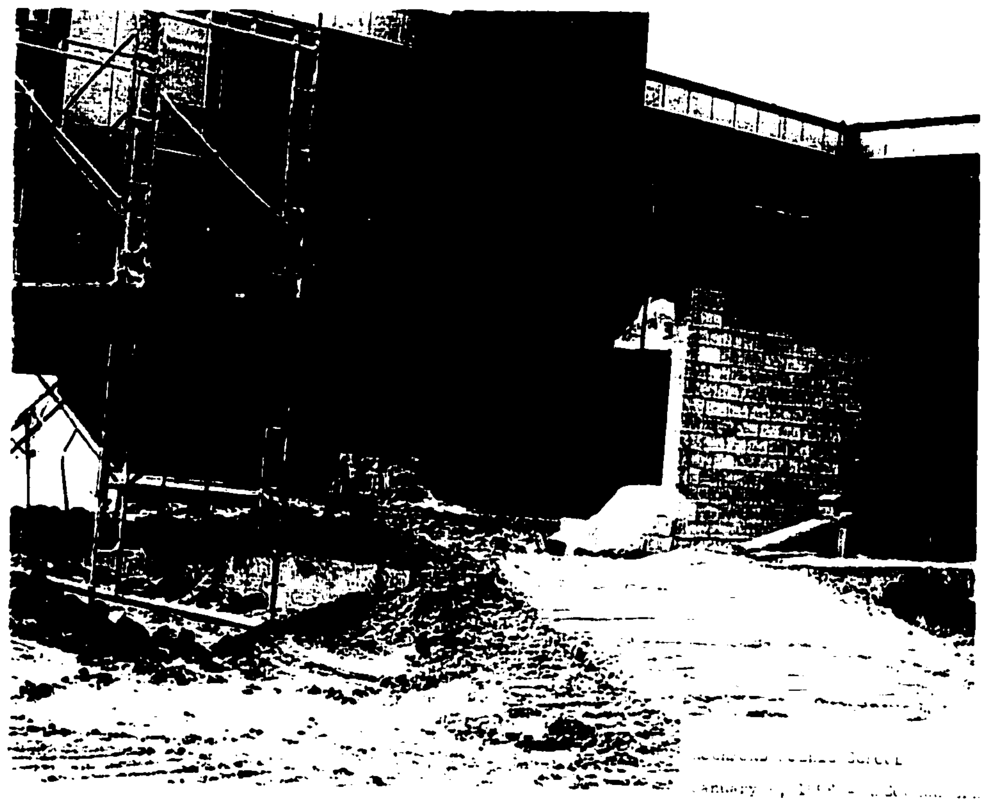

Fig. 1.6 Addition to a School Building

There is a need therefore to study the impact of this unique environment on the overall project performance in terms of its Cost, Schedule and Quality. Explanation of the above statements is provided in the following section.

1.2 MOTIVATION OF THE RESEARCH

This research has been motivated by four main reasons:

(a) Large Investments in Reconstruction Projects

The construction industry is one of the largest industries worldwide. Reconstruction of operating facilities constitutes a significantly large and growing portion of construction spending. Therefore, research done in the area of reconstruction of operating facilities is of high practical value.

Table 1.1 compares investments in the construction industry with investments in all industries and with some of the major industries as per the Gross Domestic Product at factor cost [Statistics Canada, 1998]. Also, Table 1.2 illustrates construction spending in Canada from 1993 to 1997. Construction in the U.K. amounted to fifty billion pounds in 1996, which is 8% of the GDP (Gross Domestic Product) [ECI, 1996].

Table 1.1 : Investment in the Construction Industry vs. All Industries

	1997	1998
All industries	690,202	707,487
Construction	38,947	40,261
Fishing	935	900
Agriculture	12,350	11,999
Mining	27,398	28,907

All amounts are in $ millions

Table 1.2 : Construction Spending in Canada, 1993 - 1997

	1993	1994	1995	1996	1997
Residential	16,432.5	17,590.2	13,241.7	15,718.3	18,303.5
Industrial	1,755.6	2,250.2	2,822.8	2,642.9	3,455.0
Commercial	4,267.8	4,993.2	5,441.4	5,566.9	6,519.4
Institutional & government	3,130.4	2,803.1	3,088.9	2,227.4	2,956.1
CANADA	25,586.3	27,636.7	24,594.7	26,155.5	31,234.0

All amounts are in $ millions

Note : The difference in expenditures in the construction industry between Table 1.1 and Table 1.2 is due to road work

Companies within the building construction industry accounted for 175 billion dollars of business in 1992 in the United States of America. Table 1.3 illustrates spending in construction vs. reconstruction in the United States in 1992. The national average spending on reconstruction is approximately 25 % of spending on new construction [U.S., 1998]. However, in large cities this percentage is much higher. It was mentioned in a more recent dissertation, that up to one half of the total construction budget has gone to some form of renovation, remodeling or reutilization of existing buildings for the last decade in the United States [Lee, 1996]. Fig. 1.1 illustrates spending in reconstruction vs. new construction in one of the largest school boards in North America.

Table 1.3: Investments in Reconstruction and Total Construction in the U.S.A. in 1992

	Total Construction	Reconstruction
Single Family Houses	49.5	12.0
Other Residential	8.0	1.8
Industrial / Warehouses	21.0	2.3
Commercial / Institutional	95.7	16.6
Total	175	32.7

All amounts are in $ billions

All amounts are in $ millions

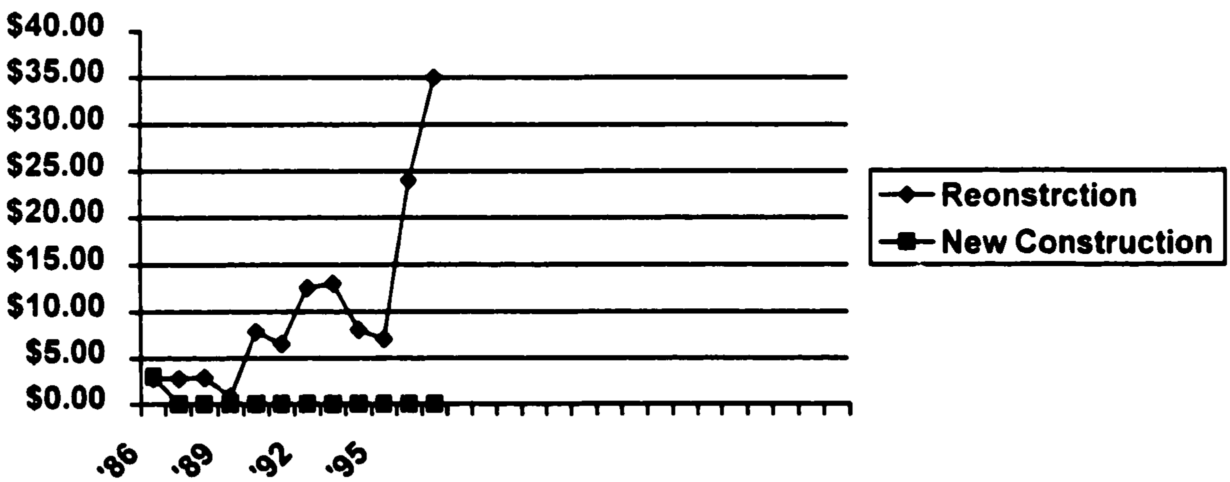

Fig. 1.7 : Spending in New Construction vs. Reconstruction in the North York School Board, 1986 - 1997

(b) The Increasing Importance of Reconstruction Projects

Reconstruction projects are becoming increasingly more important as building owners and metropolitan cities face economic constraints [Sanvido and Riggs, 1993]. Four main reasons have led to the increasing importance of reconstruction projects:

- *Demographical factors*

The population in metropolitan areas increased dramatically in the last few decades due to a variety of reasons. Since these metropolitan areas suffer from lack of space to build new buildings, they tend to upgrade existing buildings in order to accommodate the increased service requirements of the increased population. Increased enrollment in schools and universities is an example of this demographical factor.

This factor imposes a need to increase the capacities of the schools or universities through expanding or replacing the existing buildings. Hospitals and government offices that are rendering services to the public face the same challenge.

- *Environmental factors*

The increased public awareness of environmental hazards and the proposed regulations to overcome such hazards impose another constraint on building owners and local and central governments to comply with these regulations. This increases the need for more reconstruction projects. Asbestos removal is a good example of these types of projects.

Since asbestos is designated as a hazardous material, building owners and public organizations are sponsoring programs to remove materials containing asbestos from their facilities. Unfortunately, asbestos is present in floor tiles, ceiling tiles and pipe insulation, which makes its removal and the subsequent replacement of the building components a complex and awkward task. This is due mainly because appropriate safety regulations have to be satisfied and the existing facility has to be kept operational during this type of reconstruction.

- ***Social factors***

Social factors also contribute to the increasing need for reconstruction of operating facilities. One example is the barrier free programs where building owners and public organizations adopt plans to upgrade their buildings to secure access for persons with disabilities. This may include removing stairs, constructing ramps, building elevator shafts and modifying existing washrooms. Such construction projects involve a large amount of uncertainty and complexity.

- ***Technological and economical factors***

Given the high pace of change in science and technology, it is crucial to remain competitive in today's market place in order to meet the public expectations of the level of services provided by public organizations. These organizations have to design programs continuously to improve and upgrade their facilities. This may include such projects as interior renovations of a computer facility or a blood-testing laboratory to accommodate more advanced equipment. Another example could be retrofitting the mechanical and electrical systems for energy conservation purposes.

(c) Poor Performance of Reconstruction Projects vs. New Construction Projects

Preliminary investigation and background research revealed that new construction projects significantly outperform reconstruction projects in meeting their cost and time targets [Attalla, 1996]. These results were obtained through the use of two quantifiable measures.

The variable Cost Performance Factor (CPF) was used as a means of measuring cost performance of construction projects and to establish a benchmark to compare the cost performance of different projects. This cost performance factor utilizes the cost overrun as the basis for measuring cost performance. This approach was used in previous research and is also general practice in the construction industry as confirmed by different construction professionals who were interviewed. Previous researchers and the construction industry consider cost overrun an indicator of poor cost performance of construction projects.

The Cost Performance Factor can be obtained by this formula.

$$CPF = \frac{\delta C}{Original\ Contract\ Value} X\ 100$$

Where δC is the total value of change orders issued during the project life.

Table 1.4 compares the cost performance for reconstruction and new construction projects [McKim, et al. 1999]

Table 1.4 : Cost Performance in Reconstruction and New Construction

	Average CPF	Standard Deviation σ
RECONSTRUCTION	19.9	18.4
NEW CONSTRUCTION	4.6	4.3

It is obvious from Table 1.4 that new construction projects have a better cost performance history at an average value of 4.6 and a standard deviation of 4.3 than reconstruction projects which tend to have a higher cost overrun rate at a CPF average value of 19.9 and are more volatile at a standard deviation of 18.4.

This cost difference can also be noted in two recent publications about two case studies. The first case describes the reconstruction of the Grand Central Terminal in New York [Rasmussen, 1997]. The owner maintained the operation of the facility for 500,000 users every day while moving through a huge construction zone. A new bridge scaffolding system was utilized. The total cost was about 175 million dollars. The second case was the reconstruction of the Green Line Transit in Chicago [Krug, 1997]. The owner was able to take the facility out of commission before proceeding with the reconstruction. Because the facility was not operational, the owner saved 50% of the schedule and two thirds of the project cost. The impact of reconstructing an operational facility is very clear.

Schedule Performance Factor is another variable used to measure schedule performance of construction projects. SPF utilized schedule slippage as the basis for measuring the schedule performance of a construction project.

SPF was obtained by the following formula.

$$SPF = \frac{\delta S}{\text{Original Duration of the Project}} \times 100$$

Where δS is the total time delay during the project life. Table 1.5 compares SPF for new construction projects and reconstruction projects [McKim, et al., 1999]

Table 1.5 : Schedule Performance in Reconstruction and New Construction

	Average SPF	Standard Deviation σ
RECONSTRUCTION	22.3	26.2
NEW CONSTRUCTION	12.6	14.2

These findings indicate that reconstruction projects have a higher tendency for schedule slippage with a SPF average value of 22.3 and are more volatile at a standard deviation of 26.2. New construction projects, on the other hand, are more stable with a SPF average value of 12.6 and SD of 14.2.

(d) Lack of Research on Reconstruction Projects

In spite of the increasing importance of reconstruction projects, very little useable information was found in the literature about the overall management and control of these types of projects. The little information found in the literature dealt with the reconstruction problem from two aspects. One dealt with only the engineering aspect of some of its elements. See [Kaminetzky and Lavon, 1996].The second dealt with the problem on an individual basis to provide some analysis of the problems mentioned in one single case study . See [Kerr et al., 1992], [Hermie, 1995], [Krizek et al., 1996], [Rasmussen, 1997] and [Krug,1997].

Details of the information provided in previous literature will be provided in chapter two.

1.3 RESEARCH OBJECTIVE

It is apparent that reconstruction projects are different from new construction projects. Therefore, there is an immediate need for a more rigorous and comprehensive study in this area to provide more light into the performance, control and management of reconstruction projects. This research aims at investigating the reconstruction environment and developing a predictive model for the overall performance of the project in terms of its cost, schedule and quality performance.

The detailed objectives of this research are as follows:

1. Identify the managerial and organizational factors that govern the success of reconstruction projects.
2. Identify the reasons for the poor performance of reconstruction projects or the overall failure of the project.
3. Based on the above, this research will identify the tools and factors that suit the specific environment of reconstruction projects and facilitate their control and management.
4. This work will develop a quantifiable and objective measure of the overall performance of reconstruction projects in terms of their cost, schedule and quality performance.
5. Develop a model for predicting the overall performance of reconstruction projects and its deviation from preset baselines. The model enables project managers to determine the suitable control techniques which can be used in a potential project to improve its performance.
6. Apply the model to a set of completed projects and validate its performance.
7. Facilitate the use of the model through computerization and experimentation such as sensitivity analysis.

1.4 RESEARCH SCOPE

This research aims at developing a model for identifying the factors and tools that suit the specific environment of reconstruction projects and facilitates their control and management. The intended user of this model is the owner organization since it is the party which initiates the project, secures funding, determines the start and finish dates, selects the contracting strategy, defines the scope of work and imposes the necessity of applying proper management techniques in the reconstruction contract.

The model is, also, limited to institutional and commercial buildings, which have similar environments of their reconstruction requirements. This also ensures consistency because different types of facilities may involve significantly different control and management requirements.

The study is also applicable to reconstruction projects contracted in a lump sum form of contract. A lump sum arrangement provides an owner with one convenient construction price for completion of all work directly and incidentally associated with the scope of work [Roberts, 1983]. A lump sum contractual agreement is common practice because of its simplicity and also because it provides the owner with a single point responsibility. Moreover, a high majority of building reconstruction projects use a lump sum contract format.

1.5 RESEARCH METHODOLOGY

The approach, developed in this research in order to achieve the aforementioned objectives, consists of the following steps:

1. Literature Review:

A literature review was first carried out to gather valuable information contained in previous research related to the present study. The literature review included a research of previous publications on reconstruction projects. Also, a review was performed to gather information relating to previous models concerned with the control, performance or success of construction projects. More importantly, the literature review included a comprehensive research for traditional and non-traditional factors and tools that are being used in new construction and reconstruction projects. The literature review also included a search about the utilization of both Statistical Regression Analysis and Artificial Neural Network in developing predictive models.

2. Preliminary Field Review :

The collected information was compared to a preliminary field review with several construction practitioners from the industry. This preliminary field review serves three purposes. The first is to identify the reasons behind the poor performance of reconstruction projects. The second is to confirm or deny the influence of the identified factors on the performance of reconstruction projects. The third purpose is to identify other factors which may be used by the construction professional to control and manage his / her construction projects. The result of this stage was the formulation of a set of control factors to be included as independent variables in the data collection and the model building process.

3. Data Collection :

The predetermined control factors (model variables) were used to obtain factual data in a structured questionnaire and structured interviews format. The data was collected from completed projects.

4. Model Construction and Validation :

The collected data was used to build predictive models and validate them. Two methods were used to build the models. These methods were Regression Analysis and Artificial Neural Network. Details about this step are explained in chapters four and five.

5. Computerization and experimentation

A spreadsheet interface has been developed in order to facilitate the use of the Neural Network predictive models. The interface was developed on *Microsoft Excel* using its macro tools. Also, a sensitivity analysis module has been incorporated into the user interface in order to assess the sensitivity of the model's predictions to variations in the project characteristics. Fig. 1.8 illustrates the research methodology.

1.6 THESIS ORGANIZATION

Chapter two presents the results of the literature review, which is divided, into four sections. The first section deals with previous publications related to reconstruction projects, while the second section deals with current construction models. The third section compiles comprehensive information about construction control categories and their respective control factors. The fourth section is a review of Artificial Neural Network and Regression Analysis and their use in the development of predictive models in construction.

Chapter three explains the preliminary field review process and presents and summarizes its results. Furthermore, it presents the development of the questionnaire survey and explains its structure. This chapter, also, includes a detailed explanation of the data collection process and the collected data. It concludes with a preliminary data analysis.

Chapter four discuses several experiments, which were performed in order to develop predictive models for the overall performance of reconstruction projects utilizing Statistical Regression Analysis. It explains the development of two models, one utilizing Detailed Project Data and the other utilizing Summarized Project Data. It also discusses the utility and validation of the developed models.

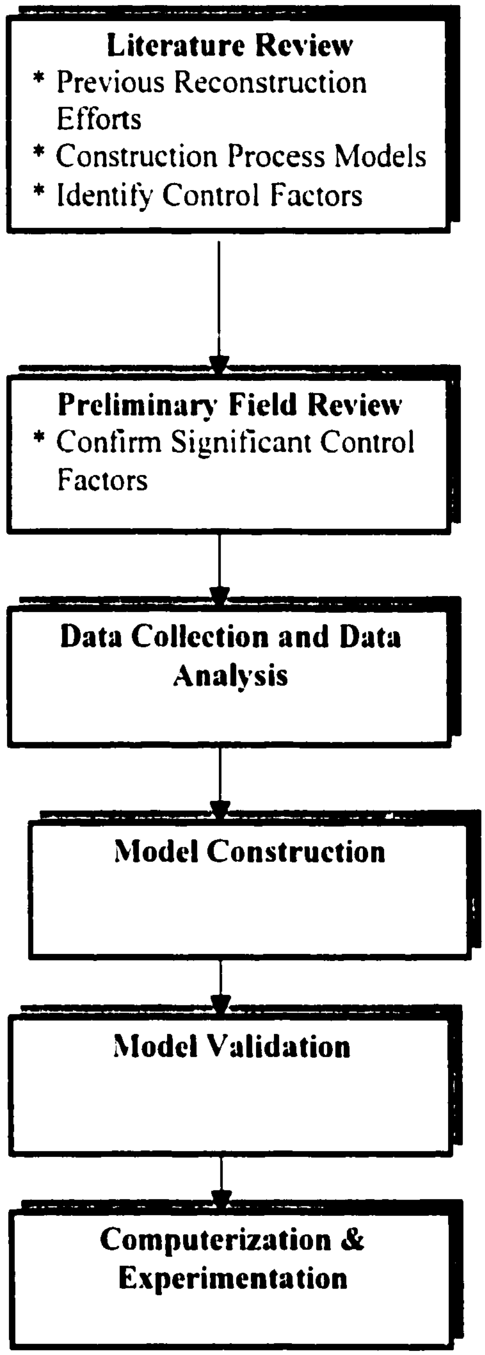

Fig. 1.8 Research Methodology

Similar to chapter four. chapter five discuses different experiments for the development of predictive models for the overall performance of reconstruction projects utilizing Artificial Neural Networks. Two predictive nets were developed, one for Detailed Project Data and the other for Summarized Project Data.

Chapter Six describes the development of a spreadsheet user interface in order to facilitate the use of the Neural Network models. Moreover. this chapter explains the development of a sensitivity analysis tool to help the user account for the uncertainty and subjectivity in the assessment of the input data. This chapter also compares the results of both Regression Analysis and Neural Network models.

Finally. chapter 7 summarizes the contribution of this work and provides the conclusions made from the findings and the developments of the research. It also includes recommendations and description of future extensions to this study.

CHAPTER 2 LITERATURE REVIEW

This chapter presents the results of a comprehensive literature search in several aspects related to this work. The prime objective of this literature review is to identify those control factors that were reported as contributing to the enhancement of the performance of reconstruction projects. These factors will become the independent variables in the model building process. In order to achieve this objective, information related to reconstruction projects and models concerned with the control, success or performance of construction projects was reviewed. Also the different control categories and their respective control factors were reviewed. Furthermore, information related to model building methodologies utilizing Artificial Neural Network and Regression Analysis was reviewed.

2.1 RECONSTRUCTION PROJECTS

As mentioned earlier in this work, very little useable information was found in the literature about reconstruction projects. The reviewed literature pertaining to reconstruction projects dealt with the problem through a case study methodology that did not provide enough insight regarding the control and performance of reconstruction projects. The objective of this study is to obtain information related to the use of specific control factors from a reasonably large sample of reconstruction projects. This information should enable researchers to draw conclusions and make valuable inferences about the control and performance of the overall population of reconstruction projects.

The $175 million reconstruction project of Grand Central Terminal faced considerable problems with existing site conditions [Rasmussen, 1997]. The project had to proceed while keeping 500,000 pedestrians moving each day. There were no accurate as-built drawings, which caused significant problems.

Another case study about a reconstruction project for a high rise building in downtown New York explored the project from the structural side only without consideration of the management process [Kaminetzky and Lavon, 1996]. However, it was mentioned that a written plan for the construction sequence was very crucial to the success of this project.

In a case study about the $400 Million reconstruction project of the Green Line in Chicago, it was mentioned that making the facility non-operational saved 50 % of the schedule and 66 % of the cost. This gives an indication about the challenges that face reconstruction projects in operating facilities. In this study, there was no mention of any control factors that may contribute to the success of reconstruction projects [Krug, 1997].

Another example of reconstruction projects is the case study about the reconstruction of the Exchange Place Station in New York [Kerr et al., 1992]. In this study, the author focused on the engineering aspect without any discussions about the management aspect of the project. See also [Hermie, 1995].

Kirtzek provided a very detailed and articulate analysis in a case study about the reconstruction of an operating academic building [Kirtzek et al, 1996]. The study provided a comprehensive analysis of the problems, constraints and lessons learned from the project. However, the study focused on stating conditions that needed to be satisfied in order for the project to succeed without explaining what tools can be used to influence those conditions. The study, however, recommended the use of CPM as an adequate schedule control technique. It can be concluded from this study that there is a strong need for an effective project management system in addition to continuous communications between all parties, and contract documents that enable the project team to deal with uncertainties and changes. There is also a need to deal with physical space constraints in order to accommodate simultaneous construction building operations as well as the need to deal with existing site condition uncertainties and, finally, contractors should be experienced. Since this research is focused on examining control factors, lessons learned from the aforementioned study will be used for further field review to determine what possible control factors can be used to overcome these problems.

Also, using a case study approach, the success related factors for the reconstruction and full replacement of a high school in Toronto, Canada were fully discussed [Attalla et al, 1999]. The project was a major undertaking and exhibited several difficulties in maintaining the operation of the old facility and the safety of 2,800 occupants.

In an exploratory study by the Construction Industry Institute, critical success factors to retrofit projects were examined [Sanvido and Riggs, 1991]. These factors are: an experienced and cohesive project team, contract incentives, partnering arrangements, special procurement and pre-planning strategies, and a high level of management support.

Also, this exploratory study did not produce any control techniques that enable the project team to actually influence the project and enhance its performance. The study was performed based on information gathered from sixteen projects only, which is not considered a large representative sample that can enable researchers to draw conclusions about the overall population of reconstruction projects. Also, the results were not validated against another independent sample. Table 2.1 include the Critical Success Factors as developed by Sanvido and Riggs

2.2 REVIEW OF CURRENT CONSTRUCTION CONTROL MODELS

Project control is not a specific set of services that can be applied in the same manner to each and every project. A project control system is not the development of something entirely new. It is more the bringing together of many proven project control factors. Since the exact combination of control factors varies significantly to meet the unique needs of each project, no single detailed control system is appropriate to every construction environment.

Table 2.1 Critical Success Factors for Retrofit Projects [Sanvido and Riggs, 1991]

CRITICAL SUCCESS FACTORS FOR RETROFIT PROJECTS
1- Experienced and Cohesive Project Team
2- Contract Incentives
3- Partnering Arrangements
4- Special Pre-Planning Strategies
5- High level of Management Support

The definition of control is "to check or verify, and hence to regulate" [Shorter Oxford English Dictionary]. It is also defined as "making situations behave according to certain desired performance criteria" [Beer, 1996]. Project control can also be defined as "the processes required to define the objectives of the project and the resources used to meet these objectives; the policies and activities required to provide these resources; the efficient use of these resources; and the efficient and effective conduct of specific tasks to achieve the project objectives" [Sanvido, 1989].

The prime objective of this research is the development of a model to manage and control reconstruction projects. It is, therefore, an essential part of this study to investigate previous construction control, construction processes and construction performance models.

In 1987, a model for the Determinants of Construction Projects Success was developed [Ashley et al., 1987]. It was concluded that the critical determinants of success are planning effort (design and construction), project manager capabilities, technical uncertainty, and legal political environment. Other determinants of project success were also identified such as project manager goal commitment, project team motivation, scope and work definition, control systems, safety, design-interface management and risk identification.

This model was accompanied by a list of recommendations, which would be very beneficial for future efforts in construction models. These recommendations were taken into account when developing this present study:

1) Increasing the project sample size since a sample size of sixteen projects cannot produce results representative of all projects.
2) Collecting more objective data for each project.
3) Identifying more factors and relationships.
4) The focus of this work was on heavy industrial projects, which opens the opportunity to conduct similar studies for other types of projects.
5) The development of well conceived predictive models that capture the essence of project success such as the following format:

$$\text{Project Outcome} = C_1 F_2 + C_3 F_4 + C_5 F_6 + C_7 F_8$$

Where : C_1, C_3, C_5 and C_7 are coefficients

F_2, F_4, F_6 and F_8 are potential predictive factors

Fig. 2.1 illustrates the model for the Determinants of Construction Project Success.

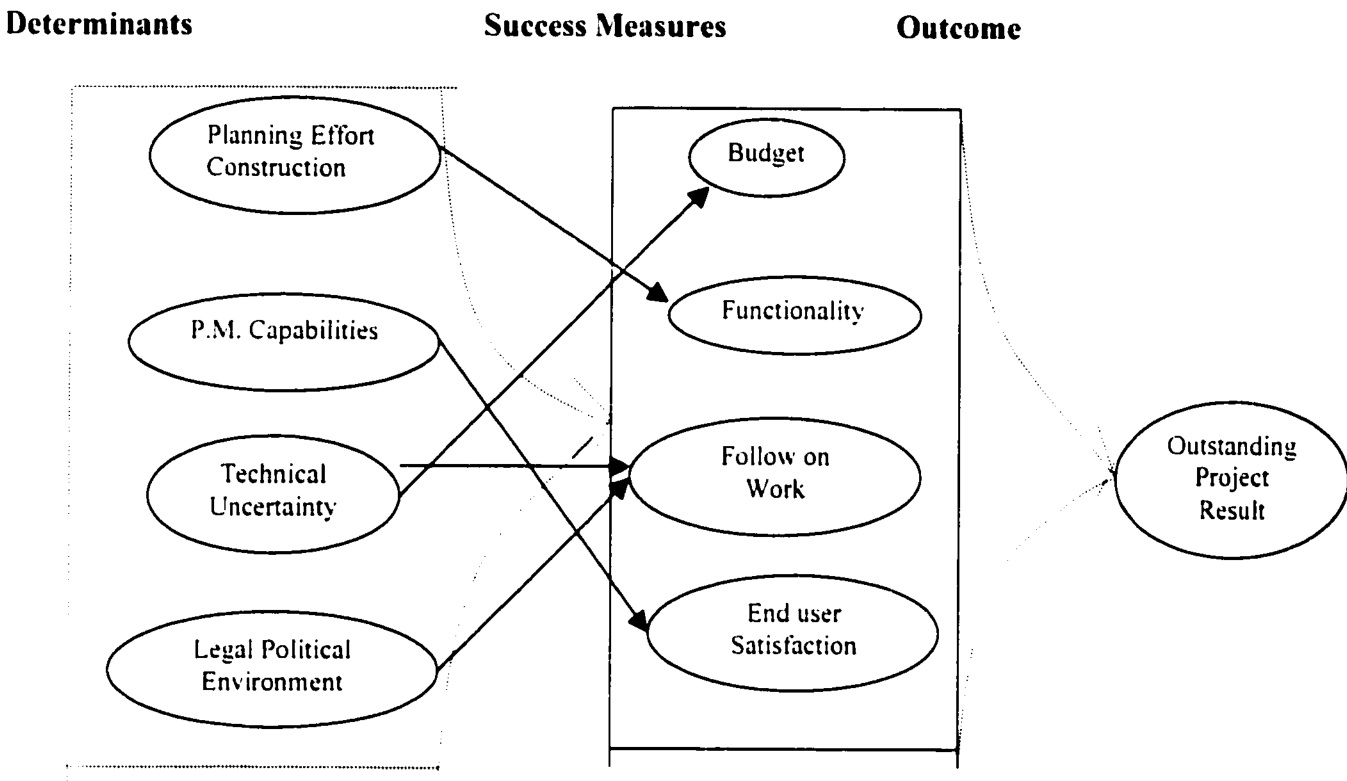

Fig. 2.1 Determinants of Project Success [Ashley, 1987]

In 1988, Sanvido developed the Conceptual Construction Processes Model [Sanvido, 1988]. In this model, the author offered a format for the processes to be followed in order for the project to be successful. These processes were management planning, management control, resource acquisition, resource allocation, operational control and operational planning. This model did not provide information about the control factors that can be used in order to optimize the performance of each process. Fig. 2.2 illustrates the Conceptual Construction Processes Model.

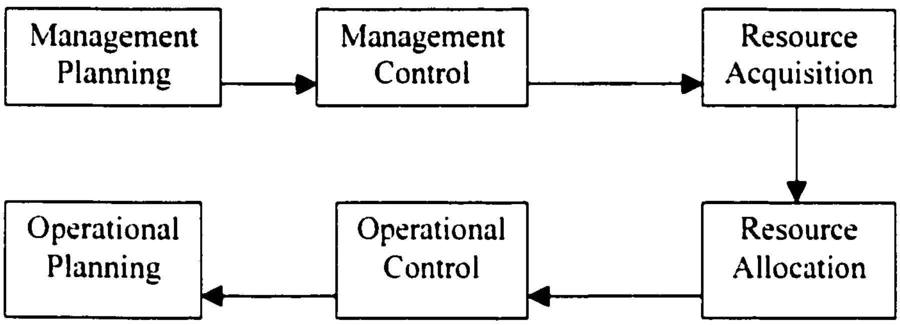

Fig. 2.2 Conceptual Construction Processes Model [Sanvido, 1988]

In 1989, Sanvido developed an Integrated Project Control Model [Sanvido, 1989]. In this model, the author outlined a frame for project control decision making. The project control processes were classified into three phases of decision making. The three phases were problem recognition, solution development and selection of solution. The model also included project control information requirements for the first phase. However, those requirements evolved around cost, schedule and quality control. In reconstruction projects, field review revealed that information requirements should also include data related to safety, communication, site, and scope definition control. Fig. 2.3 illustrates this Integrated Project Control Model

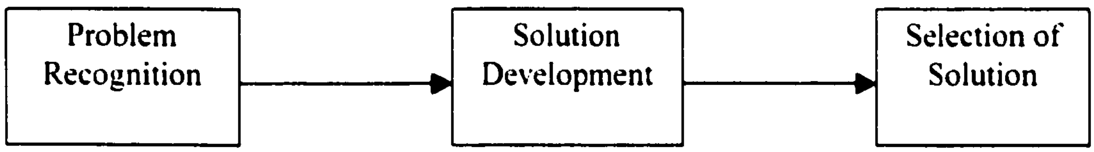

Fig. 2.3 An Integrated Project Control Model [Sanvido, 1989]

In 1990, McKim developed a project control process [McKim, 1990]. This control process included four steps to be followed for a complete project control. The four steps are: (1) a plan; (2) a method for measuring performance; (3) a test for deviation of performance from the plan; and (4) a decision and reaction process based on (3). This model did not offer control tools to be used at each step. Also, this model can be described as a reactive control process; however, it can also be extended to include a proactive control process by building forecasting techniques into the process. Fig. 2.4 illustrates this control process.

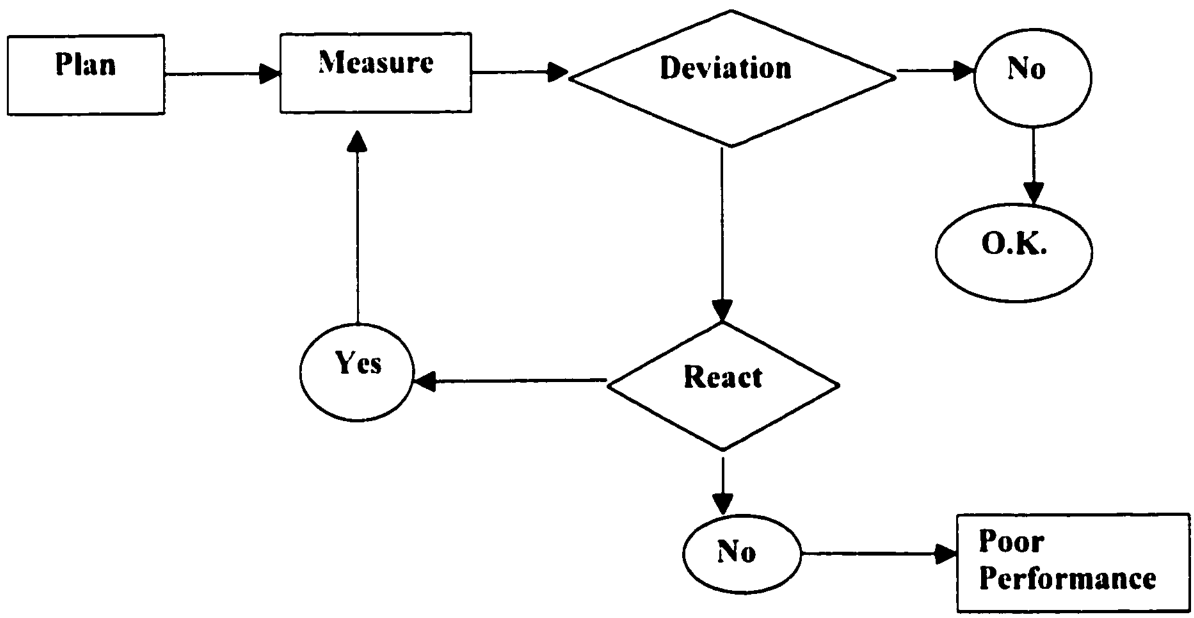

Fig. 2.4 Project Control Process [McKim, 1990]

In 1992, Sanvido produced factors for project success that were called Critical Project Success Factors (CPSFs) [Sanvido et al, 1992]. The model included four critical factors. These factors are: (1) a well organized, cohesive facility team to manage, plan, design, construct, and operate the facility; (2) a series of contracts that allows and encourages the various specialists to behave as a team without conflicts of interest and differing goals; (3) experience in the management, planning, design, construction and operations of similar facilities; and (4) timely and valuable optimization information from the owner, user, designer, contractor, and operator in the planning and design phases of the facility. These factors derived from a study performed on sixteen projects, which is a relatively small representative sample. Also, in this study, there was no analysis performed on the utilization of certain tools that may satisfy the mentioned factors. Table 2.2 summarizes the findings of this study

Table 2.2 Critical Project Success Factors [Sanvido et al, 1992]

CRITICAL PROJECT SUCCESS FACTORS
1- Cohesive Facility Team
2- Flexible Contracts
3- Experience
4- Information Input from all Stakeholders

In 1996, Alacron and Ashley developed a General Performance Model (GPM) [Alarcon and Ashley, 1996]. This model studied the impact of different management options on the performance of construction projects. Three types of management options were considered which are organizational structure, incentive plans and team building alternatives [Alarcon and Ashley, 1992]. These management options affect five drivers as seen in Fig. 2.5. The drivers propagate the effects through interactions among themselves, processes and performance measures. The model used the concepts of Cross-Impact Analysis and probabilistic inferences to capture the uncertainties and interactions among project variables.

In 1997, Pocock provided a study which concluded that the higher the interaction between the builder and the designer, the higher the overall performance of the project [Pocock et al., 1997].

SUMMARY

In this section, previous models that are related to the present study were reviewed. While they contained valuable information, they also contained common shortcomings. Some of these shortcomings are:

1) Some of the studies were not extensive in covering a reasonably large sample that can be considered a good representation of the overall population of the construction industry.
2) These models did not deal with the specific environment of reconstruction.

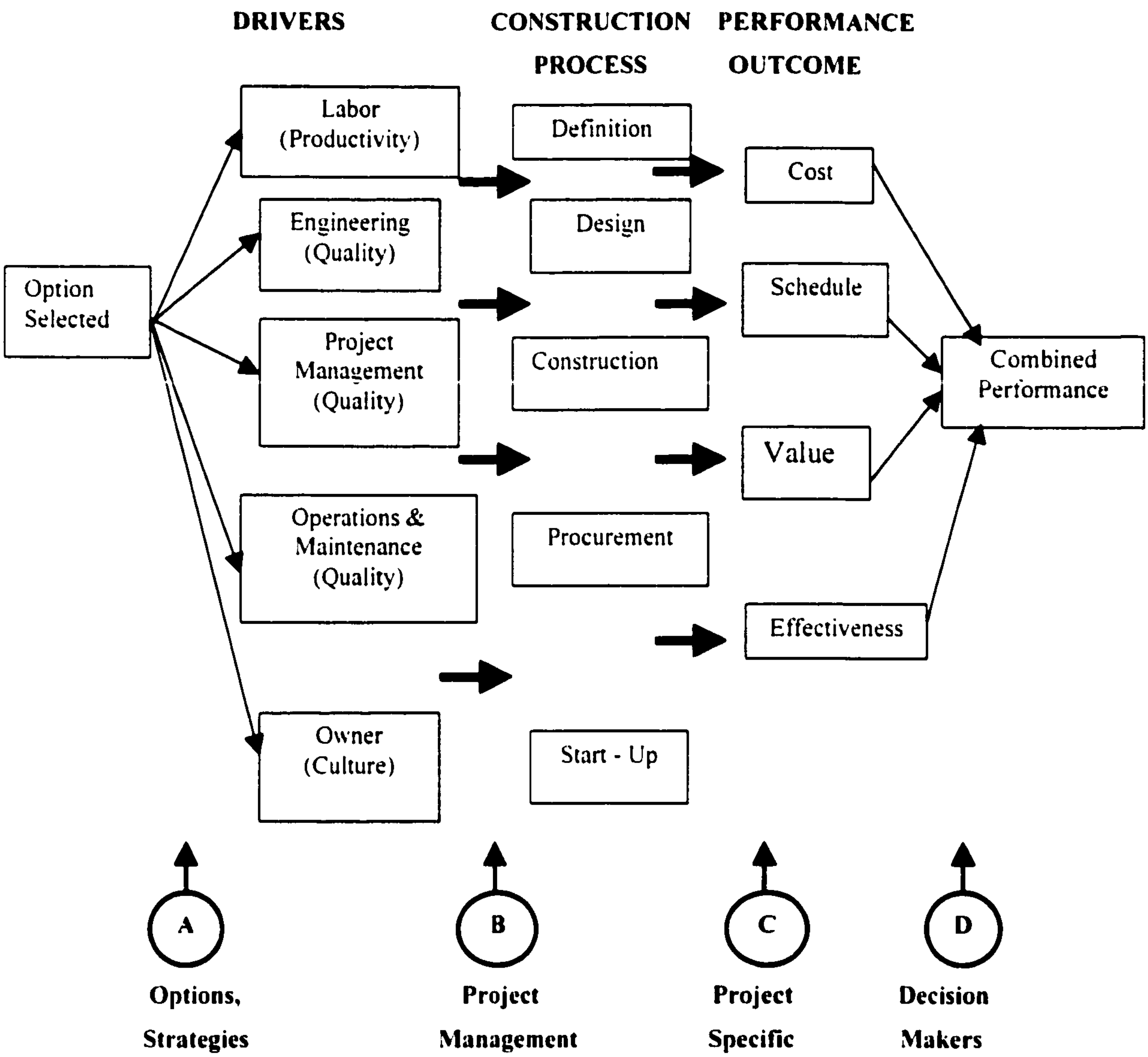

Fig. 2.5 General Performance Model [Alarcon andAshley]

3) These models focused on developing success factors in the form of conditions that need to be satisfied in order for the project to succeed. This research will focus on developing factors in the form of tools that can be used to influence and satisfy the condition.

4) The models dealt with factors related to cost, schedule, quality or organizational structure. There was not enough consideration for safety, site planning, and communication or scope definition. These categories were dealt with in separate modeling efforts in the literature. Nevertheless, they have to be included in the model as they are important to the overall performance of the project. Earlier field review by this researcher revealed that those four categories are highly significant to reconstruction projects.

2.3 CONTROL CATEGORIES AND THEIR CONTROL FACTORS

The prime objective of the literature review is to rediscover all the available project control factors that have an impact on the performance of the project. Since not much information was found under construction modeling, or during the search for reconstruction projects, the researcher reviewed the literature to gather information related to project management and control. An earlier study by this researcher concluded that safety control, site control, scope definition control and communication control should be an integral part of the overall project management model together with the three main control categories, schedule, cost and quality. These four categories were treated separately in the literature. The researcher included a review for these categories.

2.3.1 Cost Control Category

The cost control category was always considered a main control category and a main indicator of the overall performance of the project. See [Ferguson, 1993], [Ashley and Alarcon, 1996] and [Pocock et al., 1997]. In this section, the various cost control factors, which may contribute to the outcome of construction projects, are introduced.

2.3.1.1 Budget Baseline and Budget Allocations

Before a project is initiated, it is necessary for a budget that links expenditures and time to be agreed upon by the project manager and senior staff of the organization [Plicher, 1985] and [Parker, 1994].

2.3.1.2 Work Packages Costing

A work package is a "well-defined scope of work that terminates in a deliverable product or completion of service [CII, November 1988]. See also [Globerson and Shtu, 1995]. Each package may vary in size, but it must be a measurable and controllable unit of work to be performed i.e. asbestos removal, demolition, site services, landscape, ...etc.

2.3.1.3 Cost Breakdown Structure (CBS)

The Cost Breakdown Structure (CBS) involves a level-by-level hierarchical segregation of the project's components into a set of budgeted items. CBS is, usually, performed at different levels based on the amount of control desired and the level of effort to be exerted in the cost control function. CBS is the most frequently used cost control technique in reconstruction and new construction projects. A wide variety of literature recommended the use of CBS. See [PMI, 1996] and [CII, 1987].

2.3.1.4 Cost Coding

The cost coding structure is the framework upon which the cost control system is built. It provides a common language of identification and communication to be used by all those involved in a project cost control [CII, Feb., 1991].

2.3.1.5 Earned Value

The earned value concept is used to measure the progress of a combination of unlike work tasks or a complete project.

$$\text{Earned Value} = \frac{\text{(Earned dollars all accounts)}}{\text{(Budgeted dollars all accounts)}}$$

[ASCE, 1987]

2.3.1.6 Cost Variance (CV)

CV is calculated as the difference between Budgeted Cost of Work Performed (BCWP) and the Actual Cost of Work Performed (ACWP) at any point over the life of the project [Ahuja et al., 1994] and [Carr, 1993].

$$CV = (BCWP) - (ACWP)$$

2.3.1.7 Cost Ratio

Every construction project includes some activities or tasks which take place over a very long period of time during construction, or are continuous over the life of the project. These tasks are budgeted on bulk allocation of dollars rather than on the basis of production. Examples of these types of tasks are contract administration, mechanical and electrical rough-in and quality assurance. A control technique to measure these tasks is the cost ratio, which is calculated using the following formula:

$$Percent\ Complete = \frac{Actual\ Cost\ to\ Date}{Estimated\ Cost\ of\ Completion}$$

[ASCE, 1987]

The disadvantage of this technique, however, is that it does not give early warning of potential cost overruns. This technique can be used in both an owner and contractor organizations to monitor the performance of those tasks that take place over a long period of time.

2.3.1.8 Forecast Analysis

Recent researches once again discussed the significance of forecasting techniques to the cost performance of the project [Dawood and Molson, 1997]. See also [McMullan, 1996]. Forecast At Completion (FAC) can be estimated by using one of the following two formulas:

$$FAC = (ACWP) + (BAC - BCWP)$$

OR

$$FAC = BAC * \frac{ACWP}{BCWP}$$

Where BAC is Budget At Completion

2.3.2 Schedule Control Category

Schedule control was always considered a main control category in the literature. In this section, the available schedule control techniques are presented.

2.3.2.1 Work Breakdown Structure (WBS)

The development of a (WBS) involves dividing up the project into controllable parts suitable for schedule control. These parts are converted into schedule activities where one or more activity comprise one element of the (WBS). It can be considered the basic building block for the work to be performed [Yu, 1996]. This technique is one of the most largely used schedule control techniques in the industry [Popescu and Charoenngam, 1995].

2.3.2.2 Bar Charts

It is also called Gantt Chart since Henry L. Gantt developed it. A bar chart is a graphical presentation of a project activities shown in a time-scaled bar line but with no links between the activities.

2.3.2.3 Critical Path Method (CPM)

CPM is a graphical presentation of a planned sequence of the construction activities. It illustrates the interrelationship of the elements comprising a project. The project management library includes a large amount of literature about the use of CPM. One interesting study investigated the use of CPM in new projects and renovation projects. The study concluded that CPM is more suited to non-repetitive projects [Cole, 1991].

2.3.2.4 Incremental Milestones

It is used when the effort required to determine the completed units for each activity is not justifiable. It is also used when the activity includes sub-tasks that must be handled in sequence.

2.3.2.5 Time Variance

Variance analysis is widely used in the construction industry. Variances can be obtained by comparing planned man-hours versus actual man-hours, or planned percent complete versus actual percent complete.

2.3.2.6 Percent Complete

This technique is usually used with a quantifiable activity such as concrete, steel, excavation, ...etc. This measure is presented in percentage of completion based on units of work completed to date. It can be obtained by the following formula:

$$\text{Percent Complete} = \frac{\text{Actual Units to Date}}{\text{Total Forecast Units}} \times 100$$

The advantage of using this technique is that it is accurate and easily audited. When using this technique, the total forecast units have to be updated whenever a change order is incorporated into the work.

2.3.3 Quality Control Category

Since World War II, quality has always been a main control category in construction projects. Failure to maintain quality costs the U.S. construction industry over $15 billion a year in rework expenses alone. Additional costs for other quality failures may bring the total to more than twice that amount [CII, 1989a]. The literature provided several definitions to the term quality. Also, the different parties to a construction project have different definitions to the term quality. For the purpose of this research, the definition provided by the Construction Industry Institute was adopted, which is " conformance to established requirements" [CII, 1989b]. Most of the reviewed literature focused on three factors to control quality

2.3.3.1 Quality Standards and Specifications

The first step in controlling quality in construction is the preparation of clear and tight specifications for the project.

2.3.3.2 Responsibilities of Individuals towards Quality

Quality control systems require responsibilities to be clearly defined by management. People with delegated responsibilities for quality must have the authority to stop and reject poor work and take action to prevent repetition. These responsibilities need to be defined on organizational charts backed up by a text defining responsibilities of key people.

2.3.3.3 Inspection and Testing

Inspection is an important means of controlling conformance to requirements and is an essential part of any quality control system. The value of inspection, however, has limits and over-inspection wastes the owner's resources, increases the construction costs and creates adversarial relationships among the construction team. The resources available for inspection must be deployed effectively and are most productive when all the project parties accept the value and relevance of inspection or testing.

2.3.4 Scope Control Category

Poor scope definition at the budget stage and loss of control of project scope rank as the most frequent contributing factors to cost overruns [CII, 1986a]. In more recent studies, it is also indicated that "one of the most important ingredients to a successful project is the accurate definition and effective control of the project scope" [Dysert, 1997]. Also, "it is widely accepted that poor scope definition is one of the leading causes of projects failure in the U.S. construction industry" [Dumont et al., 1997]. Many owner organizations understand this fact; however, they share the misconception that it is not economically feasible to spend the time or money necessary to adequately define the scope of work early in the project's life cycle. If this is debatable in the case of new construction, it is certainly not debatable in the case of reconstruction projects. Literature search produced two control factors.

2.3.4.1 Decomposition

Decomposition involves subdividing the major project deliverables into smaller, more manageable components until the deliverables are defined in sufficient detail to support future project activities [PMI, 1996].

2.3.4.2 Benefit / Cost Analysis

It involves estimating tangible and intangible costs and benefits of various project alternatives [PMI, 1996].

2.3.5 Communication Control Category

Many investigators have researched and emphasized the significance and the impact of communication on the project outcome. See [Anumba et al., 1997], [Garcia, 1997] and [Thomas, 1996]. Construction projects are always planned and implemented by a group of people and project teams. Project teams are "organizational entities devoted to the integration of specialized knowledge for a common purpose" [Cleland, 1995]. Team members include representatives from the owner, designer, contractor and other stakeholder organizations [CII, 1993].

The most recent research identified six variables impacting communication effectiveness. They are Accuracy, Procedures, Barriers, Understanding Timelines and Completeness [Thomas et al., 1998]. However, this model did not produce tools that enable the project team to achieve those six conditions. Literature search provided two different factors. The use of these two factors may enable the team to satisfy those six conditions.

2.3.5.1 Site Meetings

Site meetings are a very traditional communication tool in construction projects. All parties including owner, architect, engineers and the contractor meet on scheduled dates to discuss design or construction related problems [Khachaturian and Gnaedinger, 1996].

2.3.5.2 Electronic Communication

The use of information technology in managing a construction project is increasing. Numerous studies discussed the rapidly increasing role of information technology in construction [Duke and Anumba, 1997] and [Evbuomwan and Anumba, 1997].

2.3.6 Safety Control Category

Statistics indicate that construction employees account for approximately six percent of the total labor force, but they incur twelve percent of all occupational injuries and illnesses and nineteen percent of all work related fatalities [Yates and Terrero, 1997]. Safety control is an integral dimension of the overall project performance and one that managers can control to the same degree that they control cost and schedule performance [Levitt and Samelson, 1993].

Different publications were reviewed in an attempt to gather tools that can be used to improve the overall performance of the project [Hinze and Raboud, 1988] and [Samelson and Levitt, 1982]. The following factors were found to be useful.

2.3.6.1 Formal Safety Meetings with Supervisors

It was recommended that the number of formal safety meetings with supervisors take place at least once a week.

2.3.6.2 Site Safety Inspection

It was also recommended that site safety inspection take place at least four times per week.

2.3.6.3 Upper Management Involvement

Upper management involvement in the application of safe practice will have a positive impact on the performance of the project.

2.3.7 Site Control Category

Space availability on a construction site can have a major impact on the efficiency and constructability of a project. When space is limited, trade-offs between activity sequencing, construction method selection, resource allocation and space allocation are necessary to generate an executable schedule and site layouts [Zouein and Tommelein, 1994].

All the reviewed literature on site control cited one significant factor to site planning, that is the production of an efficient site layout. See [Hamiani and Popescu, 1988].

2.3.7.1 Site Layout Plan

The layout of construction sites has a significant impact on the overall productivity and cost effectiveness of a construction project [Philip et al., 1997]. The outcome of site planning is a detailed drawing of the locations and areas reserved for the temporary support facilities [Yeh, 1995]. These drawings may also include access routes to the construction site. Also, details of the management of shared space between construction personnel and the occupants should be clarified.

2.4 MODELING TECHNIQUES

The literature has offered different classifications of modeling techniques or model types. The classifications were done according to the basis on which the model was formulated. The first type was models derived from assumptions concerning the relationships between variables or based on physical laws or principles, which may be called Mechanistic models. The second type is the Empirical model, with which we are more concerned in this work. An Empirical model is one which is derived from and based entirely on data [Edwards and Hanson, 1990].

When the variables of an Empirical model are measured and expressed in numbers, the model can be called a Numerical or Quantitative model. Quantitative models can also be classified as Deterministic and Probabilistic models [Gould and Eppen, 1984]. Probabilistic models can also be called Stochastic models. In Deterministic models, all the relevant data that the model will use or evaluate, is assumed to be known. In Probabilistic models, usually, a high variability and uncertainty exist in the relevant data.

Models can also be classified as Optimization models, Dynamic models and Probability models [Meerschaert, 1993]. Optimization models and Dynamic models exist more with deterministic data.

In this work, the researcher reviewed, briefly, the utilization of both Artificial Neural Networks and Regression Analysis in developing predictive models in construction. The purpose was not to acquire in depth knowledge about these two approaches. The purpose was to gather enough information, which enables the researcher to utilize these methodologies as tools for data analysis and model building. In the following subsections the advantage of using these approaches in developing predictive models in construction research was also discussed.

2.4.1 Artificial Neural Network

Many of the systems that civil engineers deal with exhibit dynamic, muti-variate, and complex behavior. This has motivated many researchers in the Civil Engineering field to experiment with non-traditional tools based on artificial intelligence such as Artificial Neural Networks (ANNs) [Hegazy et al. 1998]. ANNs, also known as connectionist systems, are a class of modeling tools inspired by biological neural systems [Al-Tababui et al. 1998].

2.4.1.1 Definitions

ANNs can be defined as "a massively parallel distributed processor that has a neural propensity for storing experiential knowledge and making it available for use". It resembles the brain in two respects:

1. The network through a learning process acquires knowledge.
2. Inter neuron connection strengths, known as synaptic weights, are used to store the knowledge [Haykin, 1994].

Detailed description of the structure and processing of ANNs is not part of this study and is available in many references such as [Flood and Kartam, 1994], [Garrett, 1992] and [Vanluchene and Sun, 1991]. A brief description of the important aspects of ANNs is provided in the following subsection.

2.4.1.2 ANNs Structures and Algorithms

The basic element of an ANNs is called a neuron, which is a simple processing element. See Fig. 2.6. ANNs gain their processing capabilities by connecting the neurons with an associated weight. This weight determines the structure of the signal, which is transmitted from one neuron to another.

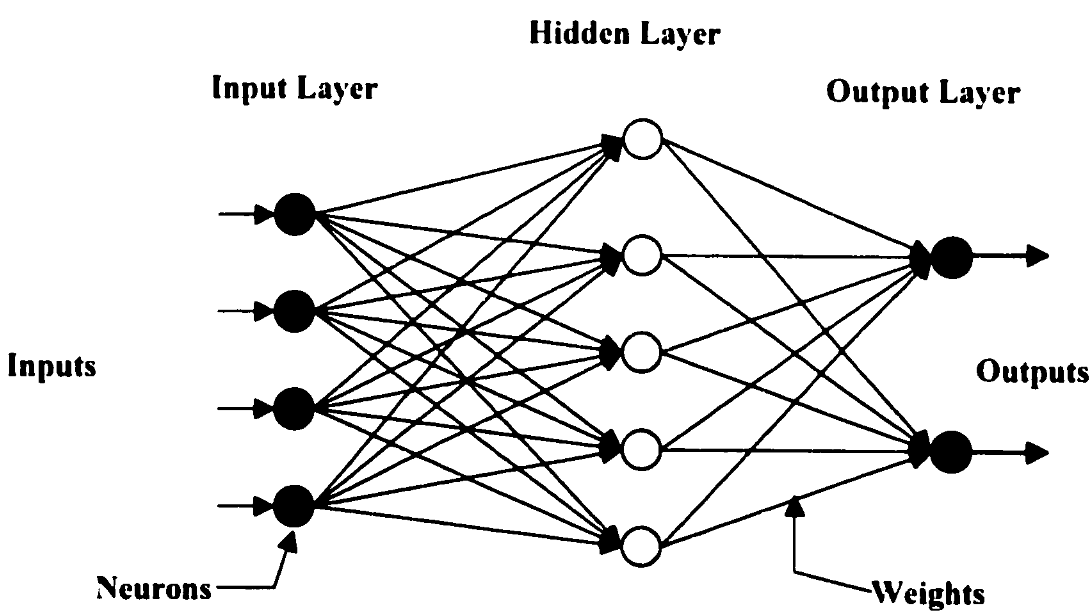

Fig2.6 ANNs with Three Layers

The total collections of weights are the parameters in the net that specifies the predictive model. These weights need to be adjusted using a suitable learning algorithm. A learning data set or training data set is required for the net to learn. The learning set is a number of observations, whose attributes are known.

Neural networks learning is classified into supervised and unsupervised nets. Supervised nets are those with learning sets that include inputs and outputs. Unsupervised nets, on the other hand, use inputs only.

Different ANNs are classified by differences in the architecture, learning algorithm and the processing algorithm. The architecture of ANNs specifies the way the neurons are interconnected. The processing algorithm is the actual method of determining the output for a given set of inputs.

The algorithm used to train the neural network is dependent on the manner in which the neurons in the network are structured. There are four different architectures for neuron setup: Single-layer feed-forward, Multi-layer feed-forward, Recurrent and Lattice structure [Haykin, 1994]. The first two types are widely used for developing prediction models. One special type of feed-forward nets is the back propagation algorithm. The back propagation algorithm is the most widely used training technique.

One form of an ANNs that can be used for prediction purposes is three layers feed forward networks such as the network shown in Fig. 2.6. This type of nets consists of three layers: an input layer, an output layer and a hidden layer. The input layer contains neurons that correspond to the input variables (Independent variables). The output layer contains neurons that correspond to the output variables (Dependent Variables). The job of the hidden layer is to act as an intermediate data abstraction between the input and output neurons.

Training such feed forward networks is usually done using back propagation, which is a supervised learning algorithm. During training, observations that include outputs and inputs are presented to the neural network. Using the back propagation process, the predictions of the network are compared with desired outputs. The network adjusts the connection weights between the neurons until a minimum error between the model prediction and the actual output is reached.

2.4.1.3 Advantages of (ANNs):

As mentioned earlier, ANNs have been proven capable of dealing with the complex muti-variable nature of Civil Engineering, in general, and Construction Engineering, in particular. ANNs have been suggested as most suitable for modeling problems involving judgment and analogy with previous situations, where a structured problem-solving mechanism is lacking [Hegazy et al. 1994a]. This is due to the fact that ANNs have several advantages. ANNs do not need pre-defined functions (learning by example). The examples (learning sets) are presented to ANNs and the network adjusts itself according to its learning rules to give the most appropriate output. ANNs have a built-in capability to adapt their weights to changes in the data. They continue learning from any point to improve performance. ANNs, also, have the ability to predict the output as a response to new unseen inputs.

ANNs have been used to analyze and solve complex engineering and construction experiments. Developing a cost prediction model for highway projects was one of the most recent application of ANNs [Hegazy and Ayed, 1998]. Moselhi has also provided a detailed description of the fundamentals of neural networks, along with their potential applications in civil and construction engineering [Moselhi et al, 1991] and [Moselhi et al, 1992]. Hegazy also developed a solution to mark up construction estimation problems [Hegazy et al, 1994 a].

2.4.1.4 Disadvantages of ANNs and means to overcome them

Despite the good performance of Neural Networks in several previous research efforts, the process of developing and implementing (ANNs) has a number of problems associated with it. The selection of a number of neurons in a layer and the number of layers in a network are vaguely defined in the literature. Large numbers of neurons and layers in a network require a larger training set and such nets converge slower than a smaller network. In other words, designing the network architecture and setting its parameters require trial and error in order to determine the best network architecture parameters that best fit the application under consideration (and the available data set). Also, selecting the learning algorithm requires some trial and error, since there is no explicit set of rules to determine whether a given learning algorithm is suitable for a particular application or not.

One of the major drawbacks that (ANNs) users overlook is "over-fitting". It happens due to over-training which leads to poor prediction, because it forces networks to develop an exact implementation of the model on the given training data. Practice has shown that successive passes through the same set of learning data (epochs), force a monotone decrease of the training error. The objective is to minimize the generalization error (Error on new data, which was not used in the training) [Pados and Kazakos, 1994]. The method, which minimizes the generalization error, is called cross-validation. The available data are divided into two sets, namely the training set and test set. The data in the training set are used during the learning phase, while the data in the test set are reserved for model performance evaluation.

Several software packages for the application of ANNs have been available commercially with different architecture, training algorithms and powerful computing abilities. The user, in most packages, has the ability to specify the learning rate, momentum, activation functions and initial weight range on a layer basis. This ability make the model building process interactive and transparent. In this work, *Neuro Shell 2* has been used for the development of the ANNs predictive models. The model building process utilizing ANNs is explained in detail in chapter five.

2.4.2 Regression Analysis

Different statistical analysis techniques can be used to develop Probabilistic or Stochastic models. Traditionally, data has been analyzed using statistical regression analysis. This method is commonly used to develop Empirical models by estimating parameters and coefficients of independent or explanatory variables in mathematical relationships that can explain most of the variations in the dependent or predictor variable [Haas, 1997].

Linear regression is particularly attractive to modelers because it lends itself so easily to model development, interpretation and comparison [Lunneborg, 1994]. It was also mentioned in the literature that "the single most commonly used stochastic model assumes that the expected value of the state variable is a linear function of time". The model is attractive not only because of its wide range of applications, but also because of the availability of good software implementation [Meerschaert, 1993]. One more advantage of regression methods is that they are frequently used to analyze data from unplanned experiments, such as might arise from observations of uncontrolled phenomena or historical records [Montgomery, 1990]. This work is based on the analysis of unplanned data.

Literature search also revealed that numerous models used linear regression successfully as an analytical tool for similar researches to this work and yielded satisfactory results. See [Thomas et al., 1998], [Kiani, 1998], [Pocock et al., 1997], [Konchar, 1997], [Dubois, 1996], [Adas, 1996] and [Cottrell, 1995].

Detailed description of the computation, testing and comparison of different regression statistics is beyond the scope of this work. Detailed information related to regression analysis is available in different literature such as [Draper and Smith,1981], [Montgomery, 1991] and [Rawlings, 1998]. Also, several software packages for performing statistical analysis including regression analysis have been available commercially with powerful computing abilities and preset defaults, which include significance criteria. *Systat* has been used for the development of the regression predictive models, which are explained in details in chapter four. A brief description of the important aspects of regression analysis is provided in the following subsection.

In Regression Models, for every project P_i, the researcher obtains a value for a response variable which is denoted by the continuous random variable y. Also, data should be obtained about the use and utilization of predictors variables which are denoted as x_1, x_2, ...x_n. The multiple regression model is given by the equation.

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \ldots\ldots\ldots\ldots \beta_n x_n + \epsilon$$

The model assumes that there is a line with a vertical intercept β_0 and partial slopes of β_1, β_2 .... β_n, called the true or population regression line. The random error $\in$ is assumed to be normally distributed with mean value zero ($\mu_\in = 0$) and the variance σ^2 for any values of x_1.......xn. The β_1.......β_n are called population regression parameters. The most important task in this analysis is to obtain the best fitted model with the best estimates for those parameters.

2.4.2.1 Fitting the Model

The principle of least squares is used to estimate the parameters. According to the principles of least squares, the fit of a particular estimated regression function $a + b_1x_1 + \ldots\ldots + b_nx_n$ to the observed data, is measured by the sum of squared deviations between the observed y values and the y values predicted by the estimated function or model:

$$\Sigma [y - (a + b_1x_1 + \ldots\ldots b_nx_n)]^2$$

For example, if we have 15 variables $x_1 \ldots\ldots x_{15}$ and we have 10 observations or 10 projects, we can estimate the value of the parameters by the following process:

$$X = \begin{bmatrix} x_{11} & x_{12} \ldots\ldots\ldots\ldots x_{115} \\ \\ x_{101} \ldots\ldots\ldots\ldots\ldots\ldots & x_{1015} \end{bmatrix} \qquad Y = \begin{bmatrix} y_1 \\ . \\ y_{10} \end{bmatrix}$$

$$\hat{\beta} = \begin{bmatrix} \hat{\beta}_1 \\ . \\ \hat{} \\ \beta_{10} \end{bmatrix} = (X'X)^{-1} * X'Y$$

→ obtain $\beta_1 \ldots\ldots \beta_{14}$ [Draper, 1981]

2.4.2.2 Assessing the Model's Utility Using R^2

The utility of the estimated model can be assessed by examining the extent to which the predicted y values are based on the estimated regression function (model) and are close to the y values actually observed. In other words, the variation explained by the model is significantly larger than the error term [Montgomery, 1991]. That can be determined by constructing the ANOVA table and the use of the coefficient of determination (R^2).

Table 2.3 illustrates the constructed ANOVA table.

Table 2.3: ANOVA Table

Source of Variation	Sum of Squares	Degrees of Freedom (DF)	Mean Squares (MS)
Regression	SSR	P –1	MSR =SSR/P-1
Error	SSE	n-P	MSE= SSE/n-P
Total	SST	n-1	MST=SST/n-1

Where

$$SSR = \hat{\beta} * X'y - n\bar{y}^2$$

$$SSE = y' * y - \hat{\beta}' * X'y$$

$\bar{y}$ is the mean of the y observations in the sample.

n = number of observations (10 in this example).

P= number of predictors variables in addition to the constant (15+1=16 in this example).

R^2 should satisfy the following formula:

$R^2 = SSR / SST$ $0 < R^2 \leq 1$ [Montgomery, 1991]

2.4.2.3 The Lack of Fit Test

If all n parameters β_1, β_2, ...β_n are zero, there is no useful linear relationship between y and any of the predictor variables x_1, x_2, ...x_n included in the model. Before using an estimated model in further inferences, it is desirable to confirm the model's utility through a formal test procedure. This test is called the F test. The value of F tends to be larger when at least one β_i is not zero than when all the β_i's are zero, since more variation is typically explained by the model in the former case than in the later. An F statistic value far out in the upper tail of the associated F distribution can be more attributed to at least one none zero β_i rather than when all β_i's are zero. This is why the model utility F test is upper tailed.

Null Hypothesis

Ho : $\beta_1 = \beta_2 = \beta_3 \ldots\ldots\ldots\ldots = \beta_n = 0$ (There is no linear relationship between y and any of the hypothesized predictors $x_1, x_2 \ldots\ldots\ldots x_n$).

Alternative hypothesis Ha: At least one among β's is not zero. (There is a useful linear relationship between y and at least one of the predictors)

$F_{observed} = MSR / MSE$

If $F_{critical} = F_{\alpha, p-1, n-p} < F_{observed}$ ➔ The null hypothesis is rejected ➔ The overall regression is significant. $\alpha = 0.05$ if we check at 95 % significance.

2.4.2.4 Testing the Significance of the Individual Predictors

The significance of each variable to the fitted model can be tested for each variable x_i. We can test whether $\beta_i \neq 0$. This can be achieved by using the T test.

$$T_{observed} = \frac{\hat{\beta}_i}{\sqrt{MSE * C_{ii}}} \quad \text{Where } C_{ii} \text{ is the } i_{th} \text{ element in } (X'X)^{-1}$$

[Montgomery,1990]

$$\text{If } |T_{observed}| > t_{\alpha/2,n-p} \rightarrow \beta_i \neq 0$$

2.4.2.5 Model Selection Procedures

Two methodologies can be used for model selection procedures. They are all possible regression subsets and sequential selection.

- All possible Regression Subsets

With (n) explanatory variables there are (2^n) possible regression models, ranging from the simplest form, where only one of the variables is included, to the most complex, in which all predictors are included. This approach generally relies on R^2 as the assessment criterion [Dover and Peck, 1993].

We calculate R^2 for all possible models, the model with the highest R^2 should be selected. However, it was argued that using R^2 to choose between models containing different numbers of variables is deceiving because adding a predictor to a model can never decrease the value of R^2. Therefore, it is more advisable to use the adjusted R^2,

$$R^2\ adj = 1 - \frac{(1 - R^2)\ (n-1)}{(n-p)}$$ [Rawlings, 1998]

- Sequential Selection

This can be implemented using three different methodologies. They are forward selection, backward selection and stepwise selection. In this section, stepwise selection is explained.

1. Calculate the correlation of all the predictor variables with the dependent variable. As the first variable to enter the regression, select the one most highly correlated with the criterion. Let X_i denote the selected predictor variable.

2. Regress Y on X_i . Retain in the fitted model if the overall F – test shows that the regression equation is statistically significant.

3. Calculate the partial correlation coefficients of all the variables not in the regression equation with the criterion. Select as the next variable to enter the one with the highest partial correlation coefficient. Denote the selected variables by X_j .

4. With both X_i and X_j in the model, compute the regression equation. Retain the new variable X_j in the regression equation if its partial F-value is statistically significant as compared to critical tabulated (1-α) values under the F-distribution with 1 and n-2-1 degrees of freedcm.

5. Select as the next variable to enter the one most highly correlated with the dependent variable, given that the variables X_i and X_j are already in the regression equation. Denote this variable by X_k.

6. Repeat the process from 2. [Rawlings, 1988]

2.4.2.6 Checking Multicollinearity

Muticollinearity arises when there is linear dependencies among the parameters of the explanatory variables. Its effect is to inflate the variance of the least squares estimators and possibly any predictions made, and also to restrict the generality and applicability of the estimated model [Wetherill, 1986]. Muticollinearity can be checked by using the Variance Inflation Factor (VIF),

$$VIF_j = \frac{1}{1 - R_j^2}$$

R_j^2 is the coefficient of determination from the regression of X_j on the other independent variables.

- If R_j^2 is close to one ➔ VIF_j is high, which means that strong correlation exists between X_j and the other independent variables.
- If R_j^2 close to zero ➔ No correlation

It was also mentioned in the literature that,

If VIF > 10 ➔ Problems with estimation

5< VIF < 10 ➔ Problem may exist

VIF < 5 No Problem.

2.5 CONCLUSION

In this chapter the results of the literature review were presented. The prime objective of the literature review was the search for traditional and non-traditional control factors that can be used as tools to control the performance of reconstruction projects. A search in the area of reconstruction projects yielded very little information. Most of the literature focused on a case study methodology that is contrary to the objective of this research. The objective of the research is to search a reasonably large sample of reconstruction projects to enable the researcher to make valuable inferences about the performance and control of the overall population of reconstruction projects.

During the search for construction control models, there were no models found in the area of reconstruction. Also, the researched models produced factors in the form of conditions that had to be satisfied in order for the project to succeed. This research will adopt a proactive approach to deal with the problem by developing a model that includes control factors or tools that can be used to satisfy the success conditions. Also, the researched models were more concerned with cost, schedule, quality and organizational structure factors. However, the participants of a field study confirmed that four other control categories are essential to the success of reconstruction projects, namely, communication control, scope definition control, site control and safety control. Therefore, the researcher reviewed the literature of related data to these subjects. Table 2.4 summarizes the control factors, which were found in the literature.

The review of the utilization of Artificial Neural Network and Regression Analysis in the development of predictive models was also presented.

Table 2.4: Categories of Factors Contributing to the Overall Efficiency of the Project

CATEGORIES	FACTORS
COST	The establishment of Budget Baseline and Budget Allocations The use of Work Packages Costing Cost Breakdown Structure (CBS) as a cost-planning tool. Cost Coding as a cost planning and communication tool. The use of Earned Value to measure cost performance. Cost Variance (CV) to measure cost performance The use of Cost Ratio Forecast Analysis
SCHEDULE	Using Work Breakdown Structure Bar Charts Critical Path Method Incremental Milestones The use of Time Variance to monitor schedule performance. Using Percent Complete reports
QUALITY	A well developed Quality Standards and Specifications Responsibilities of Individuals towards Quality are identified. Inspection and Testing
SCOPE	Decomposition Benefit / Cost Analysis
COMMUNICATION	Regular Site Meetings The use of Electronic Communication
SAFETY	Formal Safety Meetings with supervisor Site Safety Inspection Upper Management Involvement
SITE	The Development of a Site Layout Plan

CHAPTER 3 DATA COLLECTION AND ANALYSIS

In chapter one the problem statement of this research, that is, the poor performance of reconstruction projects, was presented. In chapter two, the researcher presented the results of the literature review in the areas of reconstruction projects, construction control models, data modeling and control factors relating to the three main control categories, namely, cost, schedule and quality. Also, because of the recommendations of an earlier research by this writer, four other control categories, namely, site control, safety control, communication control and scope definition control, were researched and presented in chapter two.

3.1 PRELIMINARY FIELD REVIEW

After the literature search was completed, the researcher conducted a preliminary field review through formal and informal discussions with construction professionals. The purpose of the field review was to accomplish two tasks. The first was to perform an analysis to identify reasons for the poor performance of reconstruction projects. The approach of this study was to analyze the reasons behind change orders and schedule overrun. The results of this study are tabulated in Table 3.1.

The second task was to review the obtained control factors as a result of the literature review, and confirm their significance to the success of reconstruction projects, and how they respond to the identified reasons for the poor performance of reconstruction projects. The participants used a scale from 1 to 5 to analyze the contribution of every control factor to the success of reconstruction projects. A copy of this questionnaire is included in Appendix 1.

Table 3.1 Reasons for Poor Performance in Reconstruction Projects

REASONS FOR THE POOR PERFORMANCE IN RECONSTRUCTION PROJECTS	
1	Unforeseen Existing Site Conditions
2	Scope Change by Owner
3	Design Change (upgrade)
4	Schedule Problems
5	Design Coordination
6	Regulatory Requirements
7	Poor Performance by Contractor

The result of the preliminary field review was to confirm the relative importance of the majority of the reviewed factors. Moreover, in this analysis the participants identified more non-traditional tools or factors that are being used in controlling reconstruction projects. Some of those non-traditional factors were not included in the literature. Other factors, however, were included in the literature under separate headings other than construction control. The researcher reviewed those factors in the literature to confirm their validity. The result of this exercise was the identification of thirty-six control factors in seven different control categories. These thirty-six control factors will serve as the independent variables in the process of developing the required model. In the following sections, the thirty-six factors are presented and explained.

3.1.1 Cost Control Category

It was found that the cost control category is an essential category in almost all of the interviewed owners' organizations. Owners have a particular interest in cost control from the initial concept to completion due to budgeting and programming concerns. However, different owners are found to apply a wide variety of cost control techniques in their construction projects. In this section, the various cost control factors, which were found to be significant to the outcome of reconstruction projects, and those factors that were declined in the field review, are introduced.

3.1.1.1 Budget Baseline and Budget Allocations

Planners within the owner's organization develop a cost estimate for the project whether or not the design documents are complete. As the project becomes better defined, the estimates are updated to reflect the new information. In a lump sum contract, this estimate is critical because it provides all quantity, cost and productivity targets used for the budget baseline.

3.1.1.2 Work Packages Costing

Construction owners found the use of work packages to be very useful.

3.1.13 Cost Breakdown Structure (CBS)

The field review revealed that CBS is the most widely used cost control technique.

3.1.1.4 Cost Coding

The field review results did not recommend this factor for further consideration.

3.1.1.5 Earned Value

Also, the use of Earned Value was not considered as an important factor by the preliminary field review.

3.1.1.6 Cost Variance

Construction owners use cost variance as a cost control technique to measure the cost overrun or underrun of the budget established for the work accomplished to date based on the earned value.

3.1.1.7 Cost Ratio

The participants of the field review did not strongly recommend the use of the Cost Ratio.

3.1.1.8 Forecast Analysis

Construction owners' organizations use cost forecasting in an attempt to predict the future cost performance of the overall project or certain aspects of the project by utilizing the past and current performance of the project costs. Forecasting the cost at completion helps the owner decide whether or not to proceed with certain phases of the work based on the overall budget of the reconstruction project.

3.1.1.9 Unit Prices

Some owners tend to ask the contractors to provide unit prices for certain activities as part of their tender submission. These unit prices are usually used later during the construction process to assess the values of extras to the contract. This technique was reported to help minimize the quoted values for change orders by the contractor.

3.1.1.10 Cash Allowances

Any undetermined scope of work at the time of tendering may be included in the contract through cash allowances. When the scope becomes more defined during the construction process, the owner is then able to solicit prices from vendors or sub-contractors to carry out this portion of the work under the supervision of the general contractor. Some owners use this technique to eliminate or reduce the painful and costly change orders in light of the level of uncertainty associated with reconstruction projects.

3.1.1.11 Cash Flow

When a contract is awarded, the contractor may be asked to submit an estimate of progress payment requirements over the life of the project. The owner then determines a realistic schedule of anticipated cash flows. This process enables the owner to determine his/her long term investment options. It can also be used as a performance monitoring tool that compares planned progress vs. actual progress.

3.1.2 Schedule Control Category

In reconstruction projects, construction owners consider the time factor to be of an utmost importance. Because of the fact that construction is proceeding in an operating facility, any change in the duration has a significant impact on the users, services and operation of the facility. Therefore, construction owners apply a wide variety of schedule control techniques in an attempt to start and finish the various stages in timely fashion. Literature search and preliminary investigations with construction professionals have led to the identification of nine factors or tools that may impact the schedule performance of the project. In this section, the hypothesized factors are explored.

3.1.2.1 Work Breakdown Structure (WBS)

WBS is one of the most widely used schedule control techniques in reconstruction projects.

3.1.2.2 Bar Charts

Different owners develop bar charts at different levels of details. Some owners develop the bar chart at the detailed activity level, while others develop it at the work package level.

3.1.2.3 Critical Path Method (CPM)

Construction owners use CPM to determine the length of a project and to identify activities, events and constraints, which are used on the critical path. They also use it to determine early start and finish and the float. The critical path is the particular sequence of activities in a CPM network that has the least total float and is the largest path in the network. The critical path, therefore, is a chain of critical activities. Any delay in the duration of a critical activity causes a correspondent delay in the completion of the project.

3.1.2.4 Incremental Milestones

This technique is useful to top management and senior staff because it enables them to monitor the performance of the project in a generic format. It can be used in all types of organizations.

3.1.2.5 Time Variance

Owners used variance analysis to monitor the performance of their projects. Variances were obtained by comparing planned percent complete versus actual percent complete. They used S curve reports or bar chart tracking reports

3.1.2.6 Percent Complete

This technique was reportedly used as a schedule control technique in reconstruction projects.

3.1.2.7 Coordination Schedule

In reconstruction projects, owners need to coordinate reconstruction activities with the schedule of those who will continue to occupy and use the remaining portion of the building. One example is demolition activities, which are always disturbing tasks because they inevitably involve a high level of noise, dust, dirt, odor and debris. However, they must be completed while respecting the welfare and schedule of building occupants. Another example is the disruption of utility service. It is an extremely sensitive issue in reconstruction projects. In order to overcome this problem some owners develop a coordination schedule to incorporate the operation of the existing building and the construction activities in one master schedule.

3.1.2.8 Liquidated Damages

Liquidated damages clauses are being used as part of the general condition of construction contracts. They state that the contractor will be liable to pay the owner an "x" dollars for each day that the contractor has delayed the date of substantial completion. The project is deemed to be substantially complete, when it meets certain criteria as specified in the Construction Lien Act. The owner will have to substantiate to the court the amount of liquidated damages claimed. The use of liquidated damages is reported to work towards the expedition of the construction work by the contractor in order to avoid any potential litigation.

3.1.2.9 Change Directive vs. Change Notice

Construction projects very often face the need to change the scope of work for one reason or another. These changes usually have a negative impact on the schedule performance of the project [Hansen, 1994], [CII, 1990] and [Semple, 1996]. In such cases, the architect issues a Change Notice to the contractor. The contractor then prices the change and submits it to the architect. It usually takes a long time before the owner, architect and contractor come to an agreement as to the final value of the change which causes considerable delay to the project duration [Wideman, 1995] and [Veenendaal, 1998].

Reconstruction projects do not usually have the luxury to entertain the formal process of a change order. CCDC2 1994 introduces a new mechanism called Change Directive. When the owner requires a change in the work and (1) the change is urgently required or it would not be expedient to attempt to reach agreement on the method of the adjustment to the contract price or contract time prior to its commencement; or (2) there has been failure of the parties to agree on the method of adjustment to the contract time, then the owner may issue a Change Directive [CCDC2, 1994]. This mechanism authorizes the contractor to proceed with the change and for the final value to be determined later after a thorough examination takes place by the owner and the Architect. The use of Change Directives is reported to have a significant impact on improving the overall schedule performance.

Fig. 3.1 illustrates the formal change order process via change notice and Fig. 3.2 illustrates the suggested change order process via change directive.

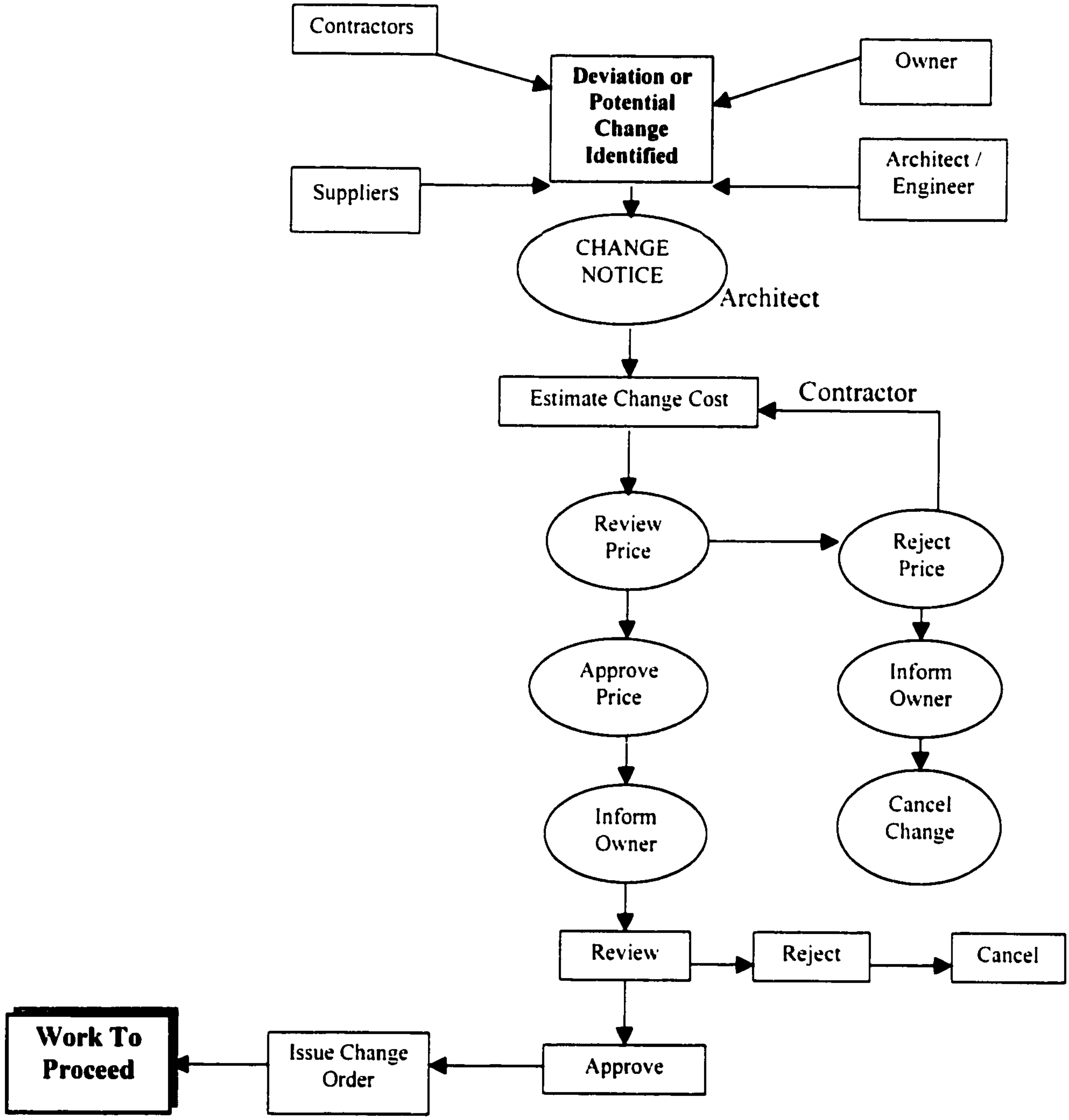

Fig. 3.1 The Formal Change Order Process via Change Notice

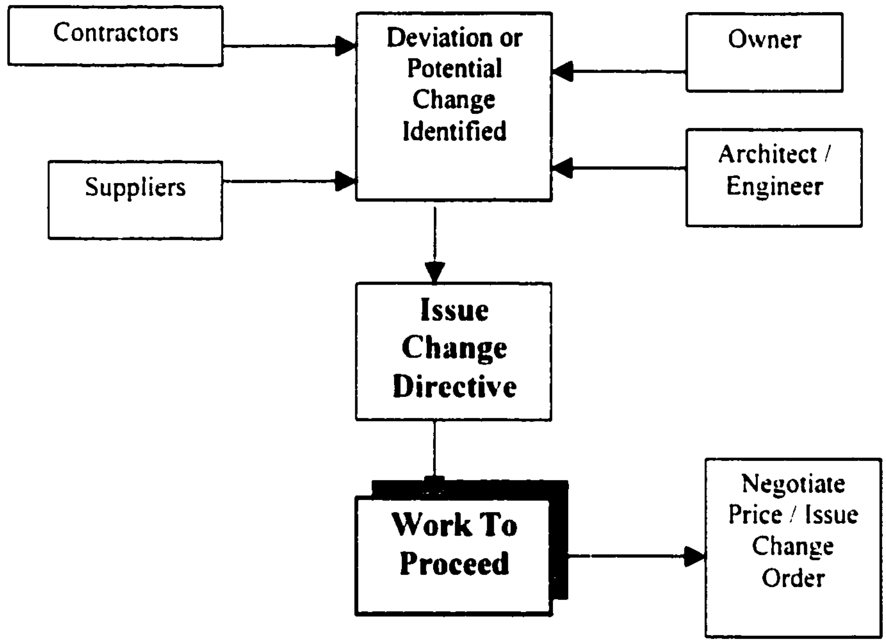

Fig. 3.2 Change Order Process via Change Directive

3.1.3 Quality Control Category

Quality control becomes more challenging in reconstruction projects involving operating facilities. Since the building end users and operators are in the vicinity of the construction operation, they build certain expectations towards the quality of the final product and they monitor it with zero tolerance. In reconstruction projects, owners have been trying to use a variety of quality control factors in order to improve the quality of their projects. In this section six factors are explored.

3.1.3.1 Quality Standards and Specifications (User / Operator Input)

The interviewees indicated that the designers meet with the owner's operation and maintenance staff to gather input. The designers, also, meet with the authorities having jurisdictions to build their specific requirements into the specifications.

3.1.3.2 Responsibilities of Individuals towards Quality

The provision of an organizational chart backed up by a text defining responsibilities of key people was found to be an essential tool for controlling quality in reconstruction projects.

3.1.3.3 Independent Inspection Firms

Most owners use the services of independent inspection firms to oversee material and workmanship in highly specialized areas such as waterproofing or building envelops.

3.1.3.4 Inspection by Operator / Maintenance

Operation and Maintenance staff within the owner organization inherits the building after reconstruction is completed. Usually, they have operation and maintenance manuals that allow them to follow systematic approaches to perform their work in the most efficient manner. This requires the assembly of the different components of the building during the reconstruction process to be carried out in a specific format. Their early inspection of the work during the construction process helps to decrease or even eliminate any rework that may be required at later stages.

3.1.3.5 Inspection by End Users

Similar to inspection by operation and maintenance staff, inspection by end users is reported to be of significance to reconstruction projects of operating facilities.

3.1.3.6 Pre-qualification of Contractors

Most owners tender their projects in an open public setting, which means that any contractor, can obtain the tender documents and submit a bid. However, some owners open their tenders to only a group of pre-qualified contractors. Contractor pre-qualification is a process used to determine a contractor's ability to perform the work associated with a project prior to the bidding process. The selection of a qualified and capable construction contractor is essential to the successful completion of the construction contract [Elton et al, 1994].

3.1.4 Scope Control Category

In reconstruction projects, the owner is faced with a higher level of uncertainty as a result of unforeseen site conditions or concealed services in the existing facility. Also, defining the scope of modifying an existing facility to serve another purpose can be considered a challenging task. From the above, it can be hypothesized that scope definition has an impact on the outcome of reconstruction projects. The literature search and field review led to the identification of three factors or tools that may correlate with the outcome of reconstruction projects.

3.1.4.1 Decomposition

Decomposition was not found to be a significant contributor to the success or failure of reconstruction projects.

3.1.4.2 Benefit / Cost Analysis

This factor was not viewed as an important factor in the preliminary field review

3.1.4.3 As-Built Drawings

The provision of adequate as-built drawings of the existing facility is a contributor to an appropriate scope definition. Some owners provide the time and effort of their own staff to keep the as-built drawings up to date. Several references analyzed and explained the significance of adequate as-built drawings to facilitate building management including reconstruction [Liu et al., 1994].

3.1.4.4 Constructability Review

Constructability in a broader definition can be viewed as a non-traditional control tool that requires customer input in every phase of the capital project planning such as front-end engineering, detailed design, operation and maintenance [Geile-Robert J., 1996]. Several references cited constructability as significant control procedures in complex projects. See [Hanlon and Sanvido, 1995], [Gibson et al, 1996], [CII, 1986b] and [Haas et al., 1997]. Field research also revealed that some owners take constructability into consideration to improve the performance of their reconstruction projects.

3.1.4.5 Design Committees

Most owners form design committees that include building users, operators and maintenance staff, in order to provide input into the desired final product.

3.1.5 Communication Control Category

In reconstruction projects, the combination of an increasingly challenging design process as well as the demand for detailed information and growing client expectations in delivery times have placed greater emphasis on the need for effective communication. Effective communication becomes more challenging when so many parties are involved in the process.

In the past few years, every owner organization has implemented various techniques, different approaches and many initiatives in an effort to improve communication within their reconstruction projects. This study explored those approaches in order to incorporate best practices into the proposed model and further check their significance to the improvement of reconstruction projects' performance. Through the literature search and the preliminary field review, the writer was able to hypothesize four factors that may correlate with high performance projects.

3.1.5.1 Site Meetings with Users Representatives

In reconstruction projects some owners implemented the idea of including a representative from the end users in the weekly or biweekly construction meetings. Those owners claim that this approach has improved the level of information flow among the project stakeholders.

3.1.5.2 Electronic Communication

Most construction owners make use of information technologies to various degrees. Owners, who employ knowledgeable staff and the technological capabilities, have applied electronic communication extensively. That can be done through the use of e-mail as a tool of communication between the various stakeholders, or exchanging engineering information electronically via floppy diskettes.

3.1.5.3 Implementation Team

In some cases it was observed that, the owner formed what was called an implementation team. This team included a broader base of representatives of those who were affected by the reconstruction. This team may include end users, operation, maintenance, neighbors and, in some instances, representatives from the public. This team meets regularly with representatives from the construction team to obtain direct information about the progress of the project, its various phases and the impact on the implementation team.

3.1.5.4 Direct Communication Sub-teams

In every construction project, owners identify the project stakeholders and form an organizational structure that explains the communication path and the flow of documentation. Fig 3.3 illustrates the Project Formal Communication Path. Because of the increasing complexity and the need for a quicker response time when dealing with a problem, owners in reconstruction projects adopted a protocol to form a direct communication sub-team that includes only those who are involved in the problem. This helps to expedite the problem solving process. Fig. 3.4 illustrates an example of the Direct Communication Teams.

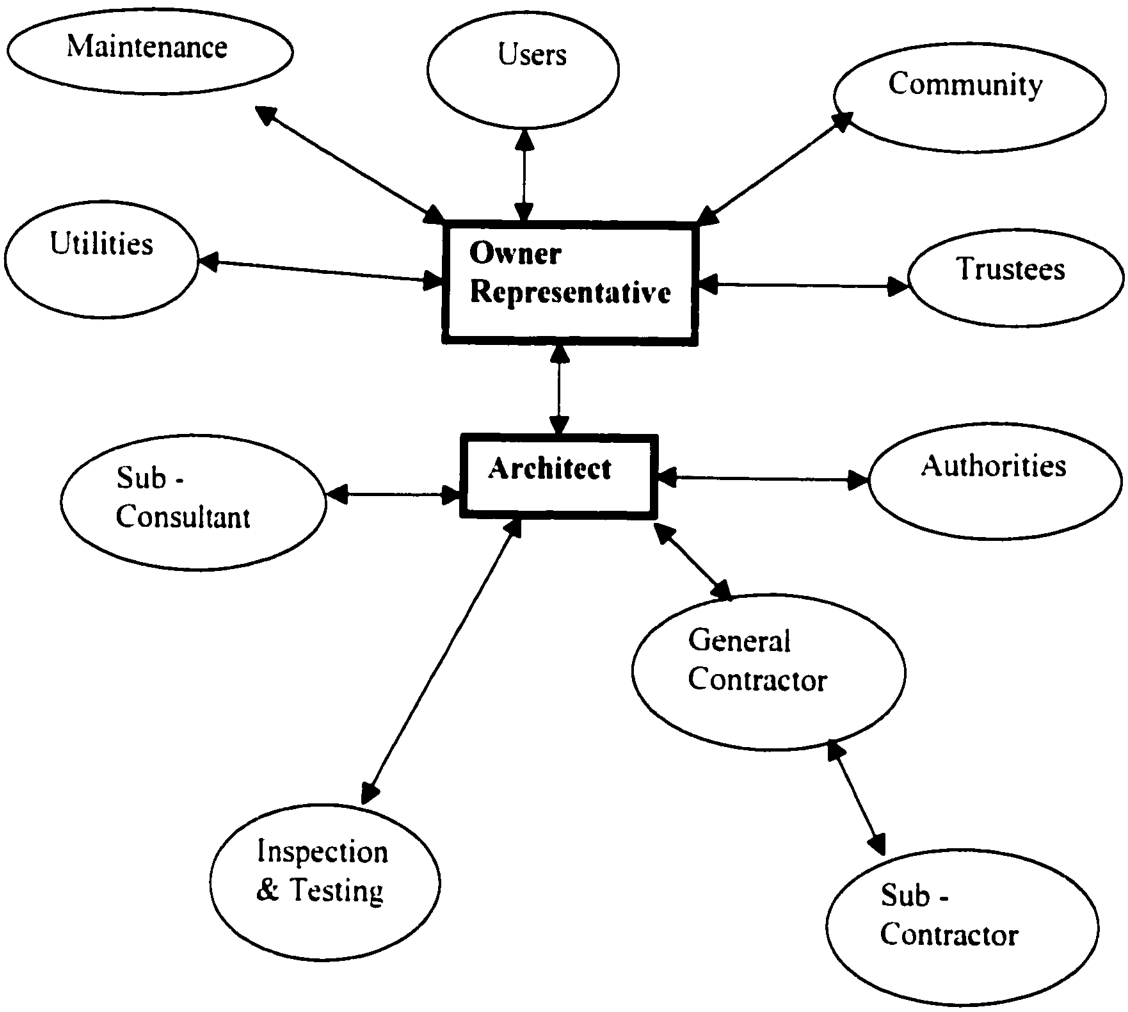

Fig 3.3 The Project Formal Communication Path

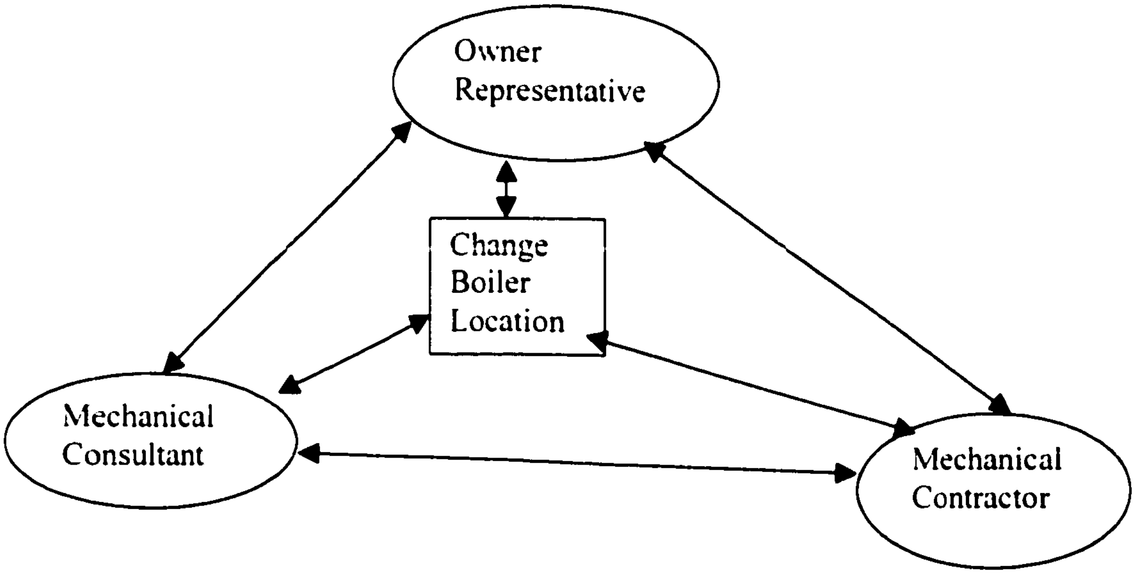

Fig. 3.4 Example of a Direct Communication Team

3.1.6 Safety Control Category

Safety control is of particular significance in reconstruction projects because the health and safety of the construction team is not the only concern, but also the health and safety of the occupants, users and operators of the building [Hollingshead, 1998]. Their presence in the building imposes limitations on the reconstruction operations, in particular activities that produce odors, smoke or noise. Another source that imposes limitations and constraints on the overall reconstruction operations is the presence of hazardous material in the old building components. Components such as asbestos material and PCB need special precautions and have to be handled in compliance with the

Health and Safety Acts. Building owners apply different methods to control safety in their reconstruction projects. Three factors were reported in the preliminary field review. They are reported to be the most frequently used tools. Also, three factors were reported in the literature, however, they were not confirmed in the preliminary field review.

3.1.6.1 Formal Safety Meetings with Supervisor

The preliminary field review revealed that, this factor is not important to reconstruction projects

3.1.6.2 Site Safety Inspection

The owner's representatives who participated in the preliminary field review did not recommend this factor for further analysis.

3.1.6.3 Upper Management Involvement

This factor was not viewed as being important by the preliminary field review.

3.1.6.4 Joint Health and Safety Committee

Occupational health and safety administration was cited as one of the important strategies to achieve excellence in safety performance [Jaselskis et al., 1996]. Some construction owners form a Joint Health and Safety Committee, which includes members from the construction team and members from the occupants or the users of the building. This committee's role is to meet regularly to discuss safety-related issues during the reconstruction of the facility. In other words, this committee's meetings become the forums in which the users were able to voice their concerns with regards to any unsafe practice by the contractor's forces. At the same time, it was an opportunity for the contractor to coordinate and plan certain phases of the work, which may result in an unsafe work environment by the users.

3.1.6.5 Awareness Sessions

Training has always been an integral part of safety planning [Davis and Tomasin, 1990]. Owners of reconstruction projects have developed special awareness sessions for their projects. These are sessions especially designed for reconstruction projects. Some of these sessions are organized for the construction workers in order to increase their awareness of sensitive issues such as odor, dust and noise, which are not normally a concern in new construction projects. Other sessions are organized for the users or occupants of the facility to increase their awareness of construction safety such as required safety clothing in construction sites and safety signs and what they mean.

3.1.6.6 Emergency Plan and Procedures

Adequate equipment for emergency procedures and general rules such as a record of inspections and test results, may be kept along with the measures to be taken in a case of "what-if". Procedures and rules are to be established and followed at all times, especially during emergencies. An appropriate emergency plan must exist in case an accident occurs.

3.1.7 Site Control Category

The unique characteristics of reconstruction projects give site control more significance. Working within an occupied and fully operated facility makes reconstruction projects struggle for space. Space congestion introduces a variety of challenges. These challenges may include available space for storage or material handling, and access to and from the construction area. The interaction between the operating portion of the facility and the reconstructed space becomes another challenge. The management and control of the shared space between construction personnel and the occupants becomes a problem facing the construction manager (i.e. parking space). The researcher was able to hypothesize two factors that may have an impact on the performance of the project.

3.1.7.1 Site Layout Plan

Including a site layout plan with the tender documents is not a traditional control factor. However, it was observed that some construction owners include it with the tender documents. This eliminates any future dispute that may arise regarding availability of space and access for the contractor to certain areas. When constraints arise after tender award, they may result in time delay and extra costs.

3.1.7.2 Relocation Schedule

Reconstruction projects very often involve several moves and relocation of occupants' work areas. These relocations may include the move of workstations or services such as telephones, computer networks, fire alarms and security systems. These activities can involve many surprises, which may subsequently, end up in delaying the project or increasing the cost of construction. The researcher, therefore, hypothesized that when a relocation schedule is developed and included in the tender documents, it may yield higher performance.

3.2 SUMMARY OF THE PRELIMINARY FIELD REVIEW

The literature review followed by a preliminary field review has identified seven categories and thirty-six factors that may contribute to the improvement of the overall performance of reconstruction projects. These factors will be considered for further analysis by this research in an effort to develop a predictive model for the management of reconstruction projects that enable Project Managers to predict the over all performance of the project. Table 3.2 provides a summary for the results of the preliminary field review. The table includes the thirty-six factors, which were considered to be relatively important, and, also, the factors, which were perceived not to be important.

Table 3.2: Results of the Preliminary Field Review

CATEGORIES	FACTORS	SOURCE	RESULTS
COST	Budget Baseline and Budget Allocations		Important
	Work Packages Costing		Important
	Cost Breakdown Structure (CBS)	**LITERATURE**	Important
	Cost Coding		Not Important
	Earned Value		Not Important
	Cost Variance (CV)		Important
	Cost Ratio		Not Important
	Forecast Analysis		Important
	Unit Prices		Important
	Cash Allowances	**FIELD**	Important
	Cash Flow		Important
SCHEDULE	Work Breakdown Structure		Important
	Bar Charts		Important
	Critical Path Method	**LITERATURE**	Important
	Incremental Milestones		Important
	Time Variance		Important
	Percent Complete		Important
	Coordination Schedule	**FIELD**	Important
	Liquidated Damages		Important
	Change Directive vs. Change Notice		Important
QUALITY	Quality Standards and Specifications (With Input from Maintenance/Operation)		Important
	Responsibilities of Individuals Towards Quality	**LITERATURE**	Important

Table 3.2: Continued

QUALITY	Inspection and Testing	**LITERATURE**	Important, But see below
	Independent Inspection Firms Inspection by Operator / Maintenance Inspection by End User Pre-qualification of Contractors	**FIE:D**	Important Important Important Important
SCOPE	Decomposition Benefit / Cost Analysis	**LITERATURE**	Not Important Not Important
	As- Built Drawings Constructability Review Design Committees	**FIELD**	Important Important Important
COMMUNICATION	Site Meetings(Bi-Weekly with users Representatives) Electronic Communication	**LITERATURE**	Important Important
	Implementation Team Direct Communication Sub-team	**FIELD**	Important Important
SAFETY	Formal Safety Meetings with supervisor Site Safety Inspection Upper Management Involvement	**LITERATURE**	Not Important Not Important Not Important
	Joint Health and Safety Committee Awareness Sessions Emergency Plan and Procedures	**FIELD**	Important Important Important
SITE	Site Layout Plan	**LITERATURE**	Important
	Relocation Schedule	**FIELD**	Important

3.3 QUESTIONNAIRE SURVEY

A questionnaire was developed in order to collect the required data for the construction of the proposed model. The developed questionnaire was first tested in order to validate its suitability for collecting the required information. The questionnaire was then revised, accordingly, taking into account comments, which were made by the initial participants.

One major change was that the thirty-six control factors were rearranged from those in Table 3.2 to follow the project life cycle. In Table 3.2, the factors were arranged in seven different control categories namely cost control, schedule control, quality control, communication control, safety control, scope control and site control. In the questionnaire, however, the factors were rearranged into eight stages based on the project life cycle. These eight stages were scope definition, tendering, schedule control, cost control, quality control, communication control, safety control and project completion. The final version of the questionnaire is included in Appendix 2.

To encourage more construction professionals to participate in the survey, the questionnaire was developed to fit one page. This approach reduced the required time for completing the questionnaire, which resulted in a positive attitude towards the research.

The questionnaire was used to collect data in a structured interview format. Each questionnaire collected observational data related to a case study about one project that was completed in the past. This data included information about the utilization of certain factors in the management and control of the project, as well as information related to its overall performance. The researcher met with different construction professionals to discuss the project circumstances in detail and to allow the interviewee to provide in a free format any additional data that may help the research. Thirty-one organizations participated in this research. The interviewees were in positions that perform different construction management and project administration functions. The questionnaire was divided into four main parts, which are explained in the following sub sections.

3.3.1 The Project

This section of the questionnaire gathered basic information about the project such as name of the project, the organization and type of building. Also, a question was included in this part regarding the type of reconstruction work in terms of Interior Renovations, Structural Modifications, Addition / Expansion or Phased Replacement.

3.3.2 Before Construction

This part of the questionnaire was divided into two sections. The first section was related to the Scope Definition and Planning Stage, and the second was related to the Tendering Stage. As shown in the questionnaire (Appendix 2), various detailed factors that relate to scope definition and tendering were included in this part. In addition to the detailed questions, the participants were required to provide a summarized data in the form of an overall level of planning. This summarized data was used in the development of a summary model. Both Detailed and Summarized levels of information are explained later in this section.

3.3.3 During Construction

This part started by asking the participant to indicate a weighting percentage to represent the relative importance of controlling Cost, Schedule and Quality. These weighting percentages should add up to 100%. These percentages were used later as weighting factors in the determination of the overall project performance. The process of calculating the overall performance of the project is explained later in this chapter. Also, this part included detailed questions pertaining to six different control categories. The six areas were: Schedule Control, Cost Control, Quality Control, Communication Control, Safety Control and Project Completion. In addition to the detailed questions, the participants were, also, required to provide a summarized data in the form of an overall level of schedule control, cost control, quality control, communication control and safety control.

3.3.4 Project Performance

This part captured information about the actual outcome of the case study. The required information included The Original Contract Value, The Total Value of Change Orders, The Planned Duration, The Actual Duration and The Cost of Rework or Repairs paid for by the contractor. This information was used to obtain Cost Performance Factor, Schedule Performance Factor and Quality Performance Factor. These factors were then used to produce one quantifiable measure of the overall performance of the project (Response variable) called the Project Performance Factor (PPF).

3.3.5 Detailed and Summarized Level of Information

As mentioned earlier in the previous section, the questionnaire was designed to obtain two levels of information from each case study regarding the management and control of reconstruction projects.

The first level was a detailed level, which included the previously identified thirty-six factors distributed into the different parts of the questionnaire under their respective stages of the project life cycle. The participants were asked to answer whether they used the particular factor as part of the management process of the specific project being surveyed. The available answers were ether Yes or No. These answers reduced the level of subjectivity in the data collection process.

The second level was a summarized level of information, which was the overall level of control in a particular category or stage. At the end of each section within the questionnaire, the participants were asked to assess the overall level of effort exerted in controlling a particular category in the specific project. This information included Level of Planning, Level of Schedule Control, Level of Cost Control, Level of Communication Control and Level of safety Control. The participants were asked to rank the level of control on a scale from one to five, where five was the highest.

These two levels of detail, became the bases for the development of two alternative models for predicting the overall performance of reconstruction projects. The two models were called the Detailed Project Data Model and the Summarized Project Data Model. Each model was developed using both Regression Analysis technique and Artificial Neural Networks technique.

3.4 DATA COLLECTION AND ANALYSIS

As mentioned earlier, before the formal data collection process began, multiple meetings took place to fine tune the questionnaire and adjust any language problem or misinterpretations. The researcher collected the data in a structured interview format in order to ensure its quality and to avoid any misunderstanding of the questions by prospective respondents. Also, some interviewees needed more than one visit in order to allow them the opportunity to prepare the required information. Through personal contact, several organizations participated in the research. These organizations provided the researcher with valuable information related to the management and control of fifty-four different projects. The total value of the projects was over $180M, which is considered to be a good representative sample for the overall population of reconstruction projects. Raw data, which was provided by the questionnaire participants, was organized in a *Microsoft Excel* spreadsheet for ease of management and transfer to other analysis software.

In this section, data classification, variable definition and preliminary analysis are explained.

3.4.1 Quantifying overall Project Performance

[Dependent Variable (PPF)]

It was crucial to the success of this study to develop an overall project performance factor that incorporates the desired performance indicators. A comprehensive literature search was performed to identify these indicators and their use. The research also focused on the development of quantifiable and objective measures and avoided subjective measures. In a study by Ashley, project success was measured by cost, schedule, quality, safety and participant satisfaction [Ashley et al., 1987]. In 1988, Sanvido used cost, schedule, resources, and quality as measures for project performance [Sanvido, 1988]. Another study used cost, schedule, resources, and productivity as success criteria [Charoenngam, 1994]. Whereas resources and productivity may be found to be appealing indicators in a construction firm, in an owner organization, tracking contractor productivity does not take place. Cost, schedule, value, and effectiveness were also used as success factors [Ashley and Alarcon, 1996]. A later study used safety, schedule, budget and rework as the variables for project success. However, the team investigated perceptions of project success rather than specific measures [Thomas et al., 1998]. Cost overrun, schedule overrun and the cost of rework were used to measure cost, schedule and quality performance. See [Sanvido et al., 1992], [Weston & Gibson, 1993], [Ledbetter, 1994] and [Gibson and Hamilton, 1994].

The researched data was summarized and then shared with construction professionals in owners' organizations to develop the proposed Project Performance Factor (PPF). The preliminary interviews revealed that the three indicators were not perceived as being of equal importance to project success. Therefore, it was decided that during the data collection process, the researcher would ask the participant to provide weighting factors to the three indicators. This approach was also followed in earlier research [Dumont et al., 1997].

The Project Performance Factor is obtained by the following formula:

$$Project\ Performance\ Factor\ (PPF) = WCPF + WSPF + WQPF \ldots\ldots\ldots\ldots [1]$$

Where WCPF is Weighted Cost Performance Factor, $WCPF = x \ X\ CPF$,

WSPF is Weighted Schedule Performance Factor, $WSPF = y \ X\ SPF$

WQPF is Weighted Quality Performance Factor, $WQPF = z \ X\ QPF$

x, y, z are weighting factors for the three indicators, where $x + y + z = 1$.

$$Cost\ Performance\ Factor\ (CPF) = \left\{1 - \frac{\delta C}{Original\ Contract\ Value}\right\} X\ 100 \ldots [2]$$

Where δC is the total value of change orders.

$$Schedule\ Performance\ Factor\ (SPF) = \left\{1 - \frac{\delta S}{Original\ Schedule}\right\} X\ 100 \ldots [3]$$

Where δS is the total delay of the project.

$$\text{Quality Performance Factor (QPF)} = \{1 - \frac{\delta Q}{\text{original contract value}}\} X\ 100 \ldots\ldots[4]$$

Where δQ is the cost of rework.

As mentioned earlier in this section, the approach of adding the three performance factors in order to obtain the Project Performance Factor was used in previous researches [Adas, 1996]. The three performance indicators are percentages and therefore unit less. Consequently, the produced factor is expected to be simple and logical since it adds three unit less values.

Table 3.3 illustrates a descriptive analysis of the obtained data related to the development of (PPF).

Table 3.3 Descriptive Analysis for (PPF)

FACTOR	MAX.	MIN.	AVE.	SD
CPF	100.00	76.00	91.40	6.77
SPF	100.00	33.30	79.60	17.70
QPF	100.00	91.00	97.60	2.56
x	0.66	0.20	0.33	0.05
y	0.50	0.17	0.37	0.07
z	0.50	0.15	0.30	0.08
WCPF	54.90	15.40	29.72	6.73
WSPF	47.00	6.66	29.8	8.96
WQPF	56.94	14.87	29.29	9.08
PPF	99.38	67.54	88.8	8.51

Fifty-four case studies provided detailed information about fifty-four completed projects. In the questionnaire the participants were asked to provide weighting factors to the three performance indicators which are Cost, Schedule and Quality. The three weighting factors indicate the relative importance of their respective indicators. Table 3.3 demonstrates that the data included some diversity, which will allow the developed model to produce good predictions under different environments. The relative importance of Schedule Control fluctuated from 20% to 66%, Cost Control from 17% to 50% and quality Control from 15% to 50%. These fluctuations are wide enough to allow proper model development.

3.4.2 Independent Variables Classification and Definition

Independent variables were arranged into two different groups. The first group was called the Detailed Project Data, which included the thirty-six factors. The second group was called the Summarized Project Data, which included eight independent variables representing the level of control exerted in each control category.

3.4.2.1 Detailed Project Data

The Detailed Project Data group is considered to be an available detailed level of information regarding the control and management of reconstruction projects. Therefore, this group included the thirty-six factors as independent variables. The goal is to analyze the collected data and draw inferences about the relationship between these variables and the overall performance of reconstruction projects (PPF). These relationships would, consequently, be used to determine the success related factors in reconstruction projects and develop a predictive model that can predict the overall performance of reconstruction projects based on a Detailed Project Data.

In order to facilitate the analysis of the obtained data, each independent variable was denoted an X symbol. The data was also organized in a *Microsoft Excel* spreadsheet. Each case study was denoted a number from P1 to P54. The answers, which were provided by the participants for every case study, were also entered in the spreadsheet against their respective variables. The actual outcome of each case study was also included together with the calculations of the PPF. Table 3.4 shows the thirty-six independent variables with their respective X symbol. The arrangements of the factors in Table 3.4 were different from those in Table 3.2. However, their arrangements in the questionnaire were based on the different stages of the project life cycle and the chronological progress of any construction project.

Table 3.4 Detailed Project Data (Independent Variables)

STAGES	FACTORS (Independent Variables)	X
BEFORE CONSTRUCTION		
SCOPE DEFINITION AND PLANNING	Work Packages Costing	*X11*
	As- Built Drawings	*X12*
	Budget Baseline and Budget Allocations	*X13*
	Constructability Review	*X14*
	Design Committees	*X15*
TENDERING STAGE	Quality Standards and Specifications (With Input from Maintenance/Operation)	*X21*
	Pre-qualification of Contractors	*X22*

Table 3.4 Continued

TENDERING STAGE	Unit Prices	$X23$
	Cash Allowances	$X24$
	Liquidated Damages	$X25$
	Site Layout Plan	$X26$
DURING CONSTRUCTION		
SCHEDULE	Work Breakdown Structure.	$X31$
	Coordination Schedule.	$X32$
	Bar Charts	$X33$
	Critical Path Method	$X34$
	Incremental Milestones	$X35$
	Time Variance	$X36$
	Percent Complete	$X37$
	Change Directive vs. Change Notice	$X38$
COST	Cost Breakdown Structure (CBS	$X41$
	Cost Variance (CV)	$X42$
	Forecast Analysis	$X43$
	Cash flow analysis	$X44$
QUALITY	Commitment to quality was clear.	$X51$
	Independent Inspection Firms	$X52$
	Specifications had to be followed strictly	$X53$
COMMUNICATION	Implementation Team	$X61$
	Regular Site Meetings	$X62$
	Rapid response mechanism	$X63$
	Electronic Communication	$X64$
SAFETY	Joint Health and Safety Committee	$X71$
	Awareness Sessions	$X72$
	Emergency Plan and Procedures	$X73$
	Special precautions had to be made	$X74$
PROJECT COMPLETION	Inspection by Operator, Maintenance and end user	$X81$
	Relocation Schedule	$X82$

3.4.2.2 Summarized Project Data

The Summarized Project Data group consists of eight independent variables. This group is designed in order to enable the research to develop a model based on a summarized data at the control category level. This model will enable the end user to predict the overall performance of the project in a case where no detailed data is available at the time of prediction. Also, this analysis is expected to provide an indication of the significance of a particular control category to the success of reconstruction projects.

In order to facilitate the analysis of the obtained data, each independent variable was denoted a symbol. The data was also organized in a *Microsoft Excel* spreadsheet. Table 3.5 shows the eight independent variables with their respective symbols. Independent variables *X21* and *X81* were selected to represent the overall level of effort exerted by the company in the Tendering and Completion phases respectively.

Table 3.5 Summarized Project Data (Independent variables)

Summarized Data (Independent variables)	Symbol
Over all level of Planning	*LP*
Over all level of Tendering	*X21*
Over all level of Schedule Control	*LS*
Over all level of Cost Control	*LC*
Overall Level of Quality Control	*LQ*
Over all level of Communication Control	*LCOM*
Over all level of Safety Control	*LSAF*
Over all level of Completion	*X81*

3.4.3 Preliminary Data Analysis

3.4.3.1 Detailed Project Data

The data was organized in a *Microsoft Excel* spreadsheet in order to facilitate its analysis and migration to other analysis tools. The variables were operationalized to a zero or a one. If the factor was included in the project management process of the case study, the answer was Yes, otherwise it was No. A Yes answer received a One in the spreadsheet, while, a No answer received a Zero. The organized data in the spreadsheet revealed the fact that not all of the thirty-six variables are contributing to the success or failure of reconstruction projects. It was evident that, it was not practical to carry the entire thirty-six variables in further detailed analysis due to the lack of significant relationship between some of the independent variables and (PPF).

The purpose of the Preliminary Data Analysis was, therefore, two folds:

1- To examine the data of the available case studies and confirm the sufficiency of the data for modeling purposes; and

2- To try to reduce the number of variables to a manageable number without loss of model accuracy

With respect to the confirmation of the sufficiency of the data for modeling purposes, *Microsoft Excel* was used to produce scatter plots and to plot the trend line between each independent variable and the PPF. Appendix 3 includes all the produced plots. Appendix 3 shows that all trend lines exhibit logical relationships between each independent variable and the dependent variable PPF, thus, confirming the sufficiency of the data. For example, the scatter plot and the trend line for X34 (Critical Path Method [CPM]) demonstrate an increase in the PPF under the utilization of CPM.

With respect to the reduction of the number of variables to a manageable number without loss of model accuracy, the data was analyzed using *Systat*. *Systate* is commercial statistical analysis computer software produced by SPSS Inc. The utility of the linear relationship between the response variable PPF and each independent predictor was tested using *Systat*. *Systat* produced the Correlation Coefficient (r), F- test and *p-value* for every linear relationship. The *Systat* output is included in Appendix 4. The results are summarized and tabulated in descending order by (r) in Table 3.6.

Table 3.6 Preliminary Analysis for the Detailed Data.

FACTOR	NAME	Correlation Coefficient(r)	F - test	*P-Value*
X12	As-Built Drawings	0.866	155.55	0.000
X81	Inspection by O&M/End users	0.825	110.73	0.000
X21	Standards & Specs. with input of O&M	0.815	102.87	0.000
X33	Bar Charts	0.798	90.866	0.000
X22	Pre-qualifications of contractors	0.754	68.617	0.000
X34	Critical Path Method	0.753	68.302	0.000
X71	Joint Health & Safety Committee	0.741	63.446	0.000
X32	Coordination Schedule	0.737	61.919	0.000
X23	Unit Prices	0.725	57.648	0.000
X63	Rapid Response Mechanism	0.696	48.807	0.000
X62	Regular Site Meetings	0.683	45.387	0.000
X42	Cost Variance (CV)	0.678	44.209	0.000
X15	Design Committee	0.591	27.858	0.000

Table 3.6 Continued

X13	Budget Baseline & Budget Allocation	0.571	25.838	0.000
X24	Cash Allowances	0.569	24.931	0.000
X52	Independent Inspection Firms	0.560	23.716	0.000
X35	Incremental Milestones	0.547	22.199	0.000
X37	Percent Complete	0.467	14.511	0.000
X36	Time Variance	0.266	3.953	0.052
X31	Work Breakdown Structure	0.223	2.709	0.106
X82	Relocation Schedule	0.207	2.330	0.133
X41	Cost Breakdown Structure	0.200	2.156	0.148
X25	Liquidated Damages	0.197	2.089	0.154
X61	Implementation Team	0.187	1.886	0.176
X44	Cash Flow Analysis	0.166	1.482	0.229
X26	Site Layout Plan	0.161	1.382	0.245
X53	Specification had to be followed strictly	0.152	1.222	0.274
X51	Commitment to quality was clear	0.152	1.236	0.271
X11	Work Packages Costing	0.146	1.132	0.292
X38	Change Directives vs Change Notices	0.129	0.883	0.352
X73	Emergency Plan & Procedures	0.116	0.705	0.405
X74	Special precautions had to be made	0.090	0.423	0.519
X43	Forecast Analysis	0.065	0.220	0.641
X14	Constructability Review	0.055	0.157	0.694
X72	Awareness Sessions	0.016	1.851	0.180
X64	Electronic Communications	0.012	0.007	0.934

Variable Selection

Based on the information provided in Table 3.6, the variables that have a significant relationship with the PPF were considered for further analysis and model building. The criteria for selecting the variables for further analysis were as follows:

1- (r) > 0.5

(r) explains the strength of the linear relationship between the independent variable and the dependent variable PPF. Most researchers consider (r) > 0.5 indicates significance and (r) > 0.7 indicates excellent correlation [Sanvido et al, 1992] and [Ashley et al, 1987]. Therefore, factors with (r) > 0.5 was considered for further analysis and model building process.

2- $F_{observed} > F_{critical}$

$F_{observed}$ should be > $F_{critical}$ in order for the variable to have a significant relationship with PPF. $F_{observed}$ is the value produced by *Systat*, which is included in Table 3.6. $F_{critical} = F_{\alpha, P-1, n-P}$. For 95% significance, α=0.05. Since we are considering one variable at a time, then P-1=1. Also, since we have fifty four observations, then n-P=52. From the standard Statistical Tables, $F_{0.05,1,53}$=4.01.

3- *P-values* < 0.0005

P-Value is the Significance Probability. It provides an evidence of the significant relationship between the independent variable and PPF. Most investigators use *P-values* < 0.0005. For more information on this test, the reader is referred to the Systat reference manual. [SPSS, 1997].

Based on the above criteria, only the top seventeen factors in Table 3.6 will be considered for further analysis and model building. The remaining factors did not prove to have a significant relationship with the overall performance of reconstruction projects PPF. For example, X37 obtained a satisfactory P-value = 0 which is <0.0005 and a satisfactory F-ratio = 14.511 which is > 4.01. However, it obtained an unsatisfactory r = 0.467 which is < 0.5.

By examining the factors that have been removed, it is possible to note that they have been compensated for by other factors that are included in the top seventeen factors. For example, Percent Complete, Time Variance and Work Breakdown Structure are schedule control factors which were accounted for by other schedule control factors that were included in the top seventeen factors such as Critical Path Method, Bar Charts and Incremental Milestones. However Critical Path Method is a more rigorous schedule control factor than Work Breakdown Structure, which may explain the selection of Critical Path Method and the removal of Work Breakdown Structure. Similarly, all removed factors have been accounted for in the top seventeen factors.

The top seventeen factors include three factors at the Planning and Scope definition Stage, four factors at the Tendering Stage, four factors for Schedule Control, one for Cost Control, one for Quality Control, two for Communication Control, one for Safety Control and one at the Project Completion stage. This preliminary analysis suggests that the management and control of planning, tendering and scheduling is significant to the overall performance of reconstruction projects.

These seventeen factors will be used in the following chapters to develop a predictive model that enables the users to predict the overall performance of reconstruction projects based on Detailed Project Data.

3.4.3.2 Summarized Project Data

The process, which was followed to analyze the Detailed Project Data, was also followed to analyze the Summarized Project Data. The *Microsoft Excel* scatter plots are included in Appendix 3. Also, the *Systat* output is included in Appendix 4. The results are summarized and tabulated in descending order by (r) in Table 3.7.

Table 3.7 Preliminary Analysis for the Summarized Data.

Category	Correlation Coefficient(r)	F - test	*P-Value*
LS (level of scheduling)	0.866	155.554	0.000
LP (level of planning)	0.851	136.448	0.000
X81 (level of Completion)	0.825	110.736	0.000
X21 (Level of Tendering)	0.815	102.876	0.000
LSAF (level of safety)	0.717	55.097	0.000
LCOM (level of communication)	0.710	52.796	0.000
LC (level of cost control)	0.668	41.963	0.000
LQ (level of quality control)	0.550	22.594	0.000

Based on the previous selection criteria, all the independent variables in the Summarized Project Data group proved to have a strong relationship with PPF. Therefore, all of these variables will be considered for further analysis and model building. The goal is to develop a predictive model based on a Summarized Project Data. The summarized data is the expected level of control to be exerted on a particular control category. These results once again prove that good Planning, Tendering, and Scheduling is significant to project success.

The model building process is described in Fig. 3.5. Chapter four deals with the model building process utilizing a Statistical Regression Analysis technique, while, chapter five deals with the model building process utilizing the Artificial Neural Network technique.

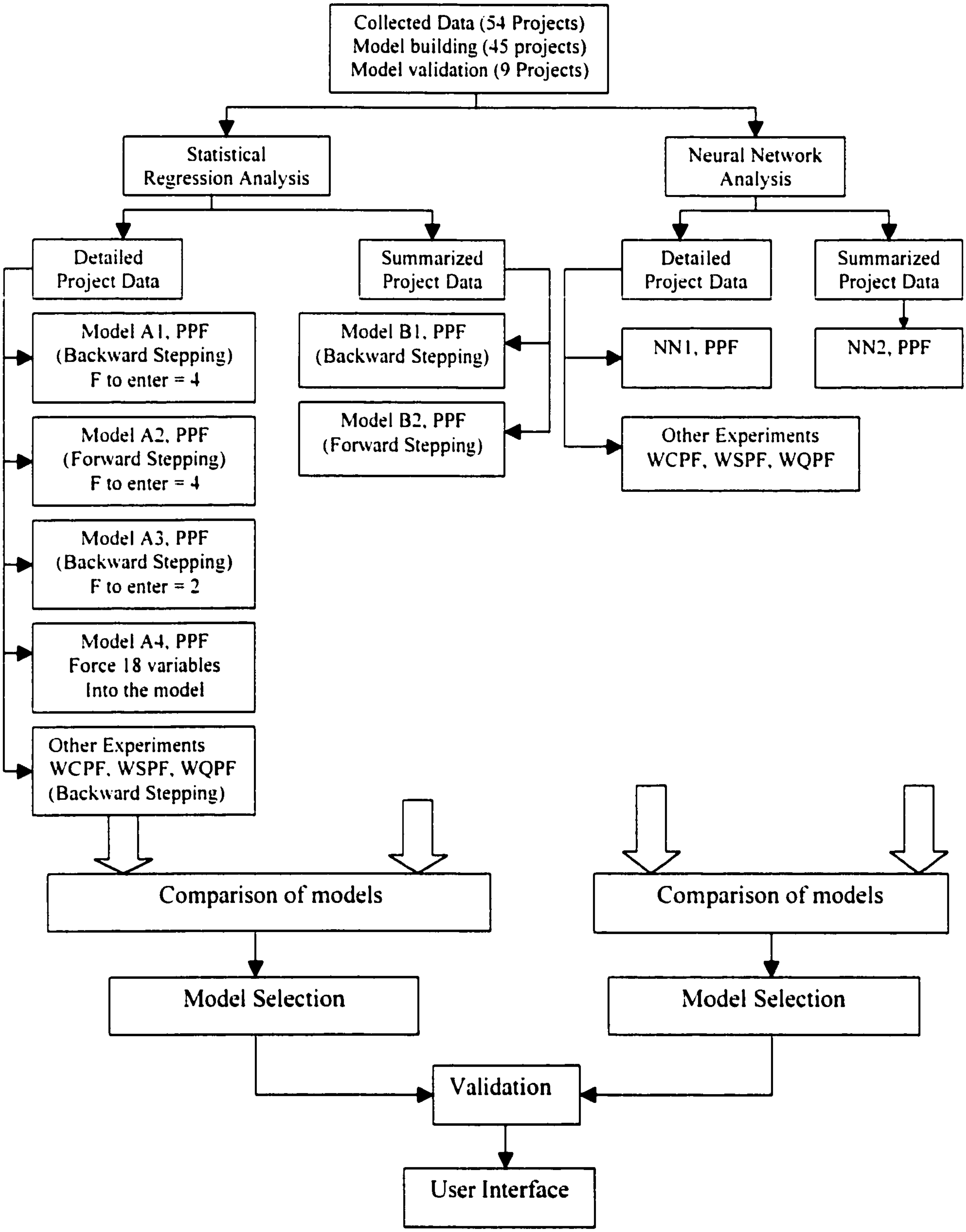

Fig. 3.5The Model Building Process

CHAPTER 4 DEVELOPING AND VALIDATING A PREDICTION REGRESSION MODEL

This chapter presents the model building process using statistical multiple regression methods. The data was analyzed using the SYSTAT 7.0 for Windows (*Systat*) software package, which is produced by SPSS Inc. Various *systat* language and procedures were used in defining the descriptive statistics, executing the multiple regression analysis and checking the model adequacy.

It was essential to divide the data into two groups. The first group was used to develop the model, and the second one to test its validation. Enough data was needed in the first group in order to ensure the development of solid models. Similarly, an adequate size validation set of data was required in order to test the predictive performance of the model. Therefore, the data was divided into two sets, a model building set which included forty-five projects and a validation set which included the remaining nine projects. It can be noted that the size of the validation set is 20% of the size of the model building set, which is considered to be a reasonable percentage.

Following the model building process, which is shown in Fig. 3.5, various predictive models for project performance were developed using Statistical Analysis and utilizing the Detailed and Summarized Project Data which were provided in the case studies. In the following sections, the process of developing the two types of models is explained. The first model is based on a Detailed Project Data, while the second is based on a Summarized Project Data.

4.1 A PREDICTIVE MODEL BASED ON A DETAILED PROJECT DATA

The preliminary data analysis of chapter three resulted in the identification of seventeen different factors that significantly contribute to the overall performance of reconstruction projects (PPF). These factors can be used proactively by project managers to control reconstruction projects and minimize the slippage or the deviation of actual project overall performance from the planed performance. As such, the seventeen factors were used to develop the proposed predictive model for the overall project performance.

In order for the model to be sensitive to the different types of reconstruction projects, another factor was added to the seventeen factors. This factor is the type of reconstruction project and is denoted by X_0. Table 4.1 shows the final list of the eighteen factors used to develop the predictive model.

As explained earlier in chapter three the collected data was organized in a *Microsoft Excel* spreadsheet. The statistical tool, which was used to analyze the data and develop the model, was *Systat*. *Systat* is compatible with *Microsoft Excel* release 4. Therefore, the data spreadsheet was saved in *Excel* release 4. The data was, then, exported from *Excel* to *Systat* using the file import option in Systat.

Table 4.1 Detailed Project Data (Independent Variables Final List)

CATEGORIES	FACTORS (Independent Variables)	X
SCOPE DEFINITION AND PLANNING	Type of reconstruction project	X0
	As- Built Drawings	X12
	Budget Baseline and Budget Allocations	X13
	Design Committees	X15
TENDERING STAGE	Quality Standards and Specifications (With Input from Maintenance/Operation)	X21
	Prequalification of Contractors	X22
	Unit Prices	X23
	Cash Allowances	X24
SCHEDULE	Coordination Schedule.	X32
	Bar Charts	X33
	Critical Path Method	X34
	Incremental Milestones	X35
COST	Cost Variance (CV)	X42
QUALITY	Independent Inspection Firms	X52
COMMUNICATION	Regular Site Meetings	X62
	Rapid response mechanism	X63
SAFETY	Joint Health and Safety Committee	X71
PROJECT COMPLETION	Inspection by Operator, Maintenance and end user	X81

Stepwise regression has been used to develop the required model. Fig 4.1 shows the regression screen in *systat.* Fig 4.1 shows a portion of the dependent and independent variables arranged in one field. Two other fields are available to add or remove the required independent or dependent variables. An options button is also available to enable users to gain access to the Regression Options screen.

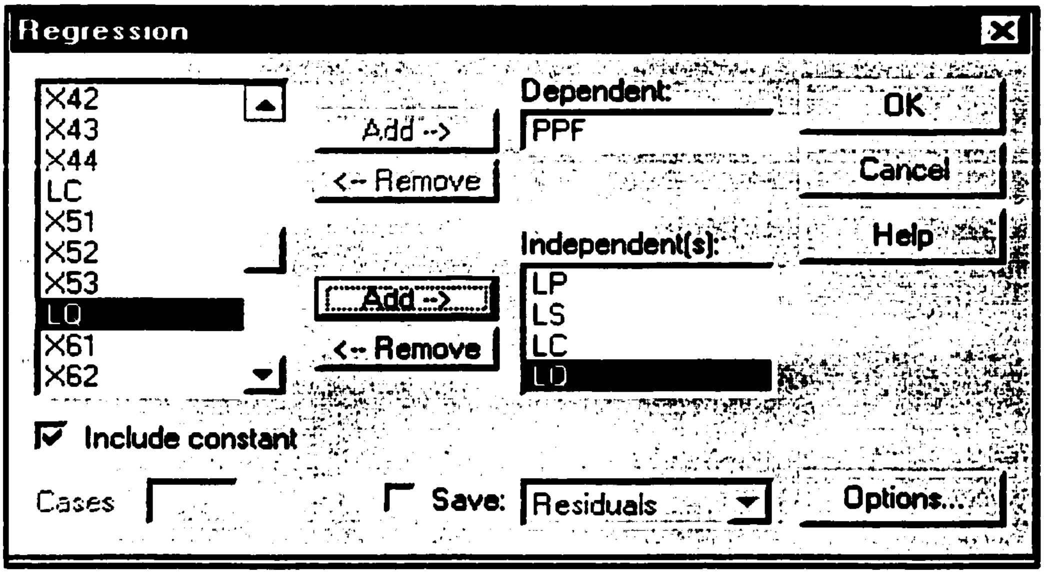

Fig. 4.1 The Regression Screen in SYSTAT 7.0

Fig. 4.2 shows the regression options screen in *systat* Fig. 4.2 shows that the user has the ability to select either a complete regression or stepwise regression. *systat* includes two different procedures for the development of stepwise models: forward selection and backward elimination. *Systat*, also, provides the user with the facility to specify add and remove criteria. The default values are F=4 to enter and F=3.9 to remove.

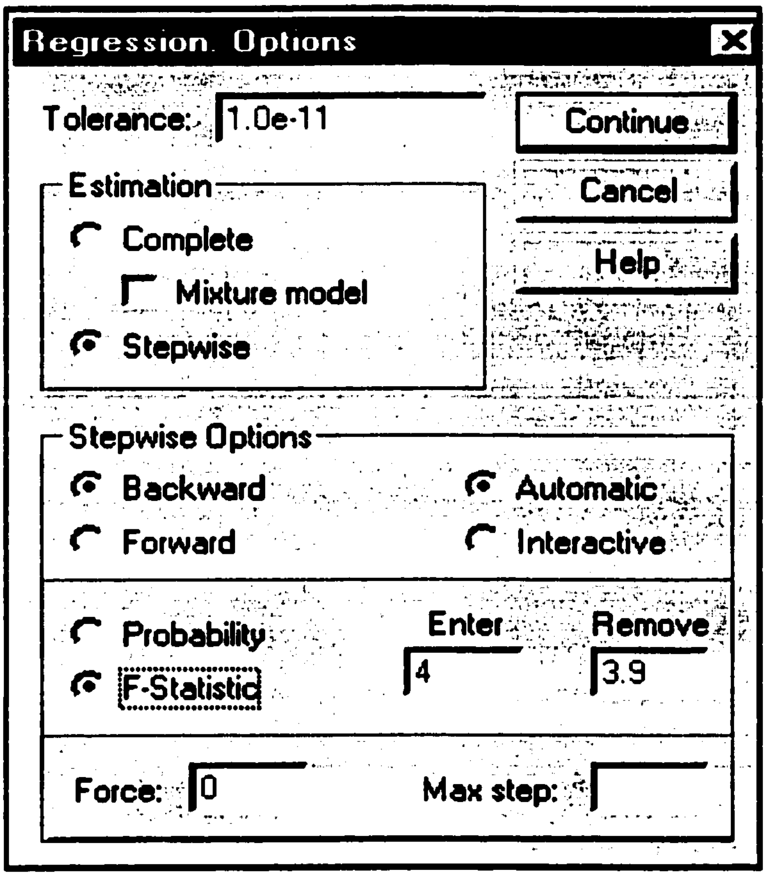

Fig. 4.2 The Regression Options Screen in SYSTAT 7.0

Forward stepping begins with no variables in the equation, enters the most significant predictor at the first step and continues adding and deleting variables until non can significantly improve the fit.

Backward stepping begins with all candidate variables, removes the least significant predictor at the first step and continues until no insignificant variables remain.

4.1.1 Model Building

As shown in Fig. 3.5, *systat* was utilized in various modeling experiments using its forward stepping and backward stepping techniques. As it was mentioned earlier Systat comes with default values for F=4 to enter and F= 3.9 to remove.

For a model that includes eighteen variables with the use of forty-five case studies:

$$F_{critical} = F_{\alpha,\, p-1,\, n-p} = F_{0.05,\, 18,26} = 2.04.$$

Where n is the number of observations, which equals 45. P is the number of potential predictors in the complete model, which equals eighteen predictors plus the constant (total 19). P-1 is the number of degrees of freedom for the regression, while n-p is the number of degrees of freedom for the error. The $F_{critical}$ value of 2.04 will be utilized later in this chapter in one of the experiments to develop the proposed predictive model.

Model A1, Detailed Project Data Vs. PPF

Backward Stepping with F=4 to enter

The default enter and remove criteria of *systat* were used to construct the required model. The default criteria were F= 4 to enter and F=3.9 to remove. The model was produced using backward stepping technique. The detailed steps of backward stepping and its *systat* output is included in Appendix 5a and summarized in Table 4.2.

Table 4.2 Detailed Project Data Model results (A1),

Backward Stepping with F=4 to enter

Adjusted Squared Multiple R = 0.904

F-ratio = 83.549 *Pvalue*=0.00

Variable	Coefficient	T Statistics	Partial F
Constant	74.589	80.615	0.000
X12 (As-Built)	6.681	3.485	0.001
X15 (Design Committees)	2.674	2.294	0.027
X22 (Pre-qualifications of Contractors)	4.748	3.574	0.001
X34 (CPM)	3.180	2.538	0.015
X81 (Inspection by O&M / end-users)	5.013	3.102	0.004

Model A2, Detailed Project Data Vs. PPF

Forward Stepping with F=4 to enter

The default enter and remove criteria of *systat* were used to construct the required model. The default criteria were F = 4 to enter and F = 3.9 to remove. The model was produced using forward stepping technique. The detailed steps of forward stepping and its *systat* output is included in Appendix 6 and summarized in Table 4.3.

Based on the information provided in Table 4.2, 4.3, Appendix 5a and Appendix 6, it can be concluded that the model developed using the backward technique (Model A1) is more useful in predicting the overall performance of reconstruction projects. It includes one more variable and also has a higher Adjusted Squared Multiple R. It was, also, reported in the literature that backward stepping is preferable over forward selection since it has the advantage of looking at all the available variables in the early stages of the model building process.

Table 4.3 Detailed Project Data Model results

Forward Stepping with F=4 to enter

Adjusted Squared Multiple R = 0.899

F-ratio = 99.280 *Pvalue* = 0.00

Variable	Coefficient	T Statistics	Partial F
Constant	74.938	86.305	0.000
X12 (As-Built)	7.462	4.004	0.000
X22 (Pre-qualifications of Contractors)	5.174	3.874	0.000
X71 (Joint Health & safety Committee)	5.110	4.150	0.000
X81 (Inspection by O&M / end-users)	3.836	2.234	0.031

Model A3, Detailed Project Data Vs. PPF

Backward Stepping with F=2 to enter

In order to examine the probability of adding more variables to the model, the enter and remove criteria were reduced below the default values in *Systat*. F=2 to enter and F=1.9 to remove were used in order to meet the $F_{critical}$ value of 2.04. The resulted model and its ANOVA table is included in Appendix 5b and summarized in Table 4.4. Table 4.4 shows the model, which includes eight variables. However, two of the added three variables, X13 and X35, have *P values* (Partial F) exceeds α=0.05. These two variables also have $t_{observed} < t_{critical}$.

$$t_{critical} = t_{\alpha/2,\, n\text{-}p} = t_{0.025,\, 36} = 2.03$$

The third variable, X24, when added to Model A1, resulted in a reduction in the overall model utility. Therefore, Model A3 is rejected.

Table 4.4 Detailed Project Data Model results,
Backward Stepping with F=2 to enter

Adjusted Squared Multiple R = 0.910

F-ratio = 56.419 *Pvalue*=0.00

Variable	Coefficient	T Statistics	Partial F
Constant	76.666	42.750	0.000
X12 (As-Built)	7.846	4.001	0.000
X13 (Budget Baseline & Allocation)	4.258	1.67	0.108
X15 (Design Committees)	3.804	2.786	0.008
X22 (Pre-qualifications of Contractors)	3.861	2.847	0.007
X24 Cash Allowances	-7.013	-2.196	0.035
X34 (CPM)	3.983	2.962	0.005
X35 (Incremental Milestones)	-2.118	-1.426	0.162
X81 (Inspection by O&M / end-users)	5.732	3.520	0.001

Model A4, Detailed Project Data Vs. PPF

Force the eighteen variables into the model

Another experiment was the use of the (Force) option in the regression option screen in *Systat*, in order to force all of the eighteen variables into the model. The detailed result of the model is included in Appendix 5c. In Appendix 5c, it is evident that only three variables posses satisfactory *(P)* values (partial F< α = 0.05). Moreover, the same three variables are the only variables in the model which have $t_{observed} > t_{critical}$

$$t_{critical} = t_{\alpha/2,\, n-p} = t_{0.025,\, 26} = 2.056$$

Also, the F-ratio for this model is 20.542, which is significantly lower than the F-ratio in Model A1. Therefore, it is concluded that the Model A1 is the selected predictive model for the overall performance of reconstruction projects. Further diagnostics and validation for the selected Model A1 is discussed in the following subsections.

4.1.2 Model Diagnostic (Model A1)

The selected predictive model is given by the formula:

PPF = 74.589 + 6.681 X_{12} (As-built) + 2.674 X_{15} (Design Committees) + 4.748 X_{22} (Pre-qualification of Contractors) + 3.180 X_{34} (CPM) + 5.013 X_{81} (Inspection by O & M end-users)

Model Utility

The Adjusted Squared Multiple R = 0.904. This statement means that, the model is able to explain 90.4% of the variability in the data. This value is considered to be an excellent indicator of the model's expected performance.

F-ratio

$F_{critical} = F_{\alpha, P-1, n-P}$. For 95% significance, $\alpha=0.05$.

Since we have five variables: → P = 1(Constant)+5= 6 →

Regression degrees of freedom = P-1 = 6-1=5

Also, since we have forty-five case studies → n=45 →

Error degrees of freedom = n-p = 45-6=39.

From the standard Statistical Tables $F_{critical} = F_{0.05,5,39} = 2.44$.

$F_{observed}$ of this model=83.549, which is significantly larger than $F_{critical}$.

P-Value

P-Value is the Significance Probability or the probability of exceeding the F-ratio when the group means are equal [SPSS, 1997]. In the end of Appendix 5a, the *Systat* Analysis Of Variance calculations show a *P-value* of 0.00 which is <0.0005. This is another indication of the overall significance of the model

T-Statistics

T-Statistics is an indication of the significance of the individual predictor. For the individual predictor to be significant

$$t_{observed} > t_{critical}.$$

$$t_{critical} = t_{\alpha/2, n-p} = t_{0.025, 39} = 2.021$$

Table 4.2 shows that all the predictors in the Model A1 have $t_{observed} > t_{critical}$.

Partial F

It assesses the partial significance of the individual predictor and its contribution to the overall model based on the fact that the other variables are already in the model. Table 4.2 shows that all the variables have (*P Value* for partial F) < α=0.05 which is the preset value in *Systat*.

Tolerance

Tolerance is an indicator of muticollinearity. Muticollinearity inflates the variance of the least squares estimators and possibly any predictions made. Tolerance is 1 minus the multiple correlation between a predictor and the remaining predictors in the model. All of the predictors in Model A1 have a tolerance >0.1, which indicates that muticollinearity, does not exist among the predictor variables.

Outliers

An outlier among a set of residuals is one that is much larger than the rest in absolute values. The presence of an outlier can affect the least squares fitting of the model. *Systat* provides a residuals-output, which includes different statistical measures for detecting outliers. The residual table is included in Appendix 5d. The first column in Appendix 5d includes the model's predicted values for PPF. The residual column includes the difference between the predicted and the actual PPF. It can be noticed that no outliers exist. Also, the correlation coefficient (r) between the predicted and the actual values of PPF is 0.96, which is considered to be an excellent correlation.

Leverage is also another measure that detects outliers. Any observation is considered to have a large leverage and is consequently considered to be an outlier if its leverage is >3p/n., where p is the number of degrees of freedom and n is the number of observations. In this model the leverage should not exceed 0.4 since it includes five predictors in addition to the constant and the number of observation is forty-five. In Appendix 5d, it can be noticed that all observations have a leverage < 0.4.

Cook's Distance is another measure that detects outliers. It measures the level of the change to the parameter estimates that result from deleting the outlier observation. As a rule of thumb, when the value of Cook's distance equals one for any observation, that calls for checking and scrutinizing that observation. It can be noted in Appendix 5d that no outliers exist in the observations.

The above model diagnostics, conclude that this research developed a solid model and prove once again the sufficiency of the data as discussed earlier in chapter three. To further examine the consistency of the model given different number of data for its development, different model development experiments were conducted utilizing different number of projects. The result of these experiments is a consistent model that involves the same five factors. Only one experiment resulted in the removal of one factor. As such, it can be concluded that the five factors that constitute the model are the ones that are most significant, regardless of the number of projects used in model development.

- ***Linear Model***

As mentioned earlier in chapter three, modelers preferred to develop their models utilizing linear regression because of the ease of use, development, interpretation and comparison of different models. Also, another advantage of linear regression methods is that they are frequently used to develop models from observational data such as this work. Further more non-linear models produce undesired statistical properties such as that their least squares estimators may not be unbiased or they may produce an over fitted model. Over fitting will have a negative impact on the model's ability to generalize. Fig. 4.3 illustrates the over fitting problem in non-linear models.

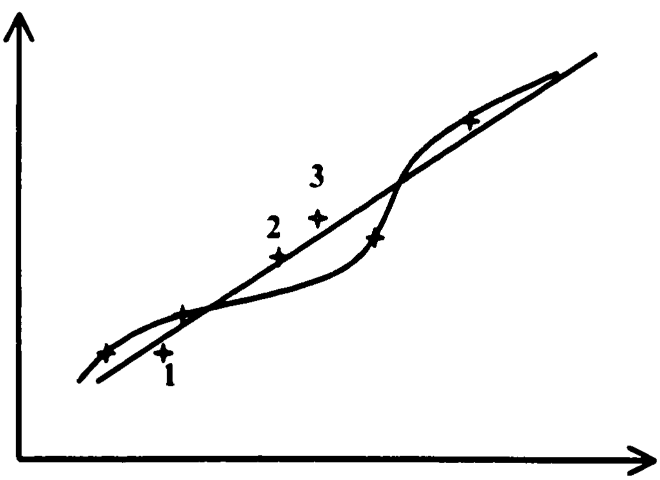

Fig. 4.3 Non-Linear vs. Linear Models

The non-linear model in Fig.4.3 is over fitted to particular observational data, therefor, will not have the ability to predict favorably for new unseen observational data. As illustrated in Fig. 4.3, the linear model has a better ability to generalize on observations 1,2 and 3. The linear model that was developed in this work avoided the draw backs of non-linear models. Also, the discussion in the previous section proved that the produced linear model has solid statistical properties.

4.1.3 Model Inferences

The selected predictive model is given by the formula:

PPF* = *74.589

+6.681 X_{12} (As-built) If As-built drawings are available for the existing facility, the model user enters $X_{12} = 1$, otherwise, the model user enters 0. $X_{12}=1$ means the PPF will increase 6.681 points.

+2.674 X_{15} (Design Committees) If Design Committees are expected to be formed, the model user enters $X_{15} = 1$, otherwise, the model user enters 0. $X_{15}=1$ means the PPF will increase 2.674 points.

+4.748 X_{22} (Pre-qualification of Contractors) If Pre-qualification of contractors is expected to be formed, the model user enters $X_{22} = 1$, otherwise, the model user enters 0. $X_{22}=1$ means the PPF will increase 4.748 points.

+ 3.180 X_{34} (CPM) If Critical Path Method is expected to be used as a schedule control tool, the model user enters $X_{34} = 1$, otherwise, the model user enters 0. $X_{34}=1$ means the PPF will increase 3.180 points.

+ 5.013 X_{81} (Inspection by O & M /end-users) If periodic inspection of the reconstructed facility is expected to involve the building's Operators, Maintenance staff and the end users, the model user enters $X_{81} = 1$, otherwise, the model user enters 0. $X_{81}=1$ means the PPF will increase 5.013 points.

For example, a potential reconstruction project in a facility that has good As-Built drawings available, Design Committees will be formed, Pre-qualifications of contractors will take place, CPM will not be used and inspection by operators, maintenance and end users will not take place, the predicted PPF will be obtained as follows:

$$PPF = 74.589 + 6.681 * 1 + 2.674 * 1 + 4.748 * 1 + 3.180 * 0 + 5.013 * 0 = 88.692$$

This result indicates that this project has an 88.692 % performance, which means that the project has an 11.308% poor performance. This poor performance can be considered as an expected value for cost overrun in this project. This interpretation may not be 100% true because of the time factor, however, it provides a physical meaning for poor or good performance.

4.1.4 Physical Significance of the Model

It can be noted that the obtained factors are highly relevant to reconstruction projects in operating facilities as compared to new construction projects. The following simple analysis reveals the physical importance of these factors specifically to reconstruction projects. Each factor covers one stage in the project life cycle from concept, to design, bidding, construction, and finally operation.

- ***As-Built Drawings***

As-Built Drawings for the existing facility has been proven to be highly important for reconstruction projects. Unforeseen existing site conditions were proven to be the highest contributor to poor cost and schedule performance in reconstruction projects. A-Built Drawings is a good tool to enhance both cost and schedule performance of reconstruction projects in operating facilities.

- ***Design Committees***

Design Committees are formed in both reconstruction and new construction projects. However this model indicates the significance of this factor to reconstruction projects in operating facilities. In this case building users, operators and maintenance staff are essential parties for design input and scope definition. Their input should be properly incorporated in order to avoid high cost overrun and schedule delays during the construction phase. Also, design committees serve as a communication tool.

- ***Pre-qualification***

Contractors' pre-qualification is crucial to the determination of the contractor's ability to deal with the unique environment of reconstruction of operating facilities. The selection of a qualified and capable construction contractor is essential to the successful completion of the construction contract.

- ***Critical Path Method***

The Critical Path Method is considered to be a high end scheduling technique. The complex nature of reconstruction projects in operating facilities made it essential to use this technique as a tool for schedule control.

- ***Inspection by Operation, Maintenance and End Users***

Since Operation, Maintenance and End Users inherits the building after reconstruction is completed, their early inspection of the work during the construction process helps to decrease or even eliminate any rework that may be required at later stages.

4.1.5 Model Validation

Model validation is different from model adequacy checking. Model validation is directed towards determining if the model will function successfully in its intended operating environment. Three types of procedures were suggested in the literature for model validation. These procedures are analysis of the model coefficients, collecting fresh data, or data splitting [Montgomery, 1990]. In this research, nine case studies were selected randomly and set aside for validation purposes.

The data, which was provided in the nine validation sets, were applied to Model A1. The model produced nine predicted values for the overall performance (PPF) for the nine projects. A correlation analysis was, then, performed between the predicted PPF and the actual PPF for the nine projects. The resulted correlation coefficient was r= 0.9121. Also, the mean absolute error between the predicted PPF and the actual PPF is 0.44. These results reveal that the developed Model A1 has excellent predictive capabilities. The results are tabulated in Table 4.5.

4.2 A PREDICTIVE MODEL BASED ON SUMMARIZED PROJECT DATA

This model was developed in order to be used by project managers, if a detailed level of information was not available. The variables as illustrated in Table 3.7, were used to develop the desired predictive model. The processes, which were followed to develop a predictive model based on the Detailed Project Data, were also followed to develop this model for the Summarized Project Data.

Table 4.5 Detailed Project Data, Model Validation (Model A1)

Project	C	X12		X15		X22		X34		X81		Predicted PPF	Actual PPF	Error
P46	*74.59*	*6.681*	1	*2.674*	0	*4.748*	1	*3.18*	0	*5.013*	1	91.031	87.89	3.141
P47	*74.59*	*6.681*	0	*2.674*	0	*4.748*	0	*3.18*	0	*5.013*	0	74.589	73.6	0.989
P48	*74.59*	*6.681*	0.5	*2.674*	1	*4.748*	1	*3.18*	1	*5.013*	1	93.5445	89.77	3.7745
P49	*74.59*	*6.681*	0.5	*2.674*	0.5	*4.748*	1	*3.18*	0	*5.013*	1	89.0275	88.83	0.1975
P50	*74.59*	*6.681*	0	*2.674*	0	*4.748*	0	*3.18*	0	*5.013*	0	74.589	80.7	-6.111
P51	*74.59*	*6.681*	0.5	*2.674*	0.5	*4.748*	1	*3.18*	0	*5.013*	1	89.0275	89.14	-0.1125
P52	*74.59*	*6.681*	1	*2.674*	1	*4.748*	0	*3.18*	0	*5.013*	1	88.957	88.11	0.847
P53	*74.59*	*6.681*	1	*2.674*	1	*4.748*	1	*3.18*	0	*5.013*	1	93.705	87.56	6.145
P54	*74.59*	*6.681*	0	*2.674*	0	*4.748*	0	*3.18*	0	*5.013*	0	74.589	79.5	-4.911
													Max	6.145
													Min	-6.111
													Mean	0.4399
													r	0.9121

4.2.1 Model Building

Similar to the development of the Detailed Project Data model (Model A1). two different regression stepping techniques were used in order to develop the Summarized Project Data model. Theses two techniques were backward stepping and forward stepping. The detailed steps for backward stepping and the constructed ANOVA table are included in Appendix 7 (Model B1). Also, the detailed steps and the constructed ANOVA table for the forward stepping are included in Appendix 8. We can note from Appendices 7 & 8 that both Model B1 and Model B2 have the same characteristics. These data are summarized in Table 4.6.

Table 4.6 Summarized Project Data Model results

Adjusted squared multiple R = 0.872

F-ratio = 76.084 *Pvalue*=0.00

Variable	Coefficient	T Statistics	Partial F
Constant	67.062	35.028	0.000
LP (Level of Planning)	3.573	4.476	0.000
LS (Level of Scheduling)	3.831	4.222	0.000
LCOM (Level of Communication)	-2.099	-2.163	0.037
X81 (Level of Completion)	5.282	2.893	0.006

4.2.2 Model Diagnostic

The fitted predictive model is given by the formula:

PPF = 67.062 + 3.573 LP (Level of Planning) + 3.831 LS (Level of Scheduling) – 2.099 LCom (Level of Communication) + 5.282 X81 (Inspection by O & M end users)

One possible explanation of the negative sign that is associated with the Level of Communication factor is that it might be the result of the inclusion of other factors in the model. It is statistically known that the contribution of any factor to a model as well as its significance depends, to a great extent, on other factors, which are already included in the model. The physical meaning in this case is that when the level of planning, level of scheduling, and level of inspection are optimized, any additional efforts spent on communication represent un-necessary efforts. In other words these efforts become costly and time consuming which, degrade the overall performance. Another possibility might be that the participants of the survey felt that the communication factor represents unnecessary extra efforts since they exercise a great level of communication during scheduling and planning which are already included in the model.

Model Utility

The Adjusted Squared Multiple R = 0.872. This statement means that, the model is able to explain 87.2% of the variability in the data. This value is considered to be an excellent indicator of the model's expected performance.

F-ratio

$F_{critical} = F_{\alpha, P-1, n-P}$. For 95% significance, α=0.05.

Since we have four variables: → P = 1(Constant)+4=5 →

Regression degrees of freedom = P-1 = 5-1=4

Also, since we have forty-five case studies → n=45 →

Error degrees of freedom = n-p = 45-5=40.

From the standard Statistical Tables $F_{critical} = F_{0.05,4,40} = 2.65$.

$F_{observed}$ of this model=76.084, which is significantly larger than $F_{critical}$.

P-Value

Table 4.6 shows a *P-value* of 0.00, which is <0.0005. This is another indication of the overall significance of the model.

T-Statistics

$$t_{critical} = t_{\alpha/2, n-p} = t_{0.025, 40} = 2.021$$

Table 4.6 shows that all the predictors in the model have $t_{observed} > t_{critical}$.

Partial F

Table 4.6 shows that all the variables have (*P Value* for partial F) < α=0.05 which is the preset value in *Systat*.

Tolerance

Appendix 7 shows that all of the predictors in the model have a tolerance >0.1, which indicates that muticollinearity does not exist among the predictor variables

4.2.3 Model Validation

The data, which was provided in the nine validation sets, were applied to the model. The model produced nine predicted values for the overall performance (PPF) for the nine projects. A correlation analysis was, then, performed between the predicted PPF and the actual PPF for the nine projects. The resulted correlation coefficient was r= 0.9274. Also, the mean absolute error between the predicted PPF and the actual PPF is 0.64. These results reveal that the developed Model B1 has excellent predictive capabilities. The results are tabulated in Table 4.7.

4.3 OTHER MODELING EXPERIMENTS

Several experiments were investigated in order to explore the possibility of utilizing the available data to develop other models. These models were predictive models for cost, schedule or quality performance individually. However, no useful models were materialized utilizing the listed eighteen factors. The *Systat* outputs for these models are included in Appendices 9, 10 and 11.

Table 4.7 Summarized Project Data, Model Validation (Model B1)

Project	C	LP		LS		LCOM		X81		Predicted PPF	Actual PPF	Error
P46	*67.06*	*3.573*	4	*3.831*	3	*-2.099*	4	*5.282*	1	89.733	87.89	1.843
P47	*67.06*	*3.573*	2	*3.831*	2	*-2.099*	2.5	*5.282*	0	76.6225	73.6	3.0225
P48	*67.06*	*3.573*	3	*3.831*	3	*-2.099*	3.5	*5.282*	1	87.2095	89.77	-2.5605
P49	*67.06*	*3.573*	3	*3.831*	3.5	*-2.099*	3	*5.282*	1	90.1745	88.83	1.3445
P50	*67.06*	*3.573*	2.5	*3.831*	2	*-2.099*	2.5	*5.282*	0	78.409	80.7	-2.291
P51	*67.06*	*3.573*	3.5	*3.831*	3	*-2.099*	3	*5.282*	1	90.0455	89.14	0.9055
P52	*67.06*	*3.573*	4	*3.831*	3	*-2.099*	3	*5.282*	1	91.832	88.11	3.722
P53	*67.06*	*3.573*	3	*3.831*	3.5	*-2.099*	3.5	*5.282*	1	89.125	87.56	1.565
P54	*67.06*	*3.573*	2	*3.831*	2	*-2.099*	2	*5.282*	0	77.672	79.5	-1.828
										Max	3.722	
										Min	-2.5605	
										Mean	0.6359	
										r	0.9274	

As part of the preliminary analysis in chapter three, all of the thirty-six hypothesized predictors were regressed individually with PPF. Only, the seventeen factors, which demonstrated strong relationship with PPF, were selected for further analysis. Therefore, it was not possible to regress these seventeen factors with a totally different set of dependent variables and obtain useful relationships.

Fig. 4.4 shows summary of the modeling experiments utilizing regression analysis techniques.

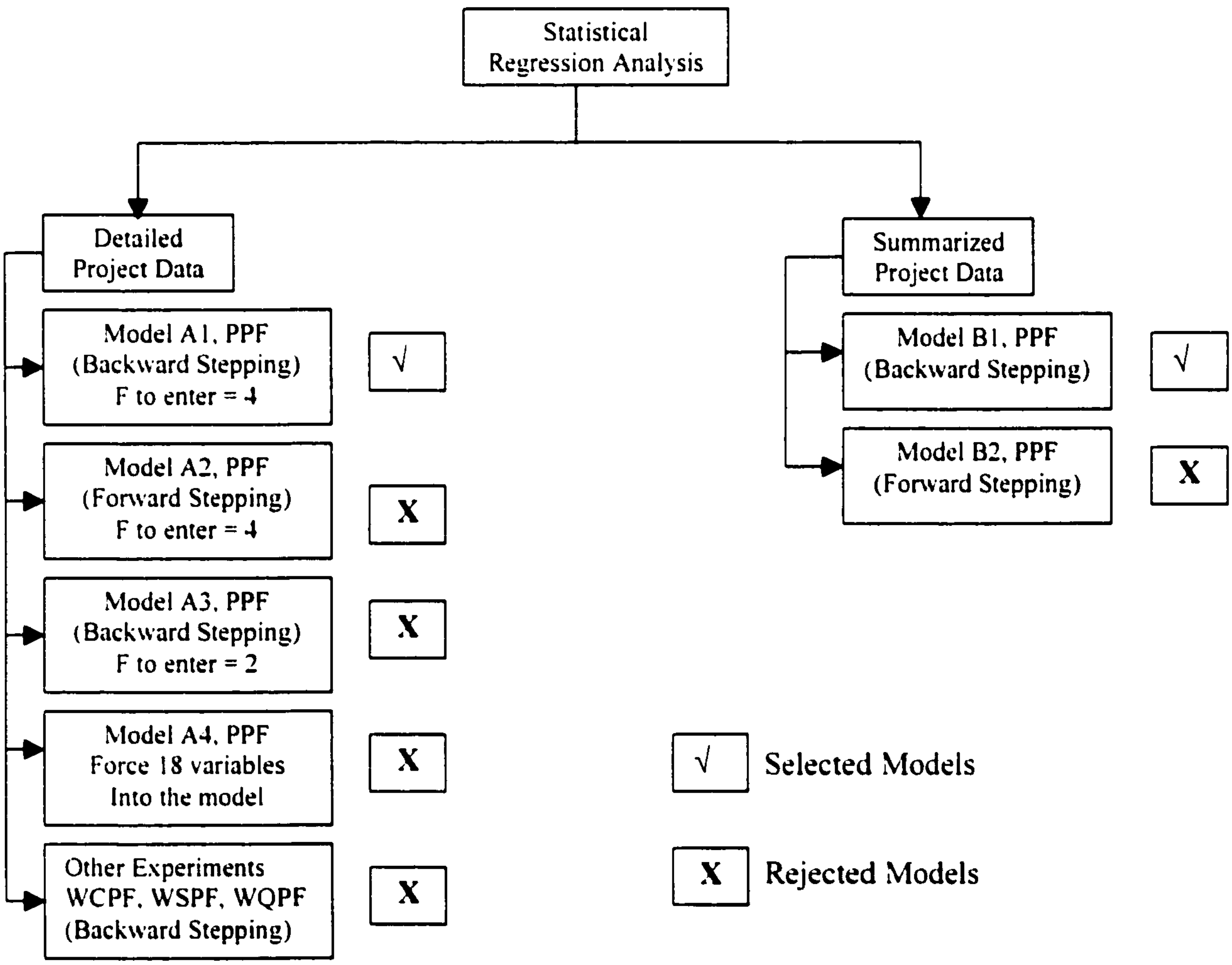

Fig. 4.4 Summary of the experiments utilizing regression analysis.

CHAPTER 5 DEVELOPING AND VALIDATING A PREDICTION NEURAL NETWORK MODEL

In Chapter four, two predictive models for the overall performance of reconstruction projects were developed utilizing statistical regression analysis techniques. In this chapter, two comparable models are developed using the Artificial Neural Network methodology. A structured methodology for Neural Networks development [Hegazy et al, 1994c] has been used to develop the required predictive models. The methodology consists of three main phases: 1) Conceptual analysis, 2) Neural Network design ; and 3) Neural Network modeling and implementation as shown in Fig. 5.1.

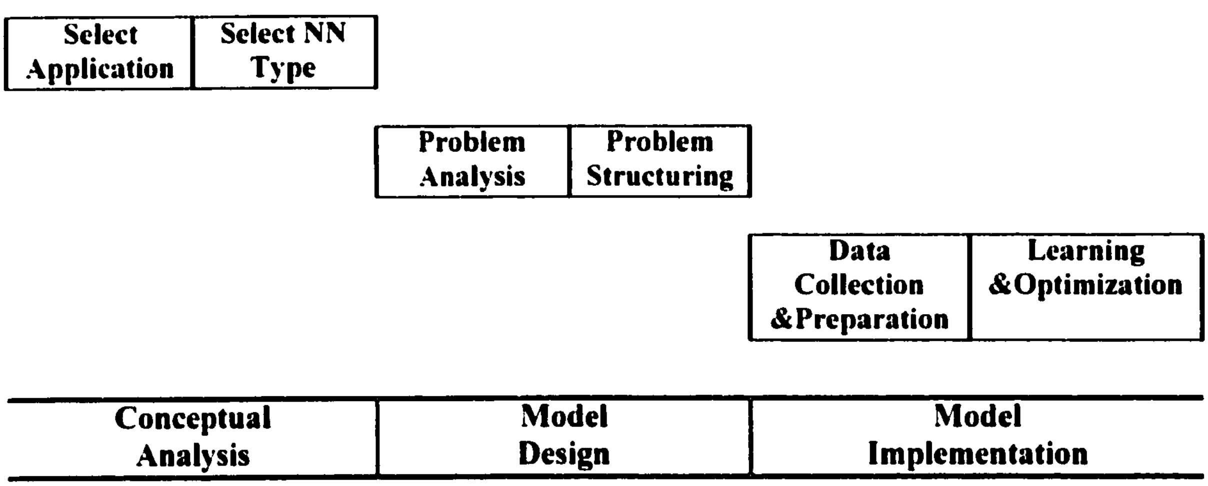

Fig. 5.1 Neural Network Development Methodology

5.1 NEURAL NETWORK DEVELOPMENT METHODOLOGY

At the conceptual analysis stage, a Neural Network paradigm has to be selected as a suitable environment for developing the required model. The selection can be accomplished based on a comparison of the model requirements against Neural Network paradigm capabilities. Based on the literature review of chapter two, the Neural Network type deemed suitable for the required model is the feed-forward-multi-layer type (Back propagation). This type of Neural Network suits the desired predictive performance of the model.

The model design phase includes two main tasks: 1) Problem analysis; and 2) problem structuring. Problem analysis is the identification of the independent factors that fully describe the problem. Problem structuring entails the arrangement and representation of the independent factors and the response variables.

Two predictive Neural Networks were designed as follows:

- **Neural Network 1:** includes eighteen independent variables as shown in Table 4.1 and one response variable which is (PPF). The objective of this net is to develop a predictive model for the overall performance of reconstruction projects based on Detailed Project Data.
- **Neural Network 2**: includes eight independent variables as shown in Table 3.7 and one response variable, which is (PPF). The objective of this net is to develop a

predictive model for the overall performance of reconstruction projects based on Summarized Project Data.

The purpose of Neural Network training is to determine the Neural Network weight values that optimize network performance. The weight values in Neural Network models can be considered similar to the variable coefficients in mathematical models. Therefore, in order to produce the best fitted model, one should develop the best set of weights.

In order to develop the model at hand, *Neuro Shell 2* has been used for its ease of use, speed of training, and for its host of Neural Network architectures including back propagation with flexible user-optimization of training parameters. *Neuro Shell 2* includes a simplified set of procedures for building and executing a complete and powerful Neural Networks application. The user has the ability to specify the learning rate, momentum, activation functions and initial weight range on a layer basis in the design module. It also has multiple criteria for stopping training in addition to different methods for handling missing data, pattern selection and viewing weight and neuron values during training.

In addition to the brain-like structure of Neural Networks, their major advantage is their ability to be trained. Training is required to adjust continuously the connection weights until they reach values that allow the network to predict outputs that are very close to the actual outputs. Therefore, Neural Networks can generalize well on new cases if over training is avoided [Hegazy et al, 1994c].

In the following sections, the process of developing the required predictive models is explained.

5.2 DETAILED PROJECT DATA, NEURAL NETWORK 1

Traditionally, back propagation training is one of the most common methods for training Neural Network on observational data. Back propagation training adopts a gradient-descent approach for adjusting the Neural Network weights. During training, a Neural Network is presented with the data many thousands of times (called cycles or epochs). After each cycle, the error between the Neural Network predicted outputs and the actual outputs are propagated backwards to adjust the weights in a manner that is mathematically guaranteed to converge [Rumelhart et al., 1986].

In *Neuro Shell 2*, two levels of mechanisms are available. These are the beginner's and the advanced. Fig. 5.2 shows the *Neuro Shell 2* initial screen. The advanced option was selected to develop the required model. Fig. 5.3 shows the *Neuro Shell 2* advanced option screen and displays the independent modules that may be used to create a Neural Network application.

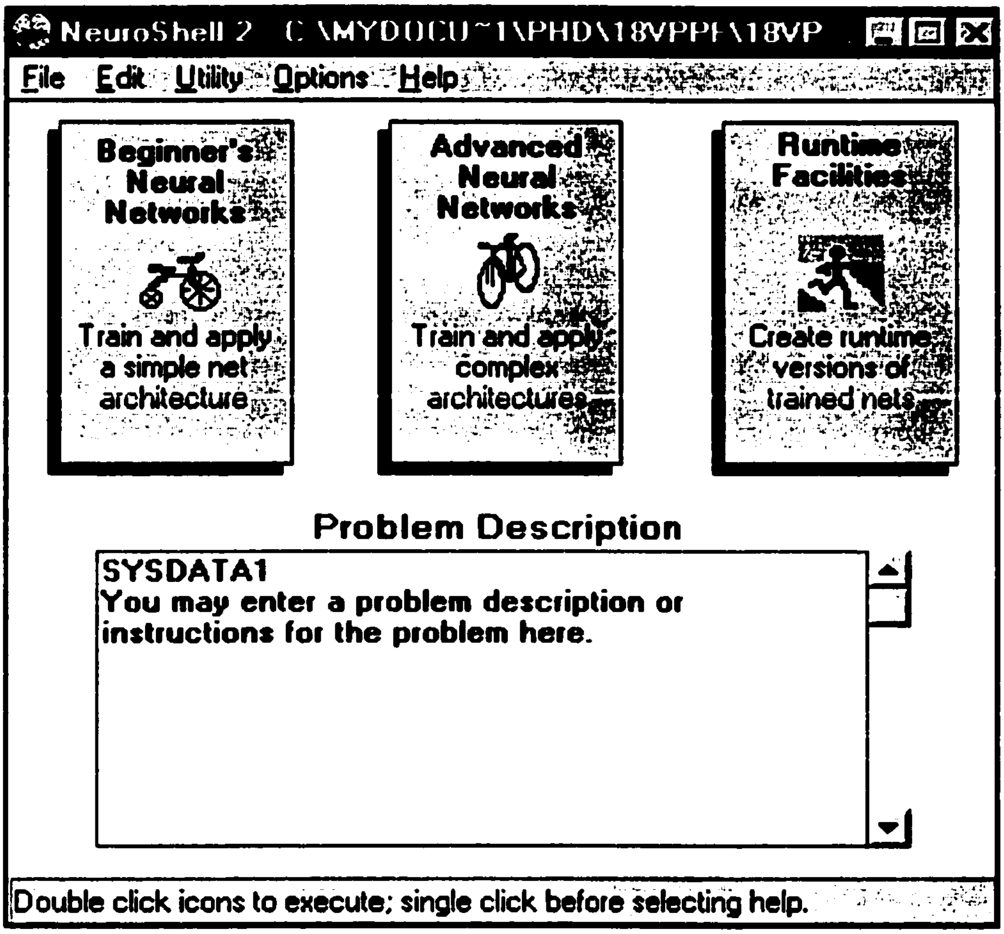

Fig 5.2 Neuro Shell 2 Initial Screen

The data was organized originally in a *Microsoft Excell* Spreadsheet. By selecting the "File Import" option from *Neuro Shell 2*, this spreadsheet was transferred into *Neuro Shell 2*. Then, the "Define Inputs/Outputs" option was used to select the input and output variables. Fig. 5.4 shows the "define Inputs/outputs" screen.

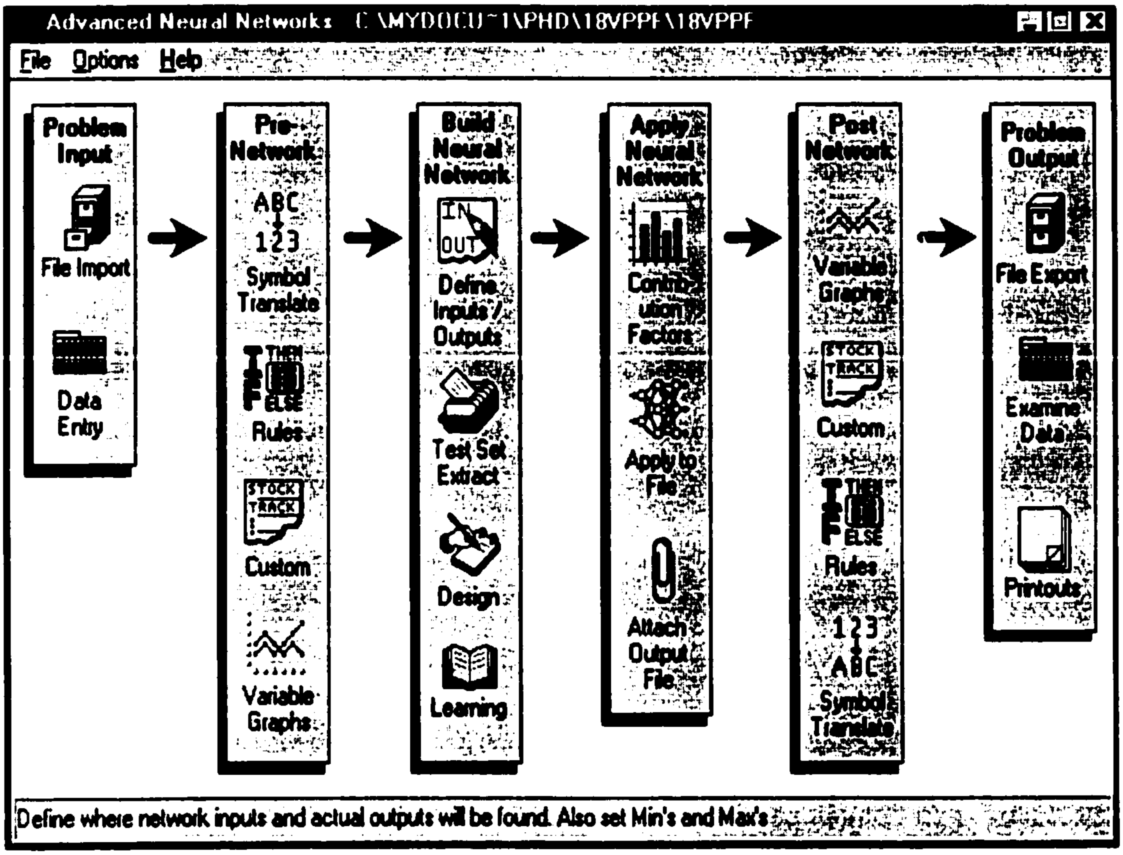

Fig 5.3 Neuro Shell 2 Advanced Option Screen

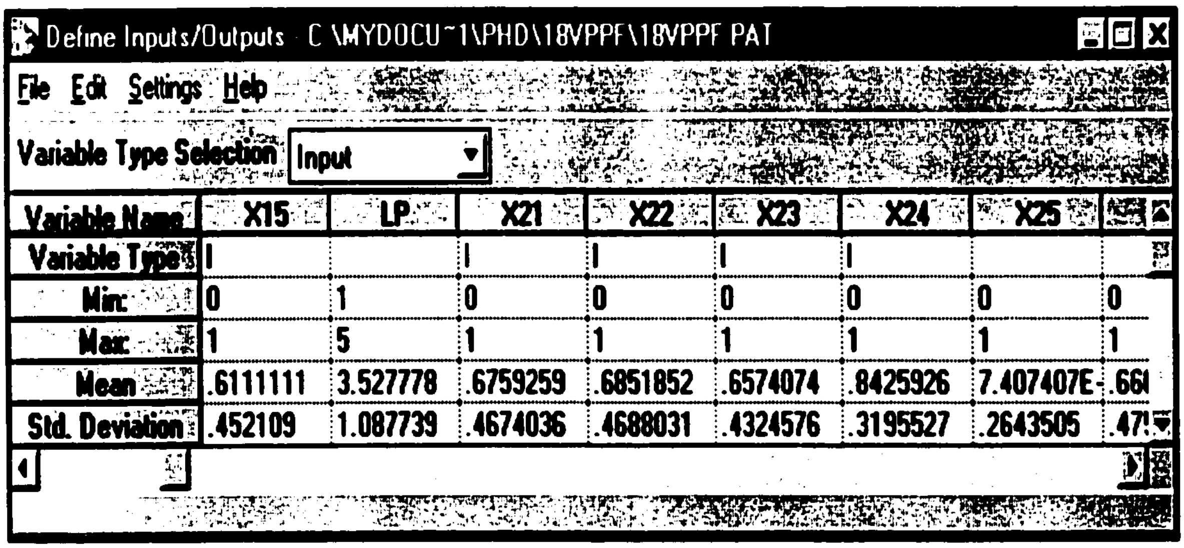

Fig 5.4 The Define Inputs/Outputs Screen

In the "Define Inputs/Outputs" screen, as shown in Fig. 5.4, the user has the ability to label every variable as Input (Independent variable) and denote it I, Actual output (Dependent variable) and denote it A and unused which means the cell is left blank. Also, this screen includes some descriptive statistics about the variables such as their standard deviation, maximum and minimum values.

Network training is dependent on the quantity of training data and on how the data is presented to the network. Therefore, several data-representation experiments and network architectures were performed during training in order to arrive at the best trained net. In these experiments, network parameters, such as number of hidden layers, number of hidden nodes, network connections and transfer functions were tested and the best result was documented.

The design option provides the user with the ability to select from different network architecture options which are preset in *Neuro Shell 2*. These different architectures include different types of scaling functions, number of neurons in each layer (slab), learning rate, initial weights and momentum. The selected architecture, which was proven to produce the best predictive net, is shown in Fig 5.5. The selected architecture ia a multi-layer feed forward back propagation. It is called, in *Neuro Shell 2*, Ward nets with three hidden layers.

Also, in *Neuro Shell 2*, the design option provides the users with the ability to set learning criteria. These criteria specify the learning and stop learning roles. Fig. 5.6 shows the

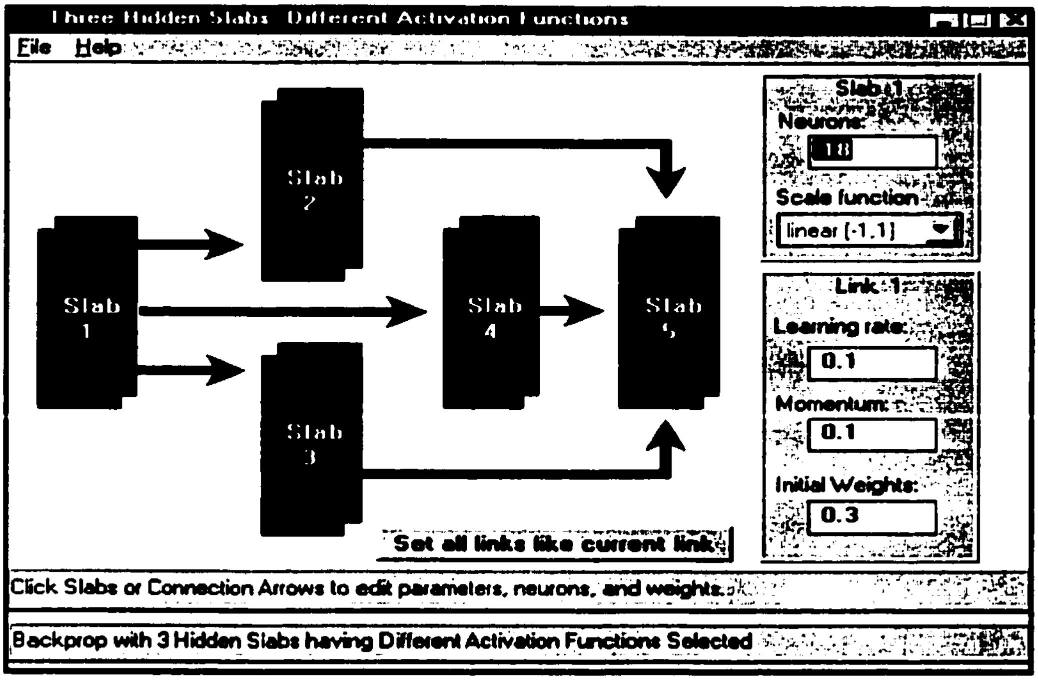

Fig 5.5 Network Architecture

selected stop training criteria. The pattern selection (Case study selection) was chosen to be Rotation, since it is desired to get the net exposed to every pattern an equal number of times. Weight update is set to TurboProp, which has the additional advantage that it is not sensitive to learning rate and momentum. The Calibration Test Interval is set to 200 (the default value) which is the number of training patterns the network processes before *Neuro Shell 2* temporarily stops training and computes the error factor for the test set. The automatic save was set to Best Test Set, which saves the network every time it reaches a new minimum average error for the Test Set.

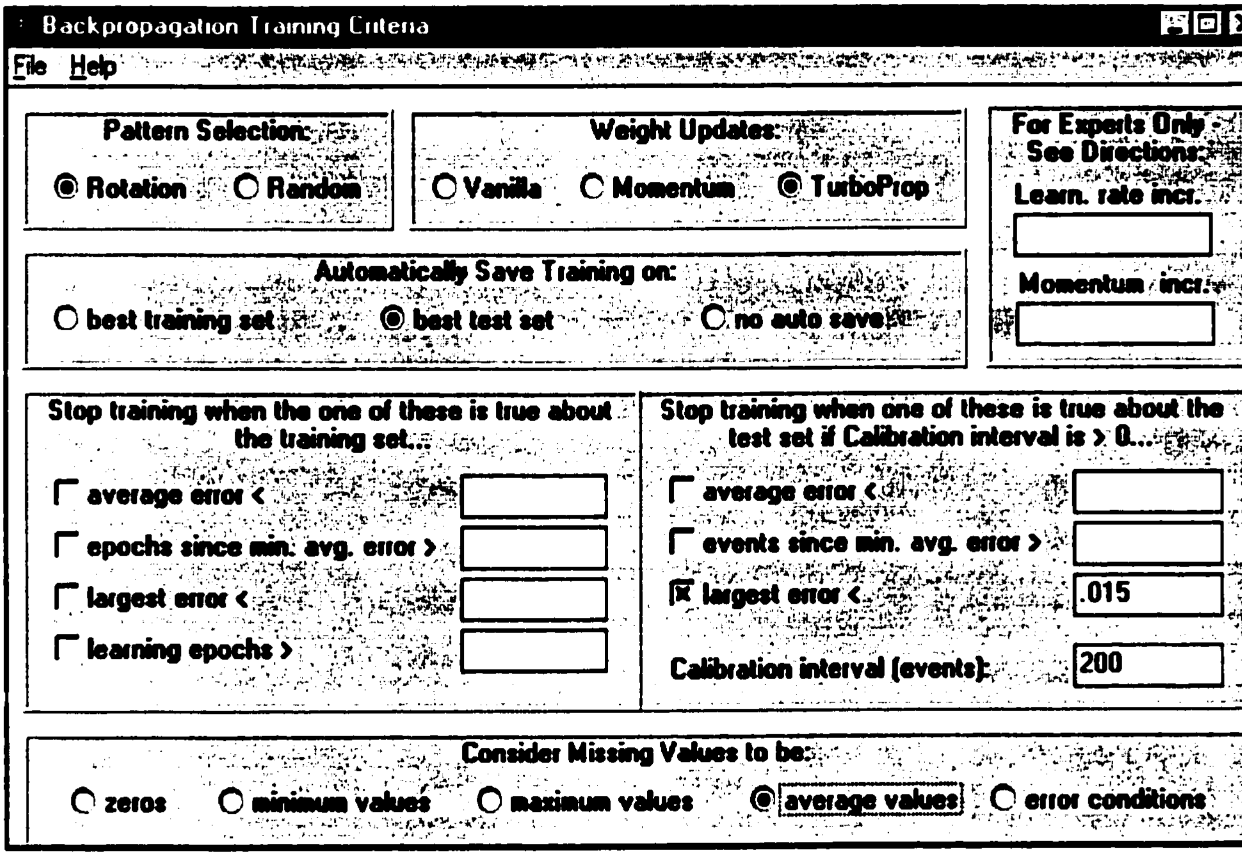

Fig. 5.6 Training Criteria

In order to overcome the over-fitting problem associated with the application of Neural Networks, the data was divided into two sets. The first is the training set, which includes forty five data sets, and the second is the Test Set, which includes the remaining nine data sets. This approach would also allow the development of the model and its validation to occur at the same time. The "Test Set Extract" option with *Neuro Shell 2* was used to extract the test set. Fig. 5.7 shows the "Test Set Extract" screen. The "Test Set Extract" screen shows that, fifty-four patterns (case studies or data sets) were included in total and forty five cases were extracted for model building, while the remaining nine cases were extracted for test purposes.

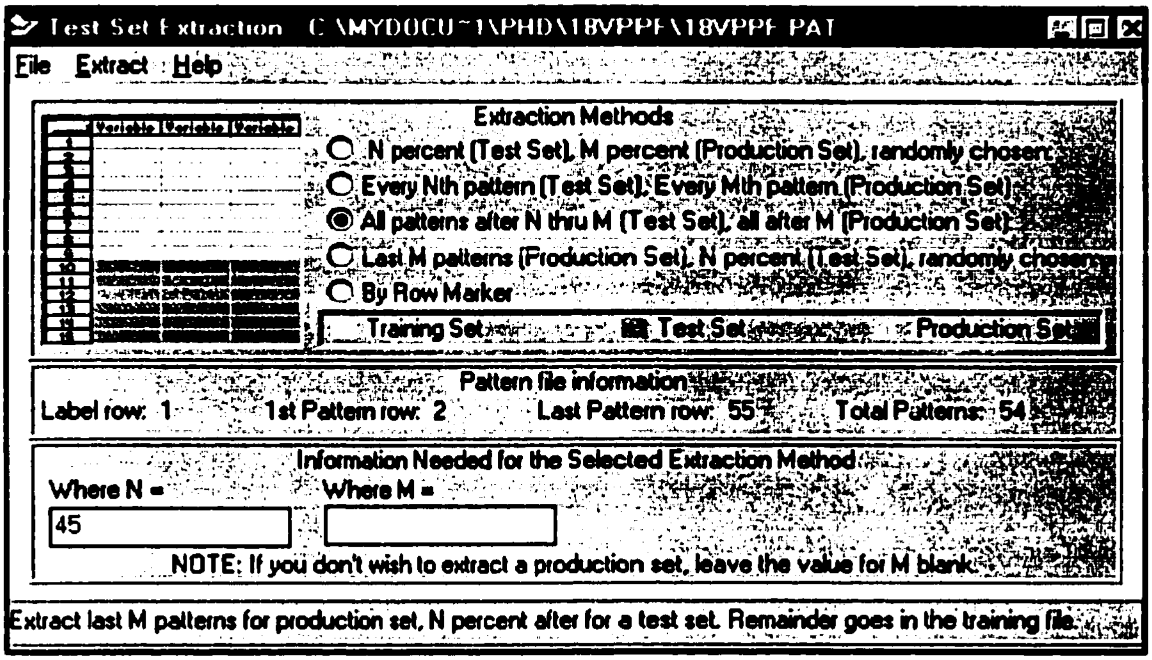

Fig. 5.7 The Test Set Extract Screen

After selecting the network architecture, extracting both the training and test sets and choosing the learning criteria, the learning module can then be used in order to train the net. Fig 5.8 illustrates the learning screen at the end of the learning period.

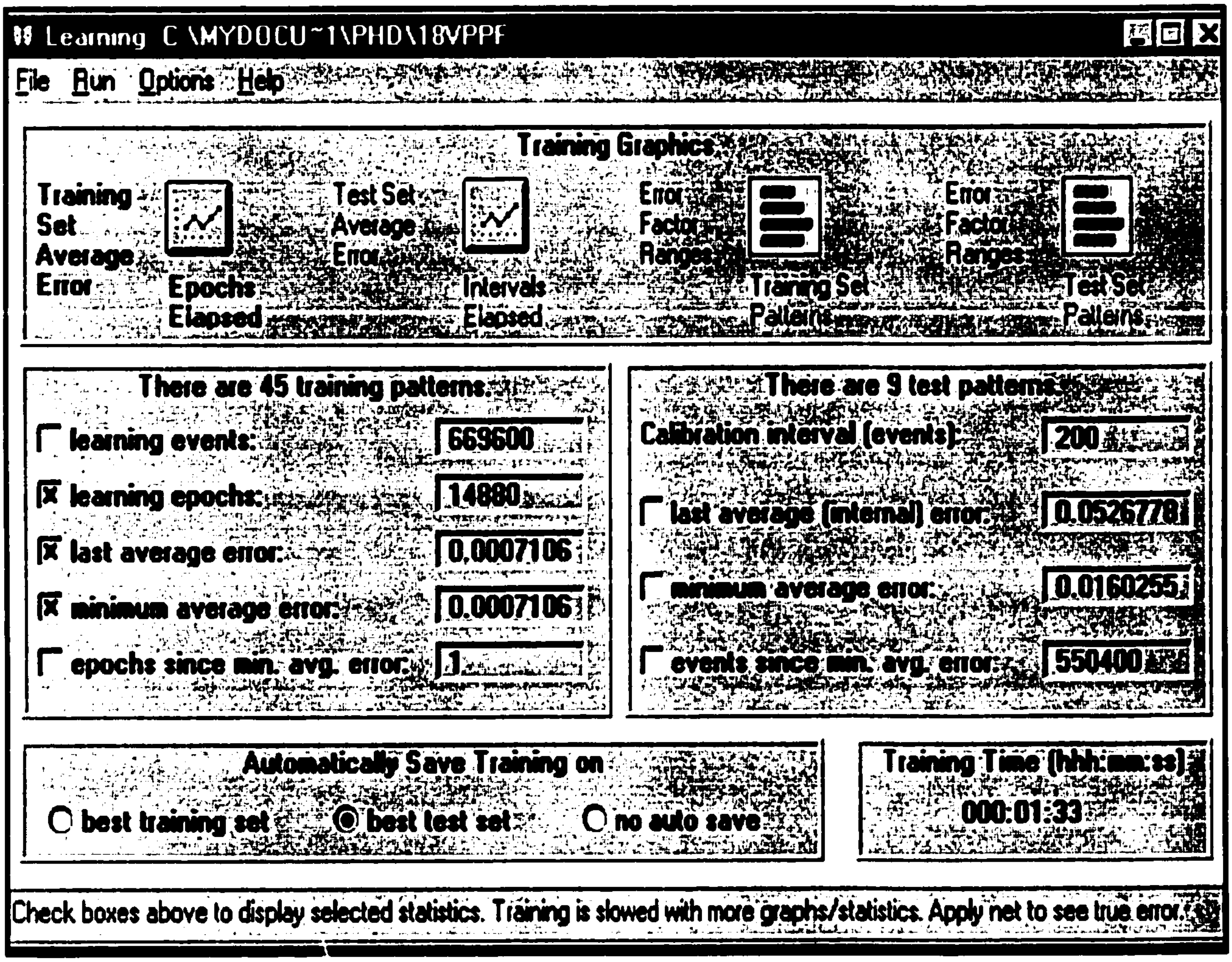

Fig. 5.8 Neural Network 1, Learning Screen

The learning screen in Fig. 5.8 shows some useful information regarding the produced net such as the minimum average error in both the test set and the training set. During training, the network computes the mean squared error between the actual and predicted values for PPF overall patterns. The way it works is that the network first computes the squared error for each output in a pattern, totals them and then computes the mean of the total for each pattern. The network then computes the mean of that number overall patterns in the training set. Also, *Neuro Shell 2*, produces these errors in a graphical format as shown in Fig. 5.9.

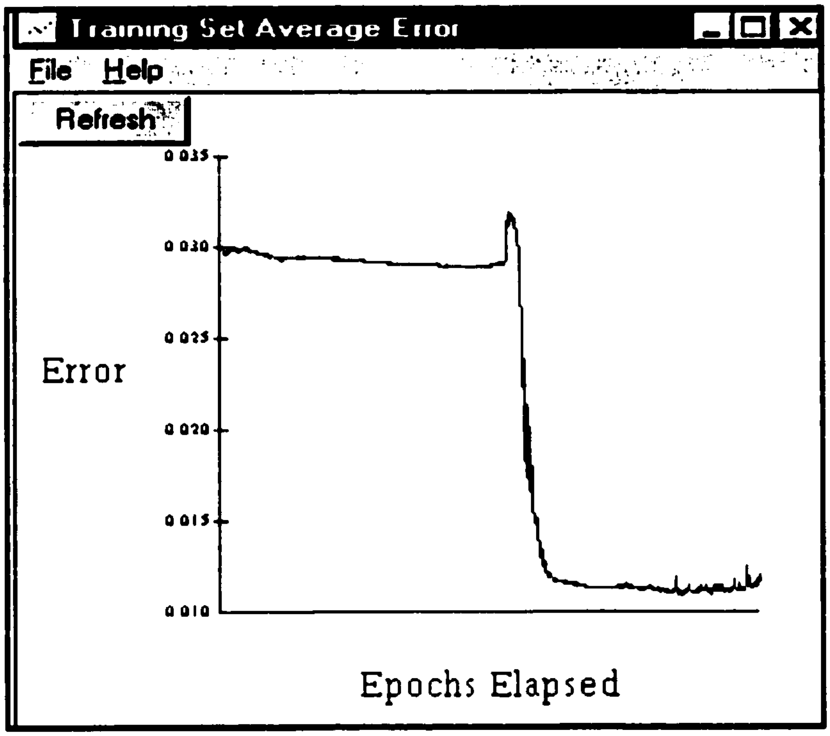

Fig. 5.9 Training Set Average Error

Fig.5.9 shows the training set average error plotted against epochs elapsed. It was clear that the error decreased and then became stable. In other words, the predictive performance of the net had improved until it reached a point where further improvement was not achievable. The user of *Neuro Shell 2* has the ability to view this graph while training is in progress, which gives the user another advantage to stop training when further training is not warranted and also to avoid over training.

Once the network was trained and a satisfactory error levels are achieved, the "Apply to file" option was used to process a data file through the trained Neural Network. A file of outputs that included the actual PPF values, the predicted PPF values and the absolute error between both the actual and the predicted PPF, was produced in a spreadsheet format. This spreadsheet is included in Appendix 12.

Neuro Shell 2 also produces model diagnostics as part of its output modules. Fig. 5.10 shows the output module.

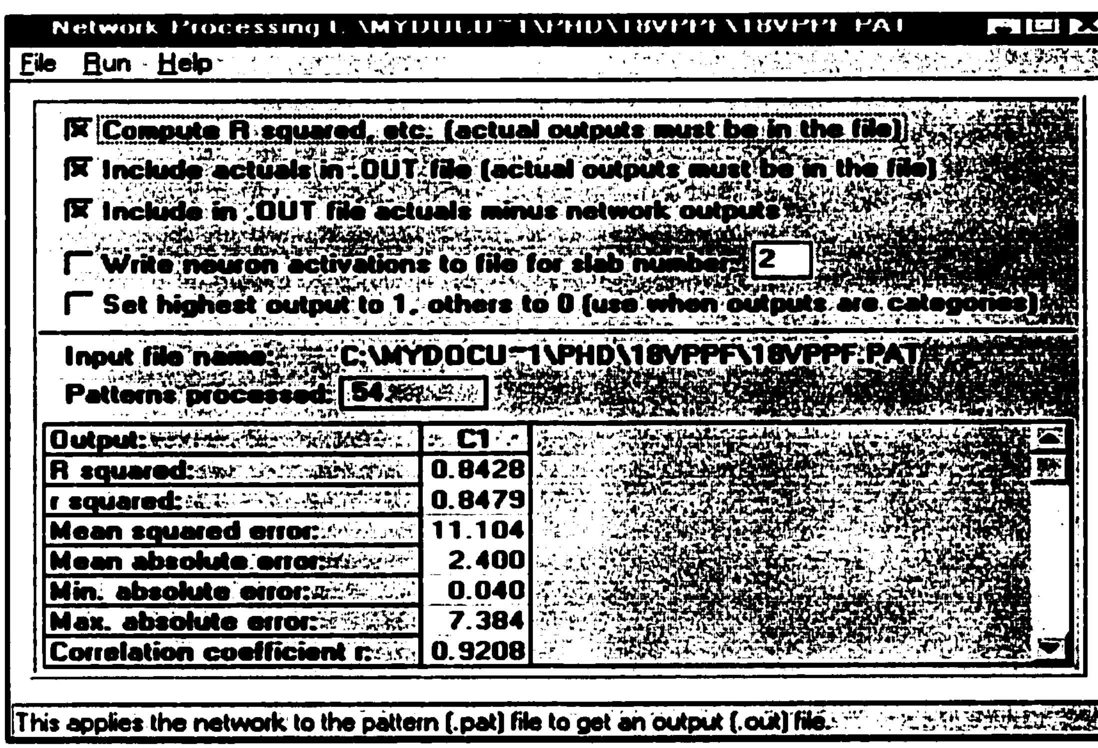

Fig. 5.10 The Output Module

Table 5.1 summarizes the model characteristics for the Detailed Project Data model (Network 1) as presented in the output module. From Table 5.1, it can be noted that the developed model has an R^2 value of 0.8428. Also, *Neuro Shell 2* calculates the correlation coefficient r between the predicted and the actual PPF. The correlation coefficient r is 0.9208. These results reveal that the developed net with its eighteen variables possesses a high predictive performance.

Table 5.1 Neural Network 1 Validation

Characteristics	Values
R^2	0.8428
r^2	0.8479
Mean squared error	11.104
Mean absolute error	2.400
Min. absolute error	0.040
Max. absolute error	7.384
Correlation coefficient r:	0.9208
Percent within 5%:	77.778
Percent within 5% to 10%:	18.519
Percent within 10% to 20%:	3.704
Percent within 20% to 30%: 0	0
Percent over 30%: 0	0

Furthermore, the post processing output in *Neuro Shell 2*, as shown in Fig. 5.11 indicates that the contribution of all factors in the model are equally significant.

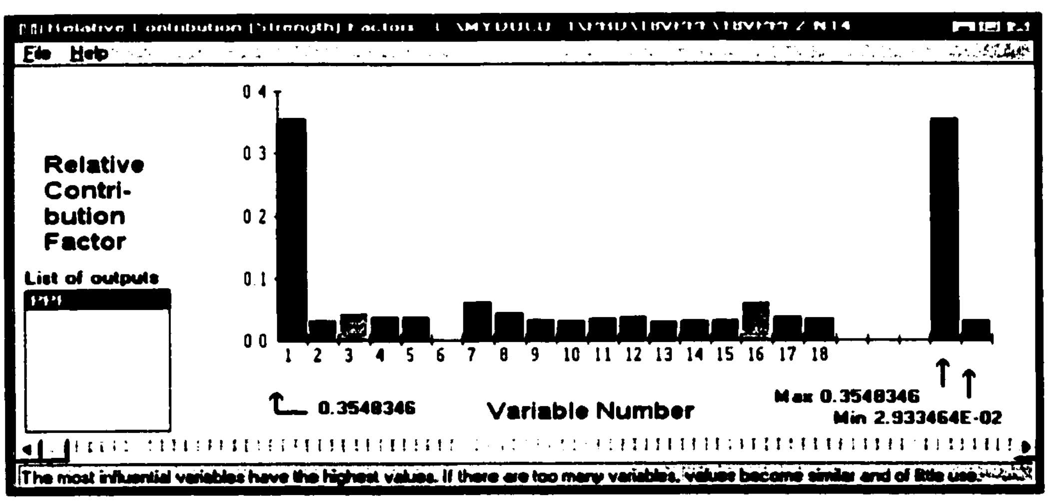

Fig. 5.11 Factors Contribution

5.3 SUMMARIZED PROJECT DATA, NEURAL NETWORK 2

The development process of this model followed exactly the same development process for the Detailed Project Data model. Fig. 5.11 illustrates the learning screen at the end of the learning period for Neural Network 2. Table 5.2 also illustrates the model characteristics. It shows that the developed model has $R^2 = 0.6777$. Also, the correlation coefficient for the relation between the predicted PPF and the actual PPF = 0.8836. The predicted values are presented in Appendix 13. These results, also, reveal that the developed net possesses a high predictive performance

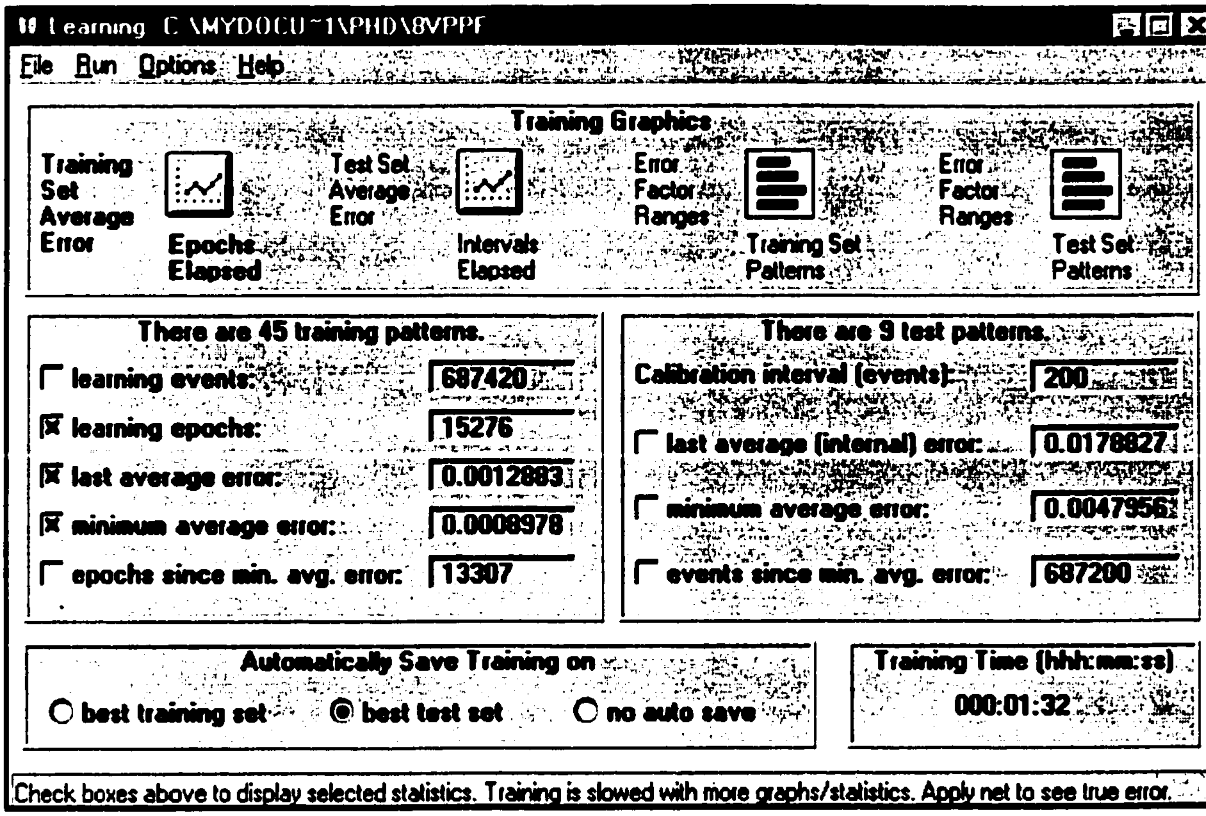

Fig. 5.12 Neural Network 2, Learning Screen

Table 5.2 Neural Network 2 Validation

Characteristics	Values
R^2	0.6777
r^2	0.7808
Mean squared error	22.769
Mean absolute error	3.945
Min. absolute error	0.019
Max. absolute error	9.368
Correlation coefficient r:	0.8836
Percent within 5%:	55.556
Percent within 5% to 10%:	40.741
Percent within 10% to 20%:	3.704
Percent within 20% to 30%: 0	0
Percent over 30%: 0	0

5.4 OTHER MODELING EXPERIMENTS

This research also investigated the possibility of developing other models to use the independent variables at hand to predict the cost performance, schedule performance and quality performance individually. In these experiments the WCPF, WSPF and WQPF were utilized as response variables.

Fig. 5.12, 5.13 and 5.14 shows the learning screen for cost, schedule and quality respectively, while the spreadsheet outputs are included in Appendices 14, 15 and 16. The models validation tables are shown in Tables 5.3, 5.4 and 5.5. The tables show that these models are not useful for predicting the required values. Similar to the explanation which was provided in chapter four, since all the predictor variables were obtained through correlation with a different response variable (PPF), it was not possible for the net to find useful relationship between the eighteen predictor variables and other response variables.

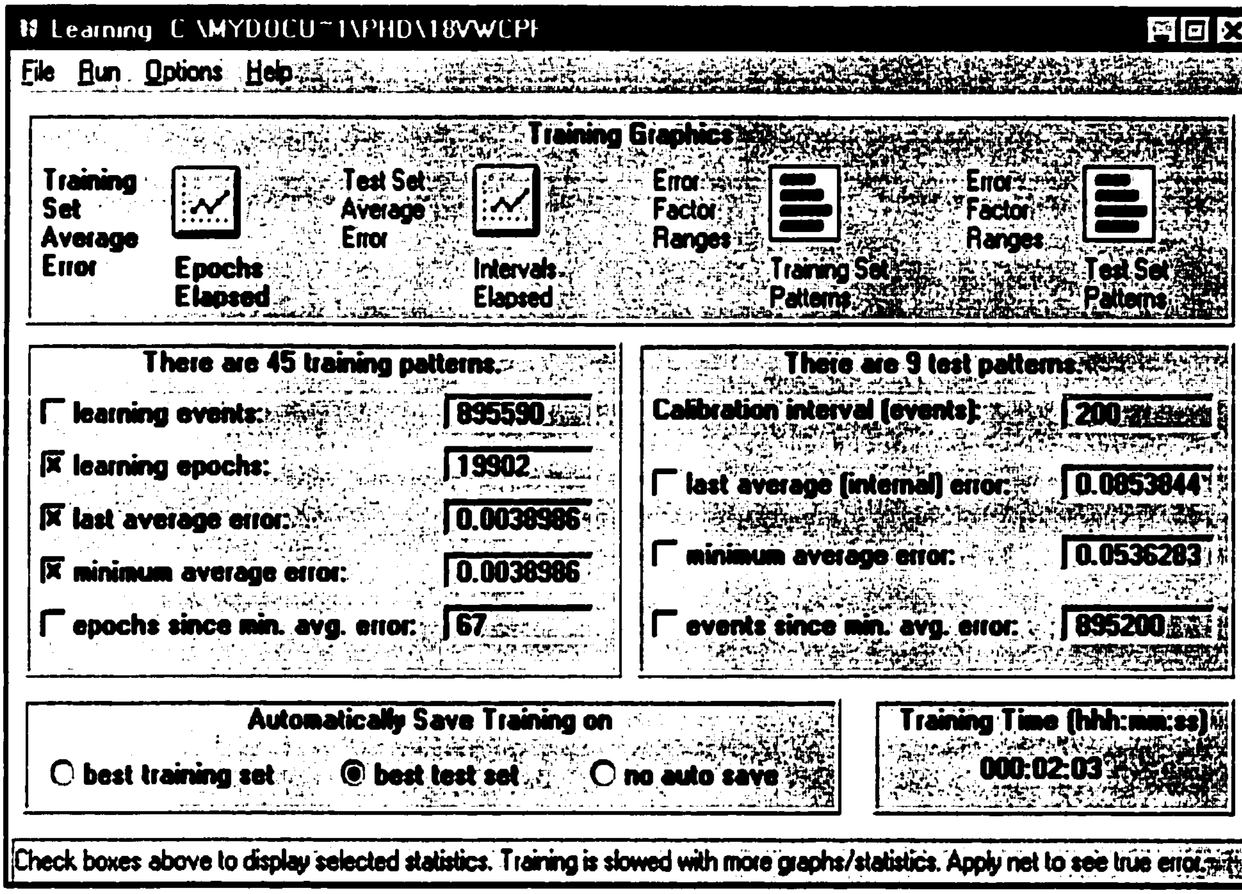

Fig. 5.13 Cost Performance Prediction Network, Learning Screen

Table 5.3 : Cost Performance Prediction Network, Validation

Characteristics	Values
R^2	0
r^2	0.0125
Mean squared error	47.302
Mean absolute error	4.941
Min. absolute error	0.089
Max. absolute error	25.758
Correlation coefficient r:	0.1117
Percent within 5%:	20.370
Percent within 5% to 10%:	22.222
Percent within 10% to 20%:	27.778
Percent within 20% to 30%: 0	11.111
Percent over 30%: 0	18.519

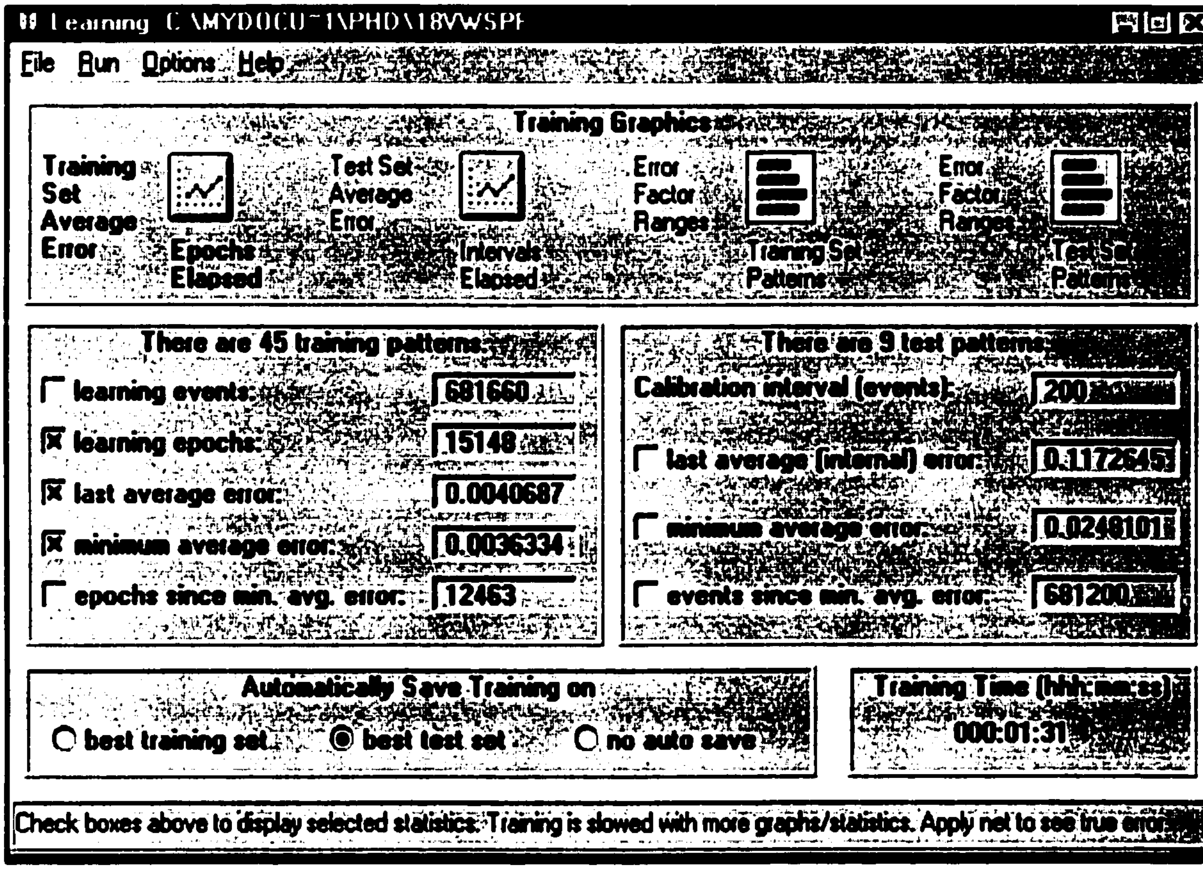

Fig. 5.14 Schedule Performance Prediction Network, Learning Screen

Table 5.4 : Schedule Performance Prediction Network, Validation

Characteristics	Values
R^2	0.4242
r^2	0.5115
Mean squared error	45.362
Mean absolute error	5.034
Min. absolute error	0.144
Max. absolute error	18.159
Correlation coefficient r:	0.7152
Percent within 5%:	25.926
Percent within 5% to 10%:	25.926
Percent within 10% to 20%:	14.815
Percent within 20% to 30%: 0	12.963
Percent over 30%: 0	20.370

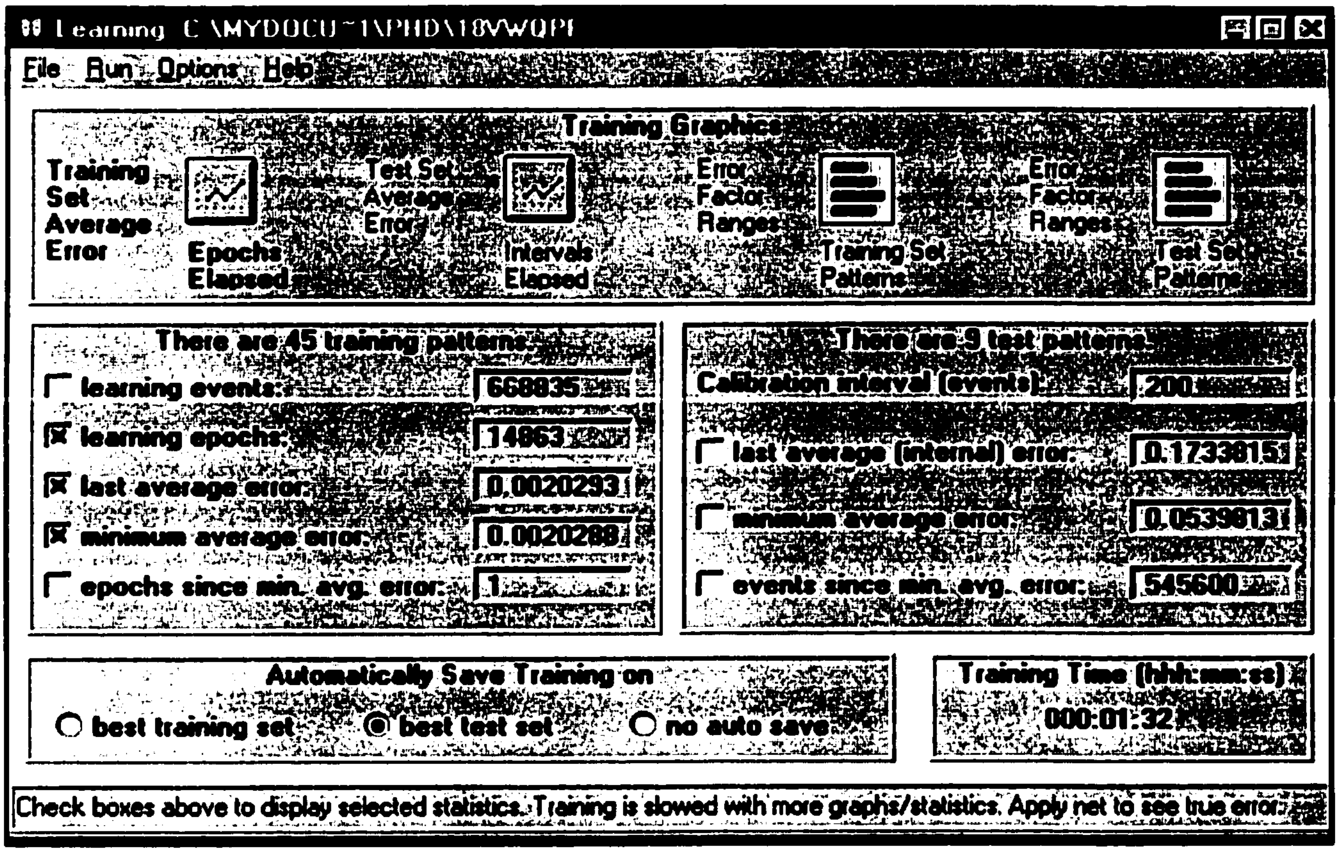

Fig. 5.15 Quality Performance Prediction Network, Learning Screen

Table 5.5 : Quality Performance Prediction Network, Validation

Characteristics	Values
R^2	0
r^2 squared	0.1144
Mean squared error	95.396
Mean absolute error	7.014
Min. absolute error	0.225
Max. absolute error	37.309
Correlation coefficient r:	0.3382
Percent within 5%:	12.963
Percent within 5% to 10%:	16.667
Percent within 10% to 20%:	14.815
Percent within 20% to 30%: 0	27.778
Percent over 30%: 0	27.778

CHAPTER 6 FURTHER EXPERIMENTATION

6.1 SPREADSHEET INTERFACE

To provide the users with simple access and usage of the developed Networks, a spreadsheet interface has been developed in order to facilitate data input and automate performance prediction. The interface was developed on *Microsoft Excel* using its macro tools. One of the useful features of the *Neuro Shell 2* Software is the ability to create Run Time versions of its trained nets. The initial screen of the *Neuro Shell 2* is shown in Fig. 5.2. Fig. 5.2 shows this option which produces a DEF file containing the trained net. The DEF file can be called from *Microsoft Excel* to automatically produce the required prediction. Using this feature, two files were created for Network 1 and Network 2. The developed user interface is explained on a case study later in this chapter.

The user interface was developed in a spreadsheet file that is used as a template for activating the model. Upon opening the spreadsheet file, the user interface will appear viewing the "Interface" sheet as shown in Fig. 6.1. At the bottom of the "Interface" sheet, the user is presented with a note regarding the *Neuro Shell* files that should be installed in the root directory. An "Instructions" button is included in the top part of the "Interface" sheet. Upon clicking on the "Instructions" button, the user will be able to view the

"Instructions" sheet. The "Instructions" sheet includes useful step by step information about the use of this user interface.

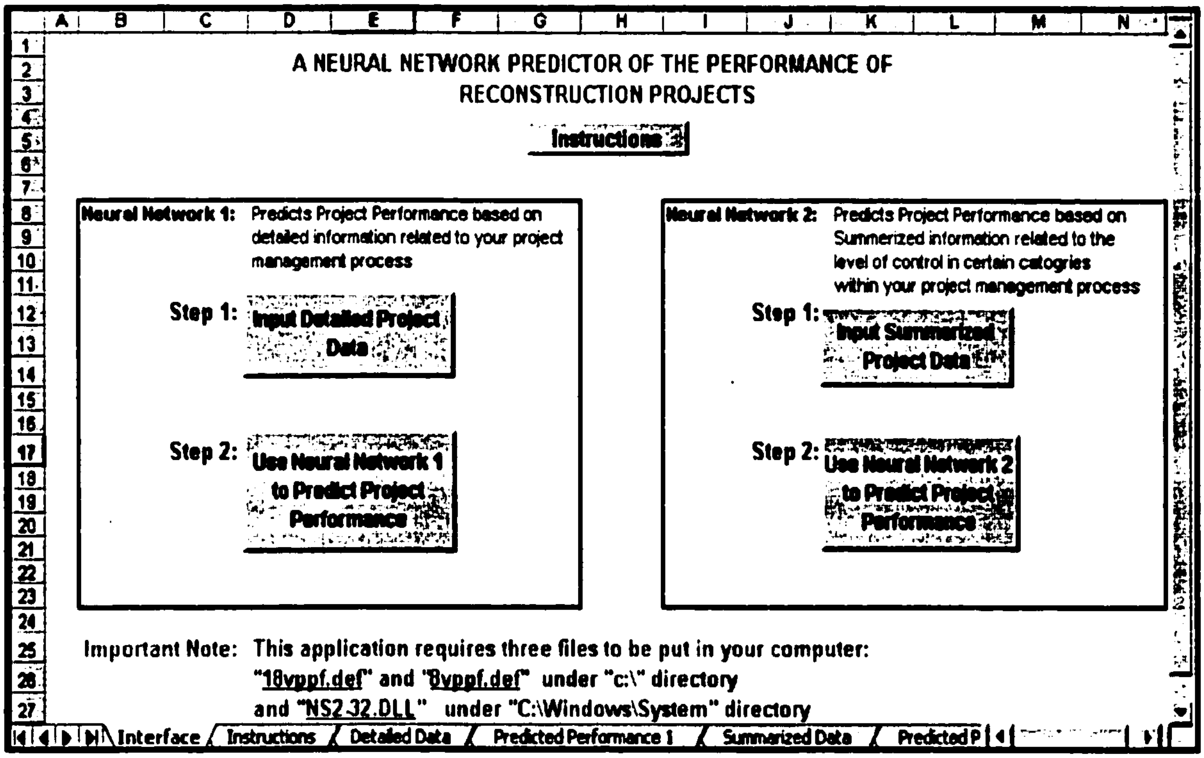

Fig. 6.1 The User-Interface "Interface" Sheet

In the "Interface" sheet, there are two separate areas, one for Neural Network 1 and the other for Neural Network 2. Neural Network 1 is developed to predict the overall project performance based on Detailed Project Data, while, Neural Network 2 is developed to predict overall project performance based on Summarized Project Data.

To use either Network, two steps are to be followed:

1) Step 1: Input the project data.

2) Step 2: Activate the Neural Network to predict the overall project performance based on the provided data.

6.1.1 The Use of Network 1 (Detailed Project Data)

6.1.1.1 Input Detailed Project Data

In order to predict the performance for a potential project, the user first enters the project data. When Detailed Project Data is available, the user utilizes Neural Network 1 and clicks on the "Input Detailed Project Data" button in the "Interface" sheet. A Detailed Data sheet will appear on the screen as shown in Fig. 6.2.

This screen presents the eighteen factors that significantly contribute to the success of reconstruction projects. Project managers can use these factors, proactively, as tools to control the performance of their projects. The utilization of these factors in the management of reconstruction projects can minimize the slippage or the deviation of the actual project performance from the planned performance. The user enters the assessments for each of these factors. Since each factor represents a control tool, the user enters one if the tool is available for the project under consideration, otherwise, the user enters zero.

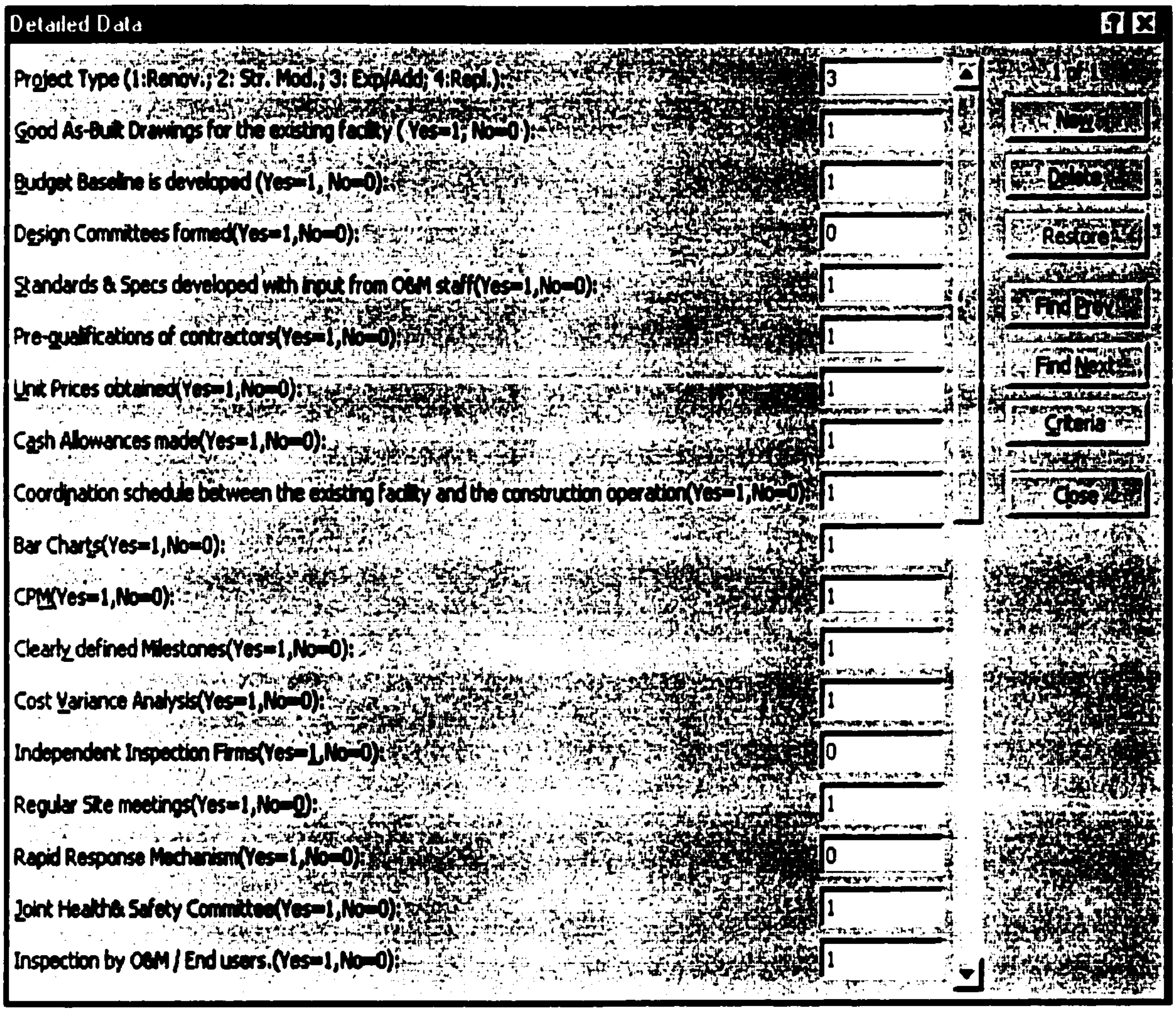

Fig. 6.2 Detailed Data Input Screen

When Data Input is complete, the user clicks on the "Close" button in the Detailed Data sheet. The user will be returned to the 'Interface" sheet.

6.1.1.2 Project performance prediction

To initiate the prediction, the user clicks on the "Use Neutral Network 1 to Predict Project Performance" button in the "Interface" sheet. The "Predicted Performance 1" screen will appear as shown in Fig. 6.3.

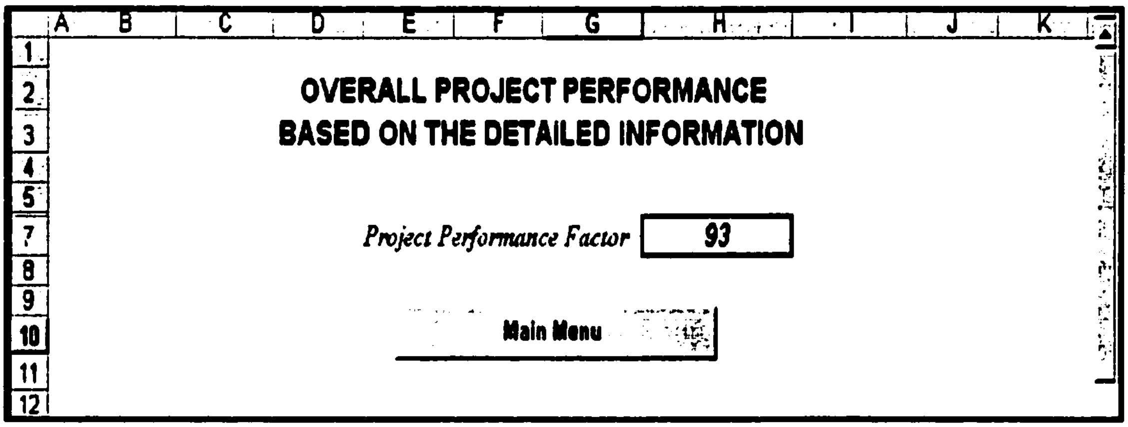

Fig. 6.3 "Predicted Performance 1" Screen, Neural Network 1

Given the data, which is shown in Fig. 6.2, the predicted performance is (93), as shown in Fig. 6.3. When the user changes any of the input data in Fig. 6.2, the value of the predicted PPF in Fig. 6.3 will be changed automatically.

The project manager can experiment with different scenarios of the expected project management factors, which may be utilized in a particular project. This experimentation can take place by manipulating the answers in the Detailed Data Input Sheet and monitoring the changes in the predicted PPF values in the Predicted Performance screen.

In this fashion, this interface can be used as a decision support tool. If at the time of performance prediction, the user is uncertain of a particular data, the user can use the sensitivity analysis tool as explained later in this chapter.

When the user clicks on the "Main Menu" button in the "Predicted Performance 1" screen as shown in Fig. 6.3, the user will be returned to the "Interface" sheet.

6.1.2 The Use of Network 2 (Summarized Project Data)

As explained earlier, this model can be used if the Detailed Project Data is not available. The user interface will be used in the same fashion as in the Detailed Project Data with the exception of some minor variances.

6.1.2.1 Input Summarized Project Data

In order to predict the performance for a potential project, the user first enters the project data. When Detailed Project Data is not available, the user utilizes Neural Network 2 and clicks on the "Input Summarized Project Data" button in the "Interface" sheet. A Summarized Data sheet will appear on the screen as shown in Fig. 6.4.

This screen presents the eight summarized factors that are used to predict the overall performance of reconstruction projects. The user enters the assessments for each of these factors. The assessments are the expected effort to be exerted in a particular control category on a scale from one to five. One is the lowest and five is the highest. As explained earlier in chapter three, the factor " Standard and specifications are developed with input from Operation. Maintenance and end users", is used to assess the overall level of tendering. Therefore, the user will enter one or zero based on whether or not the factor is available. Similarly, the factor "Inspection by Operation, Maintenance and end users" will be used to assess the level of completion.

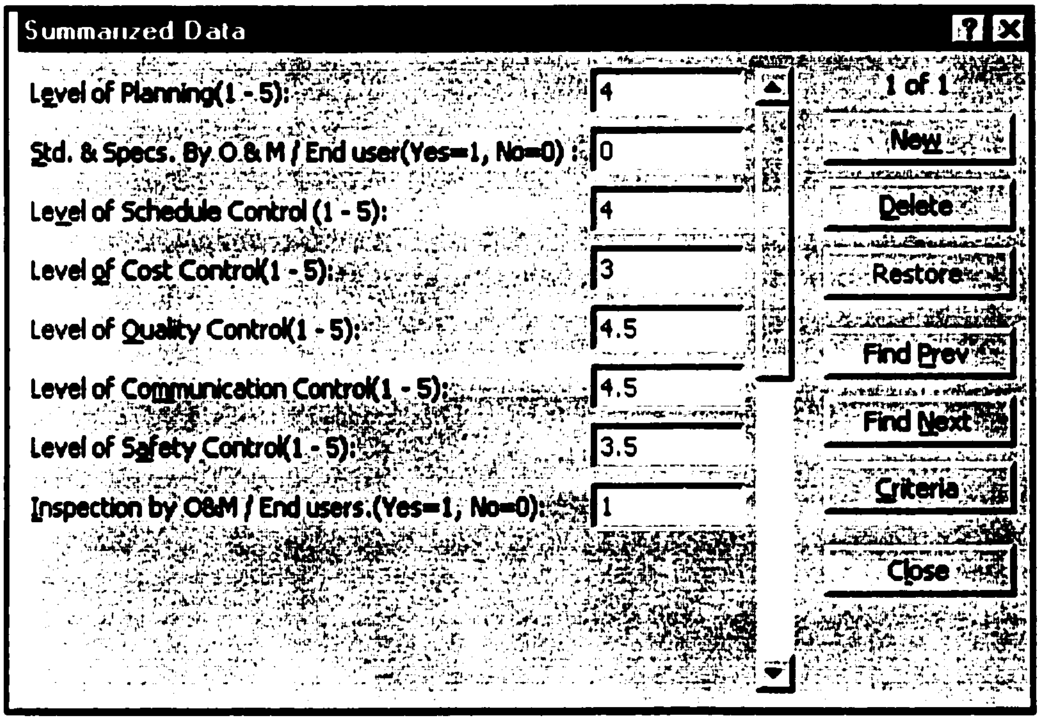

Fig. 6.4 Summarized Data Input Screen

When Data Input is complete, the user clicks on the "Close" button in the Summarized Data sheet. The user will be returned to the 'Interface" sheet.

6.1.1.2 Project performance prediction

To initiate the prediction, the user clicks on the "Use Neutral Network 2 to Predict Project Performance" button in the "Interface" sheet. The "Predicted Performance 2" screen will appear as shown in Fig. 6.5.

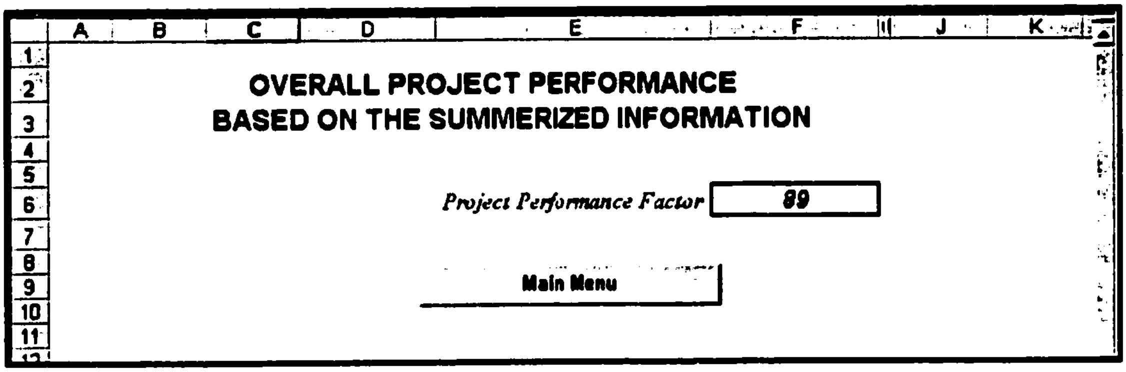

Fig. 6.5 "Predicted Performance 2" Screen, Neural Network 2

Given the data, which is shown in Fig. 6.4, the predicted performance is (89), as shown in Fig. 6.5. When the user changes any of the input data in Fig. 6.4, the value of the predicted PPF in Fig. 6.5 will be changed automatically.

When the user clicks on the "Main Menu" button in the "Predicted Performance 2" screen as shown in Fig. 6.5, the user will be returned to the "Interface" sheet.

6.2 SENSITIVITY ANALYSIS MODULE

At the early stages of any reconstruction project, the project characteristics may not be certain. In other words, some uncertainty may exist in the data provided for prediction purposes. Therefore, a tool is provided in order to assess the sensitivity of the model's predictions to variations in the project characteristics. A sensitivity analysis module has been incorporated into the user interface. This module was also coded *in Microsoft Excel* and was linked to the Neural Network spreadsheet. A group of 20 project scenarios were generated with little random variation to the initial project data. The sensitivity analysis was conducted in a manner similar to the traditional Monte Carlo simulation.

An example of the Sensitivity Analysis screen for the Detailed Project Data is shown in Fig. 6.6. This example was developed for the case study, which was discussed earlier in Fig. 6.2. In this case study the predicted overall project performance by Network 1 was (93). Fig. 6.6 shows a plot of the original predicted value of PPF (93) against the predicted value for the 20 project scenarios developed by the sensitivity analysis module. Fig. 6.6 shows maximum and minimum values of (95) and (81) respectively, for the predicted PPF under the influence of uncertainty. The Average value for the 20 project scenarios is (92) which indicates that the predicted values under the influence of uncertainty still revolve around the originally predicted PPF by Network 1.

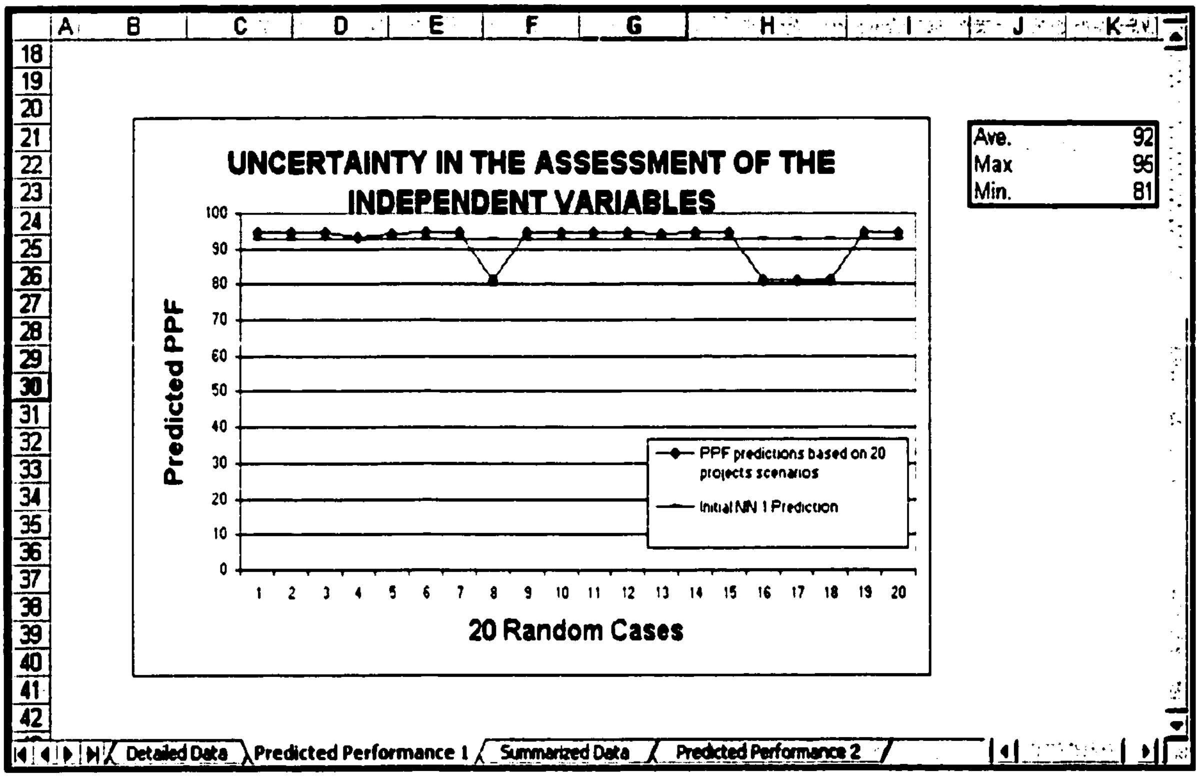

Fig. 6.6 Detailed Project Data, Sensitivity Analysis Screen

Also, an example of the Sensitivity Analysis screen for the Summarized Project Data is shown in Fig. 6.7. This example was developed for the case study, which was discussed earlier in Fig. 6.4. In this case study the predicted overall project performance by Network 2 was (89). Fig. 6.7 shows a plot of the original predicted value of PPF (89) against the predicted value for the 20 project scenarios developed by the sensitivity analysis module. Fig. 6.7 shows maximum and minimum values of (91) and (81) respectively, for the predicted PPF under the influence of uncertainty. The Average value for the 20 project scenarios is (88) which indicates that the predicted values under the influence of uncertainty is close to the originally predicted PPF by Network 2.

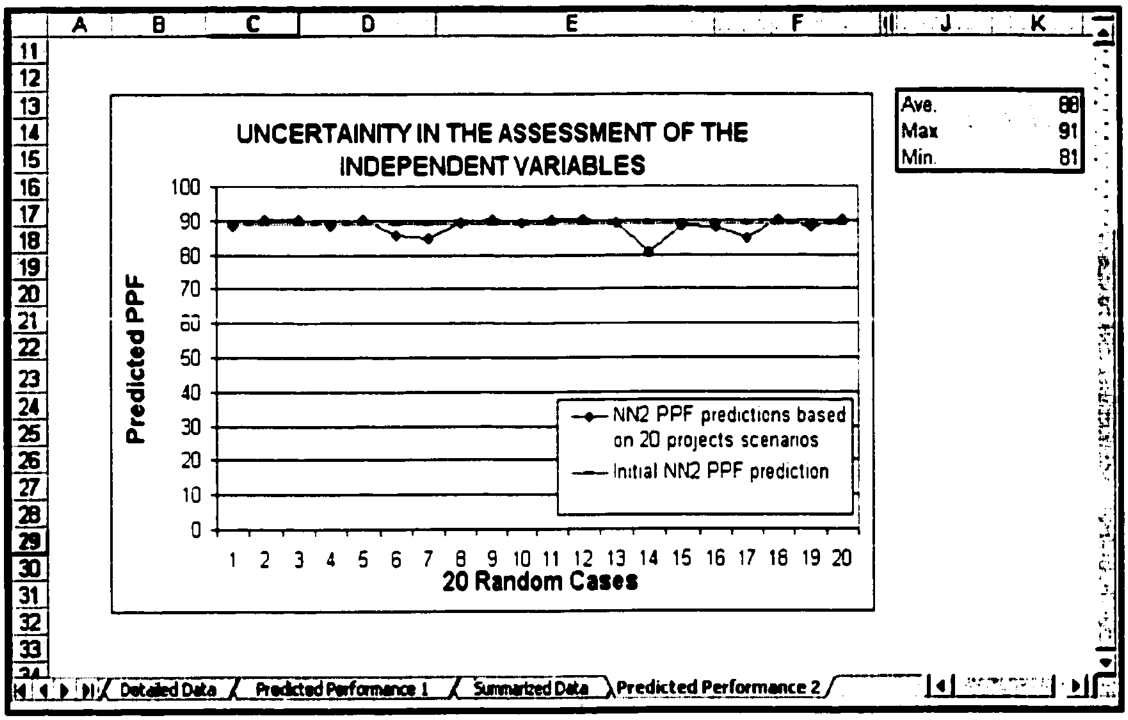

Fig. 6.7 Summarized Project Data, Sensitivity Analysis Screen

6.3 COMPARISON BETWEEN NEURAL NETWORK & REGRESSION MODELS

Table 6.1 illustrates a comparison between the different models which were developed in this work. The comparison was based on three characteristics: Coefficient of Determination R^2, Coefficient of Correlation r and the number of variables. R^2 explains the overall utility of the model or its ability to explain the variation of the data. (r) is the Correlation Coefficient between the predicted and the actual PPF.

In the case of Detailed Project Data models, both the Regression and the Neural Network models produced relatively close results for both R^2 and r. The difference, however, the Neural Network model was able to develop these results while utilizing the eighteen variables, while, the Regression model utilized five variables. From a user's point of view, the ability to use more variables in predicting the outcome of a future project may be advantageous. It would give the user of the model more flexibility and a larger opportunity to investigate different options and project control techniques.

Table 6.1 Comparison between the Models

Comparison Factor	Detailed Project Data		Summarized Project data	
	NN1	Regression	NN2	Regression
R^2	0.8428	0.904	0.6777	0.872
r	0.9208	0.9121	0.8836	0.9179
No. of Variables	18	5	8	4

In the case of the Summarized Project Data, both models Neural Network and Regression produced relatively close r and R^2 characteristics. Similar to the case of Detailed Project Data, the Neural Network model utilized more predictors (Eight as opposed to the four used by the Regression model).

CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSION

A comprehensive literature search was performed in the areas of reconstruction projects and construction control modeling to gather information about tools or factors that can be used to improve and predict the performance of reconstruction projects. A preliminary field review was also performed to review the significance of the gathered control factors. The result of both the literature search and the preliminary field review was the identification of thirty-six factors that govern the performance of reconstruction projects in terms of time, cost, and quality.

A questionnaire survey was then developed and used in a structured interview format. The questionnaire was designed to obtain three types of data. The first type was a Detailed Project Data, which is related to the utilization of the previously identified thirty-six factors in the control of reconstruction projects. The second was a Summarized Project Data, which is related to the overall level of effort exerted at different stages of the project. The third is actual performance data related to cost, duration, and quality.

Data of the three types was collected from fifty-four different projects. The collected data provided valuable information and insight about the project management process for each project and its outcome. A single quantifiable measure named Project Performance Factor (PPF) was developed to measure the overall performance of the surveyed projects and was considered as the dependent variable in the present model. A preliminary statistical analysis was performed on both the Detailed Project Data and the Summarized Project Data in relation to the (PPF). The result was the identification of the eighteen most significant variables to be considered for the development of the Detailed Project Data model and eight variables to be considered for the development of the Summarized Project Data model.

Four models were developed to predict the overall performance of reconstruction projects based on either Detailed Project data or Summarized Project Data. Two models were developed utilizing Statistical Regression analysis and two models were developed utilizing Artificial Neural Networks. Forty-five cases were used for model development while the remaining nine cases were used for model validation and testing. All four models produced high correlation between the predicted (PPF) values and the actual values. One essential benefit of the models based on Artificial Neural Networks is their use of larger number of variables and as such the models become more diverse. Artificial Neural Networks have proven to be useful and suitable for dealing with such a complex problem and developing user-friendly predicative models. They are able to detect any patterns found in the data and provide larger opportunity to investigate different options and project control techniques.

This study showed that neural networks are promising tools for used in developing predictive models in the construction domain. With recent developments in neural network software such as the one used in this study, data preprocessing and post-processing capabilities are included and make the neural network modeling more transparent. While both statistical analysis and neural networks worked well for the application at hand, neural networks can be an alternative modeling technique for problems that may include higher degree of uncertainty in the data and when statistical analysis may not be practical.

A spreadsheet interface was developed to facilitate the use of the Neural Network models. The spreadsheet works as a decision support tool that automates the prediction of an overall performance indicator (PPF) of reconstruction projects as a function of the set of control tools specified by the user. To capture the impact of uncertainty in the data input on the predicted PPF, a Sensitivity Analysis module was developed utilizing the traditional technique of Monte Carlo simulation.

7.2 SUMMARY OF CONTRIBUTION

The contribution of this research can be summarized in the following points:

1. The identification of the control factors that govern the success of reconstruction projects;
2. The identification of the reasons for the poor performance of reconstruction projects

or the overall failure of the projects;

3. Identification of the tools and factors that suite the specific environment of reconstruction projects and facilitate their control and management based on the available level of information to the user: Detailed Project Data; and Summarized Project data;
4. Development of a quantifiable and objective measure of the overall performance of reconstruction projects (PPF) that encompasses project cost, schedule and quality;
5. Development and validation of four models for predicting the overall performance of reconstruction projects and its deviation from preset baselines. Models were developed utilizing two techniques, Regression Analysis and Neural Network, for both Detailed Project Data and Summarized Project Data. These models enable project managers to determine the suitable control techniques, which can be used in a potential project to improve its performance; and
6. Development of a decision support tool that uses the developed Neural Network models, automates performance prediction, and addresses the impact of uncertainty in the project environment on its predicted performance.

7.3 FUTURE EXTENSIONS

This study dealt with a difficult problem faced by project managers of an expanding type of projects and as such the study has a high practical value. The models developed in this research enable project managers working with reconstruction projects to explore different control tools and test their potential impact on the overall performance of their projects. These models have been carefully designed based on actual project data to be both theoretically valid and easy to use. It is anticipated that construction practitioners utilizing these models will obtain valuable insights on the control of reconstruction projects.

Different extensions to this work are recommended as follows:

1. More refinement to the developed models can be carried out by applying more data, particularly those of recently finished projects, to increase the accuracy and adaptability to new situations;
2. The area of reconstruction projects is a fairly new research field. Very little research has been done in this area in spite of its increasing importance and the large investments being directed towards it. This research can be considered as the first comprehensive work in the area of reconstruction projects. More detailed research is required in this subject that can cover other aspects of its management such as risk analysis, productivity analysis and cost estimation;
3. Other useful predictive models can be developed to predict Cost performance, Schedule Performance and Quality Performance, individually; and
4. Different researches can be performed to study the performance of a specific type of reconstruction projects such as Interior Renovations, Expansions / Additions, Structural Modifications and complete Replacements.

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APPENDICIES

Appendix 1

Preliminary Field Review Questionnaire

Please indicate on a Scale of 1 to 5 the relative importance of the following factors to the success of reconstruction projects in operating facilities (1 is being the least).

COST	The establishment of Budget Baseline and Budget Allocations	1 2 3 4 5
	The use of Work Packages Costing	1 2 3 4 5
	Cost Breakdown Structure (CBS) as a cost-planning tool.	1 2 3 4 5
	Cost Coding as a cost planning and communication tool.	
	The use of Earned Value to measure cost performance.	1 2 3 4 5
	Cost Variance (CV) to measure cost performance	1 2 3 4 5
	The use of Cost Ratio	1 2 3 4 5
	Forecast Analysis	1 2 3 4 5
SCHEDULE	Using Work Breakdown Structure	1 2 3 4 5
	Bar Charts	1 2 3 4 5
	Critical Path Method	1 2 3 4 5
	Incremental Milestones	1 2 3 4 5
	The use of Time Variance to monitor schedule performance	1 2 3 4 5
	Using Percent Complete reports	1 2 3 4 5
QUALITY	A well developed Quality Standards and Specifications	1 2 3 4 5
	Responsibilities of Individuals towards Quality are identified.	1 2 3 4 5
	Inspection and Testing	1 2 3 4 5
SCOPE	Decomposition	1 2 3 4 5
	Benefit / Cost Analysis	1 2 3 4 5
COMMUNICATION	Regular Site Meetings	1 2 3 4 5
	The use of Electronic Communication	1 2 3 4 5
SAFETY	Formal Safety Meetings with supervisor	1 2 3 4 5
	Site Safety Inspection	1 2 3 4 5
	Upper Management Involvement	1 2 3 4 5
SITE	The Development of a Site Layout Plan	1 2 3 4 5

Please provide any additional factors, which were proven to be significant to the success of reconstruction projects.

1-
2-
3-

Appendix 2

Data Collection Questionnaire

SURVEY ON THE MANAGEMENT OF RECONSTRUCTION PROJECTS IN OPERATING FACILITY

All responses will remain Fully confidential and will be used for educational and research purposes only. Please respond by putting a check mark (√) next to your selection. Please use this questionnaire for **ONE** project. It is appreciated if you use copies of this questionnaire to include other projects. **To receive a copy of survey results, please check here.**

PART 1: The Project

Project Name: ____________________(Optional)

Your Organization: ________________ (Optional)
Owner organization Contractor
Other, specify ________________

Your position in your organization:
Project Manager Contract Administrator
Other, specify ________________

Location of the project:
Southern Ontario Northern Ontario
Western Ontario Eastern Ontario

Type of Building:
Institutional Commercial
Other, specify ________________

Type of Work Done:
Interior renovation Structural Modification
Expansion / Addition Phased Replacement
Other, specify ________________

PART 2: Before Construction

Please indicate which of the following were used:

At the Scope/Planning Stage:

- Work packages costing	Yes	No
- As-Built drawings	Yes	No
- Budget baseline	Yes	No
- Constructability review	Yes	No
- Design Committees	Yes	No

Overall level of Planning (5=Hi) **1 2 3 4 5** (Please circle one)

At the Tendering Stage:

- Quality standards and specs were developed with input from O&M staff	Yes	No
- Pre-qualifications of contractors	Yes	No
- Unit prices obtained	Yes	No
- Cash allowances made	Yes	No
- Liquidated damages calculated	Yes	No
- Site layout plan made	Yes	No

- Bidding method: ________________
- Contract type (e.g., lump sum) ________________

Comments:________________

PART 3: During Construction

For this project, indicate a weighting percentage to represent the relative importance of controlling:

Cost:___%; **Time**:___%; & **Quality** ___%.
(total=100%)

Please indicate which of the following were used:

Schedule Control:

- Work breakdown structure	Yes	No
- Coordination Schedule	Yes	No
- Bar charts to plot progress	Yes	No
- CPM method for scheduling	Yes	No
- Clearly defined milestones	Yes	No
- Time-variance analysis	Yes	No
- Percent complete	Yes	No
- Change Directive vs. Change Notice	Yes	No

Overall level of Schedule Control (5=Hi) **1 2 3 4 5** (Please circle one)

Cost Control:

- Cost breakdown structure	Yes	No
- Cost variance analysis	Yes	No
- Forecast Analysis	Yes	No
- Cash flow analysis	Yes	No

Overall level of Cost Control (5=High) **1 2 3 4 5** (Please circle one)

Quality Control:

- Commitment to quality was clear	Yes	No
- Independent inspection firm was used	Yes	No
- Specs had to be followed strictly	Yes	No

Overall level of Quality Control (5=High) **1 2 3 4 5** (Please circle one)

Communication Control:

- Implementation Team	Yes	No
- Regular site meetings	Yes	No
- Rapid response mechanizm	Yes	No
- Electronic communication	Yes	No

Overall level of Comm. Control (5=High) **1 2 3 4 5** (Please circle one)

Safety Control:

- Joint health and safety committee	Yes	No
- Awareness sessions	Yes	No
- Emergency plan and procedures	Yes	No
- Special precautions had to be made	Yes	No

Overall level of Safety Control (5=High) **1 2 3 4 5** (Please circle one)

Project Completion:

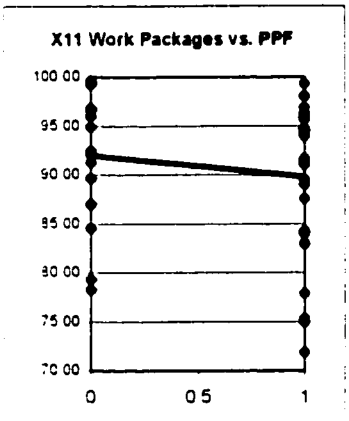
- Inspection by O&M / end user	Yes	No
- Relocation schedule	Yes	No

Overall Performance:
- **Original Contract Value: $** __________
- **Contract Value at completion:$** .
- **Original Durati** ___ **month & Actual Duration:**___ **month**
- **If things went wrong, rework/repair cost was:$**_____

Comments:________________

Appendix 3

Scatter Plots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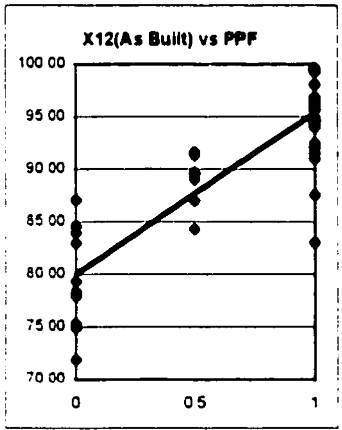
90 00
85 00
80 00
75 00
70 00
0
0 5
1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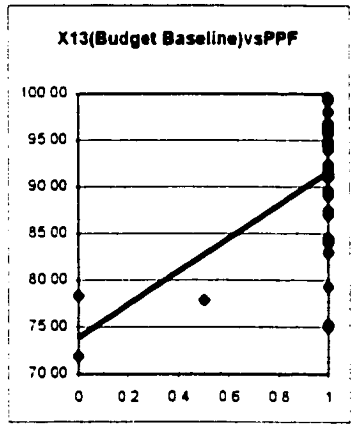
90 00
85 00
80 00
75 00
70 00
0
0 5
1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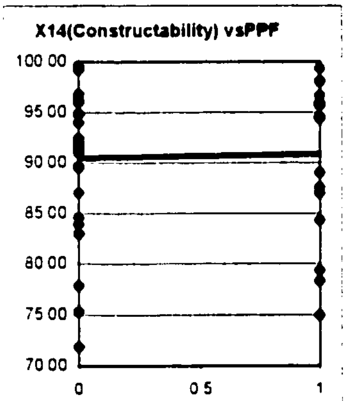
85 00
80 00
75 00
70 00
0
0 2
0 4
0 6
0 8
1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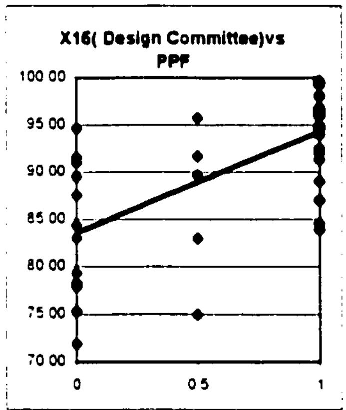
0 5
1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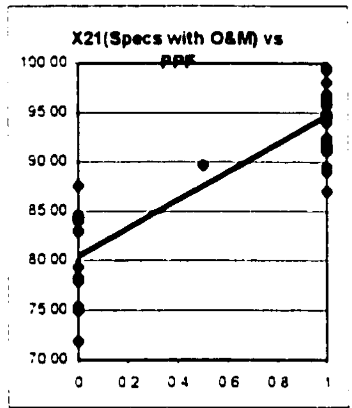
75 00
70 00
0
0 5
1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70 00
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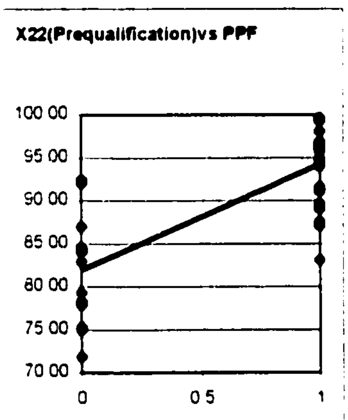
0 4
0 6
0 8
1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75 00
70 00
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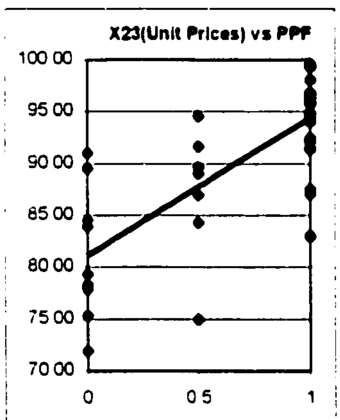
0 5
1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70 00
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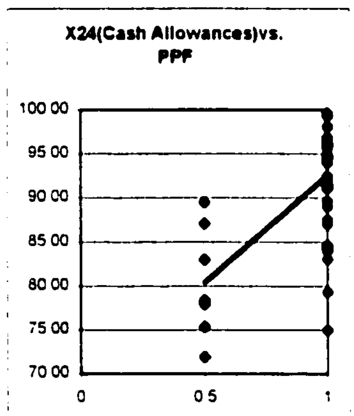
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70 00
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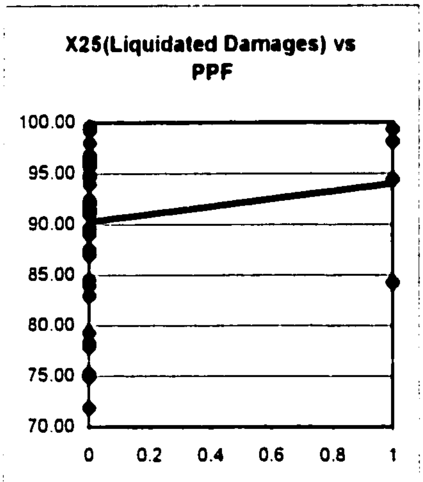
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70.00
0
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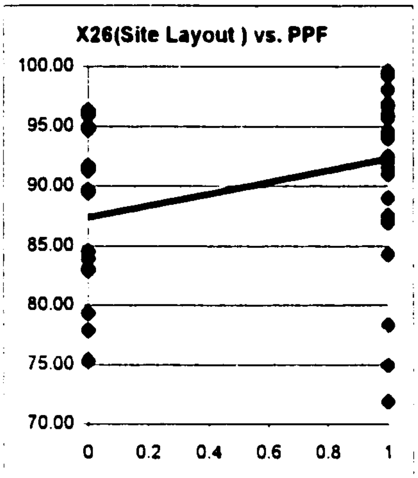
0.6
0.8
1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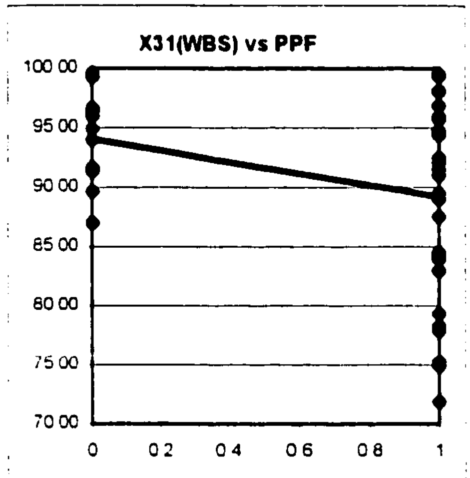
0.6
0.8
1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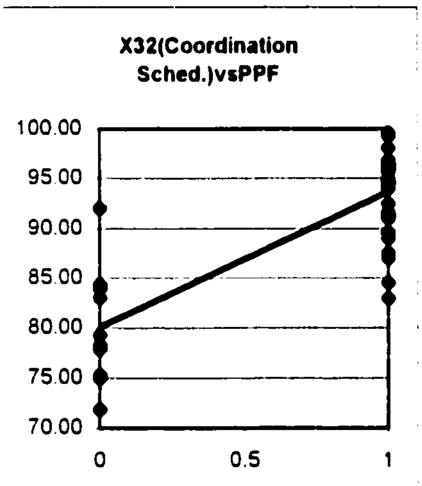
0 4
0 6
0 8
1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75.00
70.00
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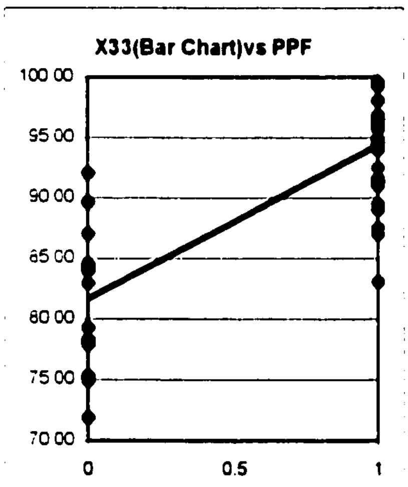
0.5
1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85 00
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75 00
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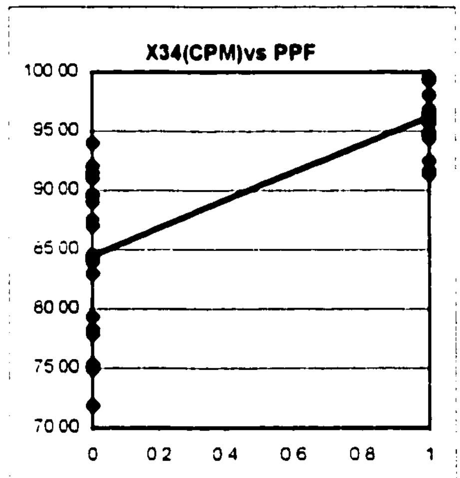
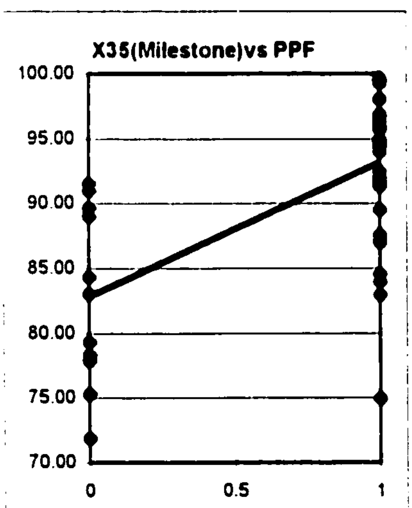
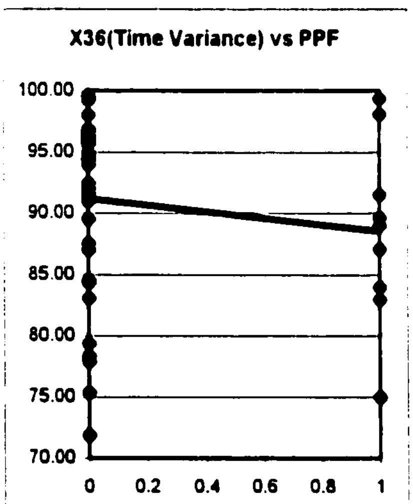
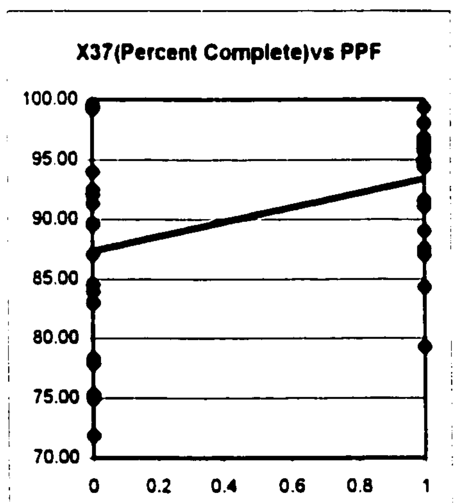
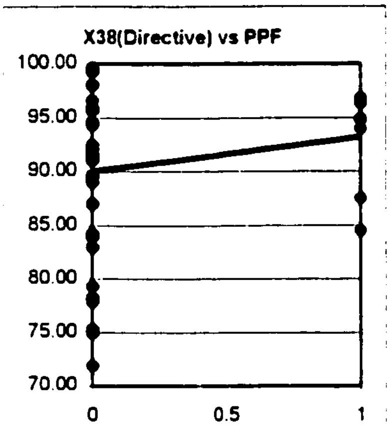
0
0.5
1

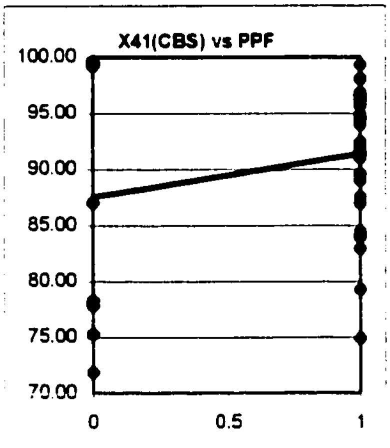

X34(CPM)vs PPF
100 00
95 00
90 00
85 00
80 00
75 00
70 00
0
0 2
0 4
0 6
0 8
1

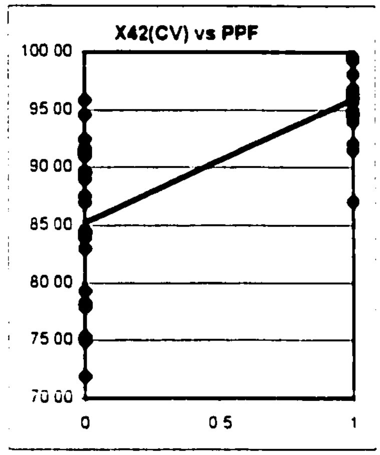

X35(Milestone)vs PPF
100.00
95.00
90.00
85.00
80.00
75.00
70.00
0
0.5
1

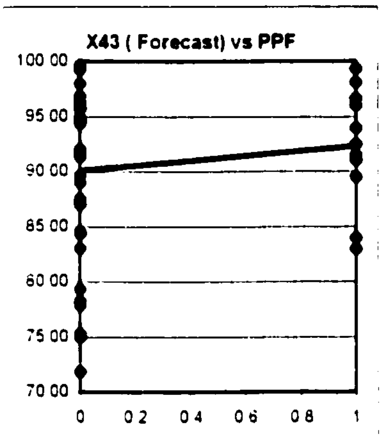

X36(Time Variance) vs PPF
100.00
95.00
90.00
85.00
80.00
75.00
70.00
0
0.2
0.4
0.6
0.8
1

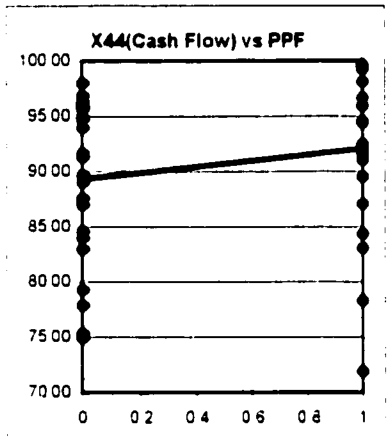

X37(Percent Complete)vs PPF
100.00
95.00
90.00
85.00
80.00
75.00
70.00
0
0.2
0.4
0.6
0.8
1

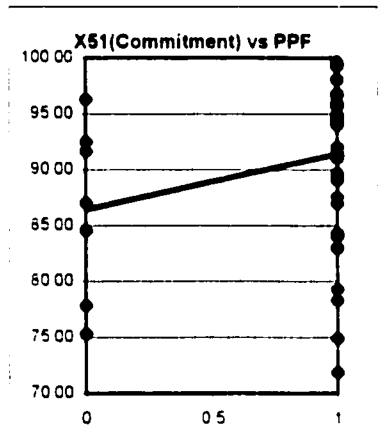

X38(Directive) vs PPF
100.00
95.00
90.00
85.00
80.00
75.00
70.00
0
0.5
1

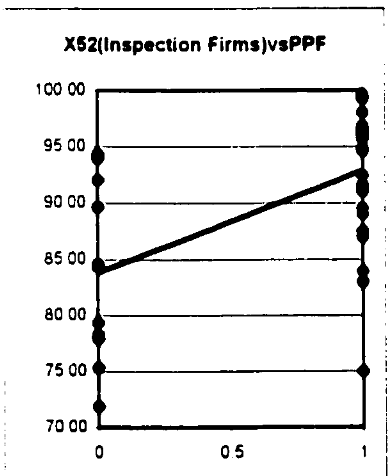

X41(CBS) vs PPF
100.00
95.00
90.00
85.00
80.00
75.00
70.00
0
0.5
1

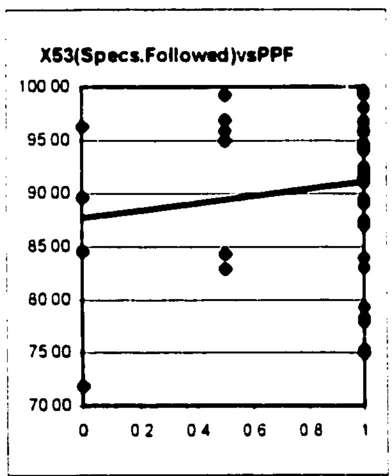

X42(CV) vs PPF
100 00
95 00
90 00
85 00
80 00
75 00
70 00
0
0 5
1

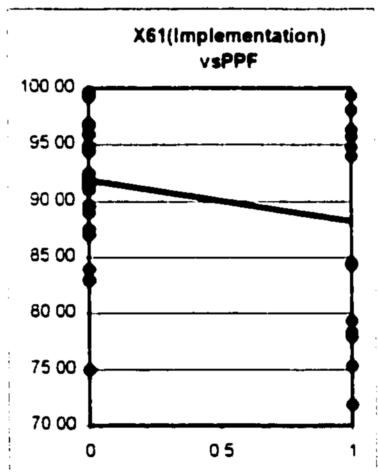

X43 (Forecast) vs PPF
100 00
95 00
90 00
85 00
80 00
75 00
70 00
0
0 2
0 4
0 6
0 8
1

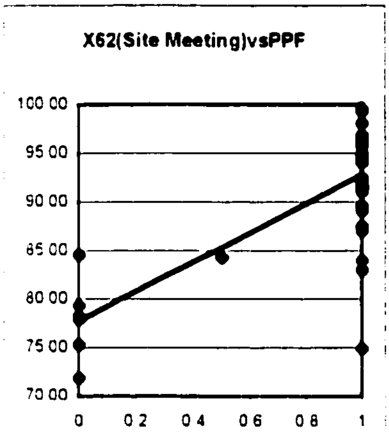

X44(Cash Flow) vs PPF
100 00
95 00
90 00
85 00
80 00
75 00
70 00
0
0 2
0 4
0 6
0 8
1

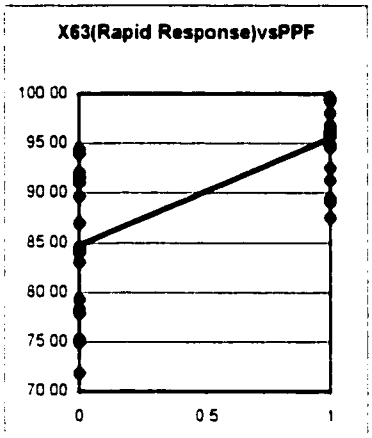

X51(Commitment) vs PPF
100 00
95 00
90 00
85 00
80 00
75 00
70 00
0
0 5
1

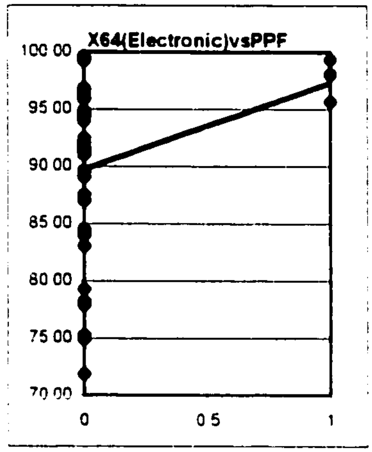

X52(Inspection Firms)vsPPF
100 00
95 00
90 00
85 00
80 00
75 00
70 00
0
0 5
1

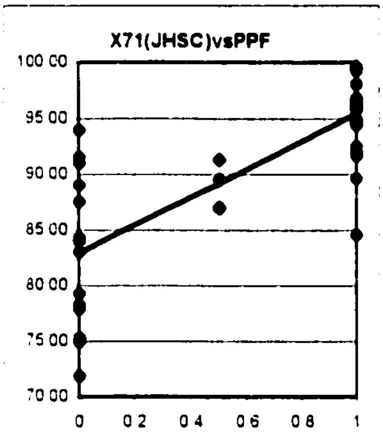

X53(Specs.Followed)vsPPF
100 00
95 00
90 00
85 00
80 00
75 00
70 00
0
0 2
0 4
0 6
0 8
1

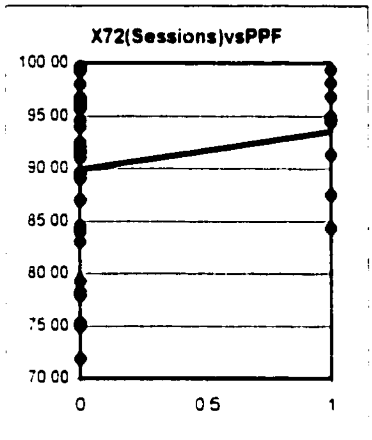

X61(Implementation)
vsPPF
100 00
95 00
90 00
85 00
80 00
75 00
70 00
0
0 5
1

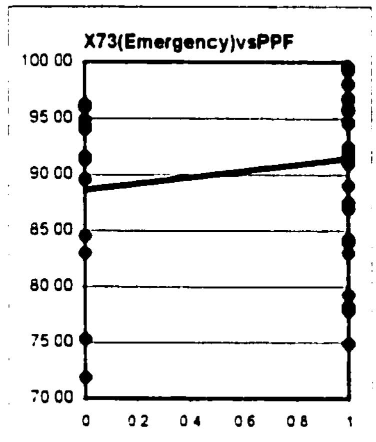

X62(Site Meeting)vsPPF
100 00
95 00
90 00
85 00
80 00
75 00
70 00
0
0 2
0 4
0 6
0 8
1

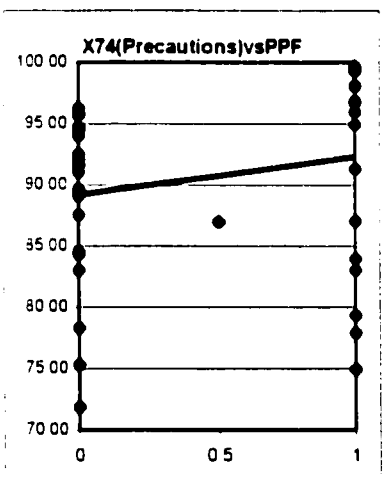

X63(Rapid Response)vsPPF
100 00
95 00
90 00
85 00
80 00
75 00
70 00
0
0 5
1

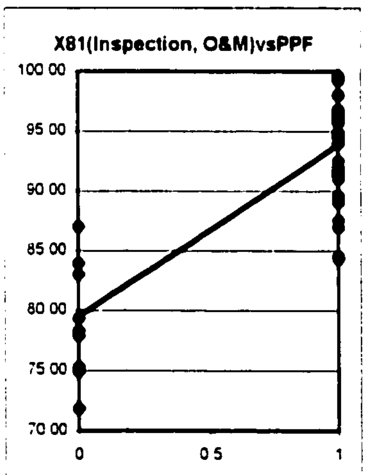

X64(Electronic)vsPPF
100 00
95 00
90 00
85 00
80 00
75 00
70 00
0
0 5
1

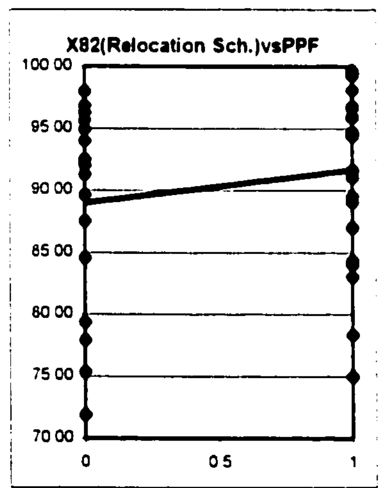

X71(JHSC)vsPPF
100 00
95 00
90 00
85 00
80 00
75 00
70 00
0
0 2
0 4
0 6
0 8
1

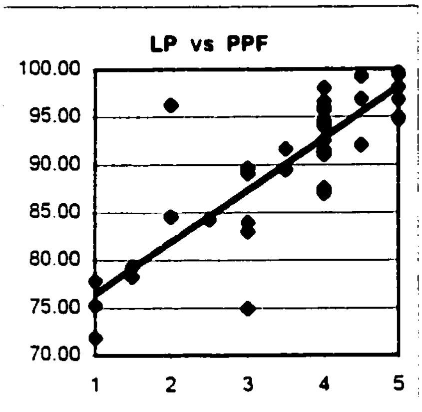

X72(Sessions)vsPPF
100 00
95 00
90 00
85 00
80 00
75 00
70 00
0
0 5
1

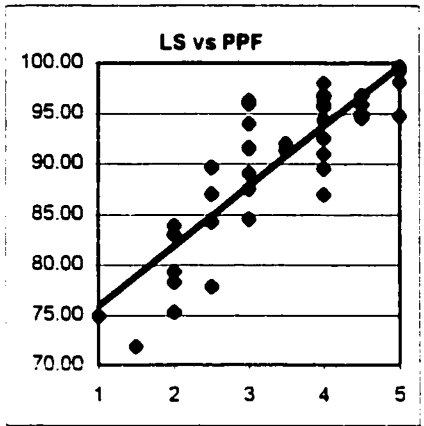

X73(Emergency)vsPPF
100 00
95 00
90 00
85 00
80 00
75 00
70 00
0
0 2
0 4
0 6
0 8
1

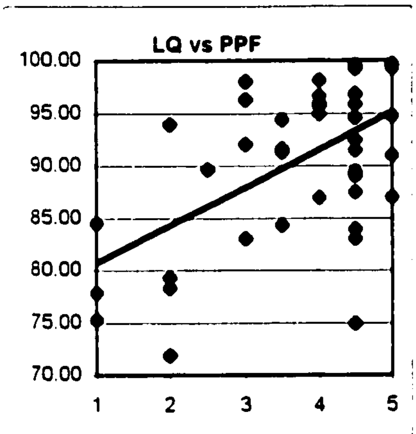

X74(Precautions)vsPPF
100 00
95 00
90 00
85 00
80 00
75 00
70 00
0
0 5
1

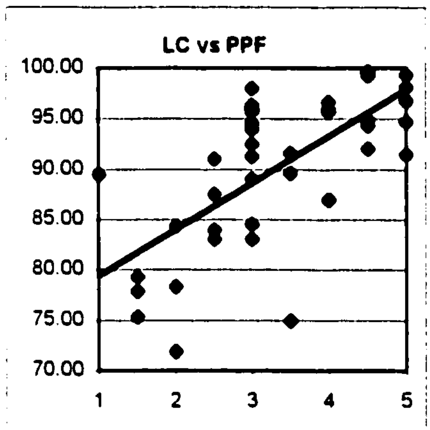

X81(Inspection, O&M)vsPPF
100 00
95 00
90 00
85 00
80 00
75 00
70 00
0
0 5
1

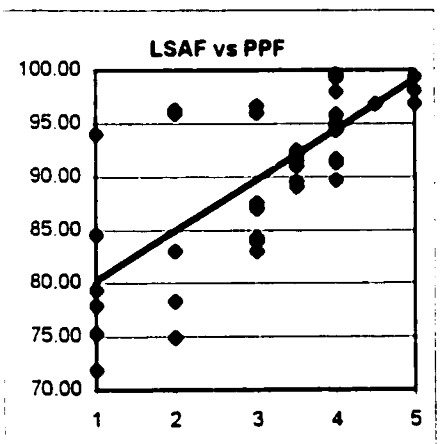

X82(Relocation Sch.)vsPPF
100 00
95 00
90 00
85 00
80 00
75 00
70 00
0
0 5
1

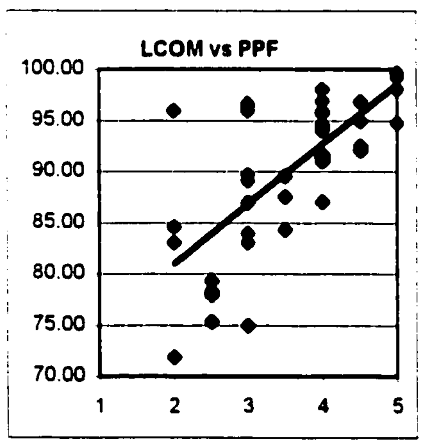

LP vs PPF
100.00
95.00
90.00
85.00
80.00
75.00
70.00
1
2
3
4
5


LS vs PPF
100.00
95.00
90.00
85.00
80.00
75.00
70.00
1
2
3
4
5


LQ vs PPF
100.00
95.00
90.00
85.00
80.00
75.00
70.00
1
2
3
4
5


LC vs PPF
100.00
95.00
90.00
85.00
80.00
75.00
70.00
1
2
3
4
5


LSAF vs PPF
100.00
95.00
90.00
85.00
80.00
75.00
70.00
1
2
3
4
5


LCOM vs PPF
100.00
95.00
90.00
85.00
80.00
75.00
70.00
1
2
3
4
5

Appendix 4
Preliminary Analysis
All variables vs. PPF

Dep Var: PPF   N: 54   Multiple R: 0.166   Squared multiple R: 0.028

Adjusted squared multiple R: 0.009   Standard error of estimate: 8.446

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	85.760	2.718	0.000	.	31.554	0.000
X0	1.370	1.127	0.166	1.000	1.215	0.230

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	105.340	1	105.340	1.477	0.230
Residual	3709.187	52	71.331		

Dep Var: PPF   N: 54   Multiple R: 0.146   Squared multiple R: 0.021

Adjusted squared multiple R: 0.002   Standard error of estimate: 8.473

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	90.291	1.849	0.000	.	48.833	0.000
X11	-2.516	2.365	-0.146	1.000	-1.064	0.292

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	81.245	1	81.245	1.132	0.292
Residual	3733.282	52	71.794		

Dep Var: PPF   N: 54   Multiple R: 0.866   Squared multiple R: 0.749

Adjusted squared multiple R: 0.745   Standard error of estimate: 4.287

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	77.691	1.062	0.000	.	73.184	0.000
X12	17.067	1.368	0.866	1.000	12.472	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	2858.846	1	2858.846	155.554	0.000
Residual	955.681	52	18.378		

Dep Var: PPF   N: 54   Multiple R: 0.571   Squared multiple R: 0.326

Adjusted squared multiple R: 0.313   Standard error of estimate: 7.031

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	75.486	2.813	0.000	.	26.837	0.000
X13	15.083	3.007	0.571	1.000	5.016	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P

Residual	2570.697	52	49.436

Dep Var: PPF N: 54 Multiple R: 0.055 Squared multiple R: 0.003

Adjusted squared multiple R: 0.000 Standard error of estimate: 8.552

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	88.385	1.489	0.000	.	59.371	0.000
X14	0.946	2.387	0.055	1.000	0.396	0.694

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	11.484	1	11.484	0.157	0.694
Residual	3803.042	52	73.135		

Dep Var: PPF N: 54 Multiple R: 0.591 Squared multiple R: 0.349

Adjusted squared multiple R: 0.336 Standard error of estimate: 6.911

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	81.980	1.591	0.000	.	51.529	0.000
X15	11.083	2.100	0.591	1.000	5.278	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	1330.671	1	1330.671	27.858	0.000
Residual	2483.855	52	47.766		

Dep Var: PPF N: 54 Multiple R: 0.815 Squared multiple R: 0.664

Adjusted squared multiple R: 0.658 Standard error of estimate: 4.963

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	78.754	1.195	0.000	.	65.905	0.000
X21	14.793	1.458	0.815	1.000	10.143	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	2533.788	1	2533.788	102.876	0.000
Residual	1280.739	52	24.630		

Dep Var: PPF N: 54 Multiple R: 0.754 Squared multiple R: 0.569

Adjusted squared multiple R: 0.561 Standard error of estimate: 5.624

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	79.401	1.364	0.000	.	58.215	0.000
X22	13.649	1.648	0.754	1.000	8.284	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	2170.024	1	2170.024	68.617	0.000
Residual	1644.503	52	31.625		

Dep Var: PPF N: 54 Multiple R: 0.725 Squared multiple R: 0.526

Adjusted squared multiple R: 0.517 Standard error of estimate: 5.898

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	79.402	1.470	0.000	.	54.013	0.000
X23	14.224	1.873	0.725	1.000	7.593	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	2005.506	1	2005.506	57.648	0.000
Residual	1809.021	52	34.789		

Dep Var: PPF N: 54 Multiple R: 0.569 Squared multiple R: 0.324

Adjusted squared multiple R: 0.311 Standard error of estimate: 7.042

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	76.019	2.724	0.000	.	27.902	0.000
X24	15.113	3.027	0.569	1.000	4.993	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	1236.161	1	1236.161	24.931	0.000
Residual	2578.366	52	49.584		

Dep Var: PPF N: 54 Multiple R: 0.197 Squared multiple R: 0.039

Adjusted squared multiple R: 0.020 Standard error of estimate: 8.398

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	88.286	1.188	0.000	.	74.338	0.000
X25	6.306	4.364	0.197	1.000	1.445	0.154

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	147.294	1	147.294	2.089	0.154
Residual	3667.232	52	70.524		

-

Dep Var: PPF N: 54 Multiple R: 0.161 Squared multiple R: 0.026

Adjusted squared multiple R: 0.007 Standard error of estimate: 8.453

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	86.841	1.992	0.000	.	43.585	0.000
X26	2.869	2.440	0.161	1.000	1.176	0.245

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	98.785	1	98.785	1.382	0.245
Residual	3715.741	52	71.457		

Dep Var: PPF N: 54 Multiple R: 0.223 Squared multiple R: 0.050

Adjusted squared multiple R: 0.031 Standard error of estimate: 8.350

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	91.292	1.916	0.000	.	47.656	0.000
X31	-3.916	2.379	-0.223	1.000	-1.646	0.106

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	188.863	1	188.863	2.709	0.106
Residual	3625.664	52	69.724		

Dep Var: PPF N: 54 Multiple R: 0.737 Squared multiple R: 0.544

Adjusted squared multiple R: 0.535 Standard error of estimate: 5.787

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	78.762	1.494	0.000	.	52.716	0.000
X32	13.834	1.758	0.737	1.000	7.869	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	2073.325	1	2073.325	61.919	0.000
Residual	1741.202	52	33.485		

Dep Var: PPF N: 54 Multiple R: 0.798 Squared multiple R: 0.636

Adjusted squared multiple R: 0.629 Standard error of estimate: 5.167

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	78.865	1.253	0.000	.	62.929	0.000
X33	14.432	1.514	0.798	1.000	9.532	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	2426.124	1	2426.124	90.866	0.000
Residual	1388.403	52	26.700		

Dep Var: PPF N: 54 Multiple R: 0.753 Squared multiple R: 0.568

Adjusted squared multiple R: 0.559 Standard error of estimate: 5.631

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	83.089	1.028	0.000	.	80.820	0.000
X34	12.745	1.542	0.753	1.000	8.265	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	2165.715	1	2165.715	68.302	0.000
Residual	1648.811	52	31.708		

Dep Var: PPF   N: 54   Multiple R: 0.547   Squared multiple R: 0.299

Adjusted squared multiple R: 0.286   Standard error of estimate: 7.170

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	81.971	1.739	0.000	.	47.137	0.000
X35	9.898	2.101	0.547	1.000	4.712	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	1141.239	1	1141.239	22.199	0.000
Residual	2673.288	52	51.409		

Dep Var: PPF   N: 54   Multiple R: 0.266   Squared multiple R: 0.071

Adjusted squared multiple R: 0.053   Standard error of estimate: 8.257

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	89.883	1.259	0.000	.	71.385	0.000
X36	-5.547	2.790	-0.266	1.000	-1.988	0.052

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	269.505	1	269.505	3.953	0.052
Residual	3545.022	52	68.173		

Dep Var: PPF   N: 54   Multiple R: 0.467   Squared multiple R: 0.218

Adjusted squared multiple R: 0.203   Standard error of estimate: 7.573

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	84.364	1.546	0.000	.	54.575	0.000
X37	7.901	2.074	0.467	1.000	3.809	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	832.239	1	832.239	14.511	0.000
Residual	2982.288	52	57.352		

Dep Var: PPF   N: 54   Multiple R: 0.129   Squared multiple R: 0.017

Adjusted squared multiple R: 0.000   Standard error of estimate: 8.493

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	88.268	1.266	0.000	.	69.718	0.000
X38	2.915	3.101	0.129	1.000	0.940	0.352

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	63.715	1	63.715	0.883	0.352
Residual	3750.812	52	72.131		

Dep Var: PPF   N: 54   Multiple R: 0.200   Squared multiple R: 0.040

Adjusted squared multiple R: 0.021   Standard error of estimate: 8.393

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	85.236	2.654	0.000	.	32.116	0.000
X41	4.317	2.940	0.200	1.000	1.468	0.148

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	151.834	1	151.834	2.156	0.148
Residual	3662.693	52	70.436		

Dep Var: PPF   N: 54   Multiple R: 0.678   Squared multiple R: 0.460

Adjusted squared multiple R: 0.449   Standard error of estimate: 6.297

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	84.029	1.113	0.000	.	75.491	0.000
X42	11.595	1.744	0.678	1.000	6.649	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	1752.803	1	1752.803	44.209	0.000
Residual	2061.723	52	39.649		

Dep Var: PPF   N: 54   Multiple R: 0.065   Squared multiple R: 0.004

Adjusted squared multiple R: 0.000   Standard error of estimate: 8.547

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	88.446	1.335	0.000	.	66.263	0.000
X43	1.275	2.720	0.065	1.000	0.469	0.641

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	16.050	1	16.050	0.220	0.641
Residual	3798.476	52	73.048		

Dep Var: PPF   N: 54   Multiple R: 0.166   Squared multiple R: 0.028

Adjusted squared multiple R: 0.009   Standard error of estimate: 8.445

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	87.502	1.542	0.000	.	56.749	0.000
X44	2.815	2.313	0.166	1.000	1.217	0.229

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	105.694	1	105.694	1.482	0.229
Residual	3708.833	52	71.324		

Dep Var: PPF   N: 54   Multiple R: 0.152   Squared multiple R: 0.023

Adjusted squared multiple R: 0.004 Standard error of estimate: 8.465

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	85.890	2.822	0.000	.	30.440	0.000
X51	3.436	3.091	0.152	1.000	1.112	0.271

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	88.546	1	88.546	1.236	0.271
Residual	3725.981	52	71.653		

Dep Var: PPF N: 54 Multiple R: 0.560 Squared multiple R: 0.313

Adjusted squared multiple R: 0.300 Standard error of estimate: 7.098

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	81.169	1.833	0.000	.	44.290	0.000
X52	10.502	2.156	0.560	1.000	4.870	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	1194.795	1	1194.795	23.716	0.000
Residual	2619.732	52	50.379		

Dep Var: PPF N: 54 Multiple R: 0.152 Squared multiple R: 0.023

Adjusted squared multiple R: 0.004 Standard error of estimate: 8.466

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	85.796	2.913	0.000	.	29.454	0.000
X53	3.629	3.283	0.152	1.000	1.105	0.274

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	87.570	1	87.570	1.222	0.274
Residual	3726.957	52	71.672		

Dep Var: PPF N: 54 Multiple R: 0.187 Squared multiple R: 0.035

Adjusted squared multiple R: 0.016 Standard error of estimate: 8.414

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	89.959	1.443	0.000	.	62.346	0.000
X61	-3.256	2.371	-0.187	1.000	-1.373	0.176

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	133.535	1	133.535	1.886	0.176
Residual	3680.992	52	70.788		

Dep Var: PPF N: 54 Multiple R: 0.683 Squared multiple R: 0.466

Adjusted squared multiple R: 0.456 Standard error of estimate: 6.258

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)

CONSTANT	77.568	1.866	0.000	.	41.568	0.000
X62	14.213	2.110	0.683	1.000	6.737	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	1777.749	1	1777.749	45.387	0.000
Residual	2036.777	52	39.169		

Dep Var: PPF N: 54 Multiple R: 0.696 Squared multiple R: 0.484

Adjusted squared multiple R: 0.474 Standard error of estimate: 6.151

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	83.323	1.142	0.000	.	72.944	0.000
X63	11.729	1.679	0.696	1.000	6.986	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	1846.856	1	1846.856	48.807	0.000
Residual	1967.671	52	37.840		

Dep Var: PPF N: 54 Multiple R: 0.012 Squared multiple R: 0.000

Adjusted squared multiple R: 0.000 Standard error of estimate: 8.564

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	88.805	1.321	0.000	.	67.201	0.000
X64	-0.234	2.803	-0.012	1.000	-0.083	0.934

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	0.509	1	0.509	0.007	0.934
Residual	3814.017	52	73.346		

Dep Var: PPF N: 54 Multiple R: 0.741 Squared multiple R: 0.550

Adjusted squared multiple R: 0.541 Standard error of estimate: 5.748

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	81.510	1.199	0.000	.	67.955	0.000
X71	13.037	1.637	0.741	1.000	7.965	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	2096.354	1	2096.354	63.446	0.000
Residual	1718.173	52	33.042		

Dep Var: PPF N: 54 Multiple R: 0.185 Squared multiple R: 0.034

Adjusted squared multiple R: 0.016 Standard error of estimate: 8.416

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	87.920	1.299	0.000	.	67.700	0.000
X72	3.748	2.755	0.185	1.000	1.360	0.180

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	131.100	1	131.100	1.851	0.180
Residual	3683.427	52	70.835		

Dep Var: PPF N: 54 Multiple R: 0.116 Squared multiple R: 0.013

Adjusted squared multiple R: 0.000 Standard error of estimate: 8.507

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	87.378	2.005	0.000	.	43.576	0.000
X73	2.062	2.456	0.116	1.000	0.840	0.405

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	51.047	1	51.047	0.705	0.405
Residual	3763.480	52	72.375		

Dep Var: PPF N: 54 Multiple R: 0.090 Squared multiple R: 0.008

Adjusted squared multiple R: 0.000 Standard error of estimate: 8.530

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	88.053	1.584	0.000	.	55.588	0.000
X74	1.513	2.328	0.090	1.000	0.650	0.519

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	30.744	1	30.744	0.423	0.519
Residual	3783.783	52	72.765		

Dep Var: PPF N: 54 Multiple R: 0.825 Squared multiple R: 0.680

Adjusted squared multiple R: 0.674 Standard error of estimate: 4.841

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	77.034	1.294	0.000	.	59.535	0.000
X81	15.821	1.503	0.825	1.000	10.523	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	2595.652	1	2595.652	110.736	0.000
Residual	1218.875	52	23.440		

Dep Var: PPF N: 54 Multiple R: 0.207 Squared multiple R: 0.043

Adjusted squared multiple R: 0.024 Standard error of estimate: 8.379

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	86.733	1.747	0.000	.	49.642	0.000
X82	3.520	2.306	0.207	1.000	1.526	0.133

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P

Regression	163.597	1	163.597	2.330	0.133
Residual	3650.930	52	70.210		

Dep Var: PPF   N: 54   Multiple R: 0.851   Squared multiple R: 0.724

Adjusted squared multiple R: 0.719   Standard error of estimate: 4.499

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	65.341	2.096	0.000	.	31.178	0.000
LP	6.637	0.568	0.851	1.000	11.681	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	2761.953	1	2761.953	136.448	0.000
Residual	1052.574	52	20.242		

Dep Var: PPF   N: 54   Multiple R: 0.880   Squared multiple R: 0.774

Adjusted squared multiple R: 0.769   Standard error of estimate: 4.074

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	66.342	1.770	0.000	.	37.488	0.000
LS	6.780	0.508	0.880	1.000	13.335	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	2951.453	1	2951.453	177.824	0.000
Residual	863.074	52	16.598		

Dep Var: PPF   N: 54   Multiple R: 0.668   Squared multiple R: 0.447

Adjusted squared multiple R: 0.436   Standard error of estimate: 6.372

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	72.447	2.662	0.000	.	27.212	0.000
LC	5.090	0.786	0.668	1.000	6.478	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	1703.532	1	1703.532	41.963	0.000
Residual	2110.995	52	40.596		

Dep Var: PPF   N: 54   Multiple R: 0.550   Squared multiple R: 0.303

Adjusted squared multiple R: 0.289   Standard error of estimate: 7.151

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	74.525	3.148	0.000	.	23.676	0.000
LQ	3.991	0.840	0.550	1.000	4.753	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	1155.382	1	1155.382	22.594	0.000
Residual	2659.145	52	51.137		

Dep Var: PPF   N: 54   Multiple R: 0.710   Squared multiple R: 0.504

Adjusted squared multiple R: 0.494   Standard error of estimate: 6.033

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	66.008	3.236	0.000	.	20.397	0.000
LCOM	6.481	0.892	0.710	1.000	7.266	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	1921.752	1	1921.752	52.796	0.000
Residual	1892.774	52	36.400		

Dep Var: PPF   N: 54   Multiple R: 0.717   Squared multiple R: 0.514

Adjusted squared multiple R: 0.505   Standard error of estimate: 5.968

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	72.202	2.373	0.000	.	30.425	0.000
LSAF	5.320	0.717	0.717	1.000	7.423	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	1962.424	1	1962.424	55.097	0.000
Residual	1852.103	52	35.617		

Appendix 5a

Detailed Project Data

Backward Stepping

F=4 to enter

45 cases and 51 variables processed and saved.

Step # 0 R = 0.967 R-Square = 0.934

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	-0.068	0.488	-0.008	0.71017	1	0.020	0.890
3 X12	9.599	4.573	0.468	0.05092	1	4.407	0.046
4 X13	4.290	3.117	0.127	0.29731	1	1.895	0.180
5 X15	3.960	2.118	0.201	0.21760	1	3.496	0.073
6 X21	0.500	2.807	0.026	0.11868	1	0.032	0.860
7 X22	5.658	2.478	0.301	0.14517	1	5.212	0.031
8 X23	-0.015	2.697	-0.001	0.15353	1	0.000	0.996
9 X24	-7.843	4.408	-0.204	0.19248	1	3.166	0.087
10 X32	-1.870	2.975	-0.092	0.11691	1	0.395	0.535
11 X33	-2.990	3.914	-0.159	0.05820	1	0.584	0.452
12 X34	3.422	2.610	0.197	0.11229	1	1.719	0.201
13 X35	-1.606	2.148	-0.082	0.21191	1	0.559	0.461
14 X42	0.067	1.998	0.004	0.19151	1	0.001	0.974
15 X52	3.187	2.800	0.162	0.12462	1	1.295	0.266
16 X62	-3.097	4.459	-0.130	0.07209	1	0.482	0.493
17 X63	-1.595	2.081	-0.091	0.17726	1	0.587	0.451
18 X71	1.001	2.837	0.054	0.10905	1	0.124	0.727
19 X81	7.659	3.418	0.378	0.08855	1	5.020	0.034
Out	Part. Corr.						
none							

Dependent Variable PPF
Minimum tolerance for entry into model = 0.000000
Backward stepwise regression with F-to-Enter=4.000 and F-to-Remove=3.900
Step # 1 R = 0.967 R-Square = 0.934
Term removed: X23

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	-0.069	0.460	-0.008	0.76878	1	0.022	0.882
3 X12	9.590	4.140	0.467	0.05981	1	5.365	0.028
4 X13	4.289	3.049	0.127	0.29915	1	1.978	0.171
5 X15	3.957	2.015	0.201	0.23138	1	3.855	0.060
6 X21	0.504	2.653	0.026	0.12793	1	0.036	0.851
7 X22	5.660	2.399	0.301	0.14922	1	5.568	0.026
9 X24	-7.841	4.309	-0.204	0.19396	1	3.311	0.080
10 X32	-1.876	2.683	-0.093	0.13841	1	0.489	0.490
11 X33	-2.987	3.803	-0.159	0.05936	1	0.617	0.439
12 X34	3.418	2.423	0.196	0.12548	1	1.990	0.170
13 X35	-1.605	2.106	-0.082	0.21222	1	0.581	0.452
14 X42	0.064	1.869	0.004	0.21076	1	0.001	0.973
15 X52	3.189	2.716	0.162	0.12756	1	1.378	0.251
16 X62	-3.105	4.149	-0.130	0.08019	1	0.560	0.461
17 X63	-1.595	2.040	-0.091	0.17762	1	0.611	0.441
18 X71	1.004	2.715	0.054	0.11462	1	0.137	0.714
19 X81	7.663	3.245	0.379	0.09461	1	5.576	0.026
Out	Part. Corr.						
8 X23	-0.001	.	.	0.15353	1	0.000	0.996

Step # 2 R = 0.967 R-Square = 0.934
Term removed: X42

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	-0.069	0.452	-0.008	0.76951	1	0.024	0.879
3 X12	9.684	3.013	0.472	0.10888	1	10.329	0.003
4 X13	4.294	2.991	0.127	0.29984	1	2.061	0.162
5 X15	3.987	1.782	0.203	0.28557	1	5.008	0.033
6 X21	0.541	2.375	0.028	0.15396	1	0.052	0.821
7 X22	5.698	2.083	0.303	0.19083	1	7.483	0.011
9 X24	-7.857	4.206	-0.204	0.19629	1	3.489	0.072
10 X32	-1.879	2.634	-0.093	0.13849	1	0.509	0.482
11 X33	-3.055	3.174	-0.163	0.08222	1	0.927	0.344
12 X34	3.428	2.359	0.197	0.12764	1	2.112	0.157
13 X35	-1.579	1.921	-0.080	0.24585	1	0.675	0.418
15 X52	3.209	2.605	0.163	0.13370	1	1.517	0.228
16 X62	-3.172	3.584	-0.133	0.10361	1	0.783	0.384
17 X63	-1.609	1.965	-0.092	0.18474	1	0.670	0.420
18 X71	0.977	2.553	0.052	0.12507	1	0.147	0.705
19 X81	7.649	3.158	0.378	0.09637	1	5.867	0.022
Out	Part. Corr.						
8 X23	0.001	.	.	0.16896	1	0.000	0.996
14 X42	0.007	.	.	0.21076	1	0.001	0.973

Step # 3 R = 0.967 R-Square = 0.934
Term removed: X0

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
3 X12	9.706	2.959	0.473	0.10912	1	10.760	0.003
4 X13	4.265	2.934	0.126	0.30103	1	2.113	0.157
5 X15	3.985	1.751	0.203	0.29558	1	5.178	0.030
6 X21	0.552	2.333	0.029	0.15410	1	0.056	0.815
7 X22	5.638	2.011	0.300	0.19789	1	7.861	0.009
9 X24	-7.791	4.114	-0.203	0.19830	1	3.588	0.068
10 X32	-1.753	2.461	-0.087	0.15332	1	0.507	0.482
11 X33	-3.046	3.119	-0.162	0.08225	1	0.954	0.337
12 X34	3.441	2.317	0.198	0.12780	1	2.205	0.148
13 X35	-1.574	1.888	-0.080	0.24592	1	0.695	0.411
15 X52	3.169	2.549	0.161	0.13501	1	1.546	0.224
16 X62	-3.224	3.507	-0.135	0.10455	1	0.845	0.366
17 X63	-1.609	1.931	-0.092	0.18474	1	0.694	0.412
18 X71	0.972	2.509	0.052	0.12509	1	0.150	0.701
19 X81	7.542	3.028	0.373	0.10127	1	6.203	0.019
Out	Part. Corr.						
2 X0	-0.029	.	.	0.76951	1	0.024	0.879
8 X23	-0.006	.	.	0.18080	1	0.001	0.973
14 X42	0.007	.	.	0.21096	1	0.002	0.969

Step # 4 R = 0.966 R-Square = 0.934
Term removed: X21

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
3 X12	9.673	2.909	0.471	0.10937	1	11.059	0.002
4 X13	4.325	2.877	0.128	0.30327	1	2.259	0.143
5 X15	4.151	1.580	0.211	0.33981	1	6.901	0.013
7 X22	5.686	1.969	0.303	0.19993	1	8.340	0.007
9 X24	-8.196	3.682	-0.213	0.23972	1	4.955	0.034
10 X32	-1.798	2.415	-0.089	0.15426	1	0.555	0.462
11 X33	-2.837	2.944	-0.151	0.08945	1	0.929	0.343
12 X34	3.493	2.270	0.201	0.12896	1	2.367	0.134
13 X35	-1.689	1.796	-0.086	0.26339	1	0.885	0.354
15 X52	3.202	2.505	0.163	0.13541	1	1.634	0.211
16 X62	-3.035	3.361	-0.127	0.11031	1	0.816	0.374
17 X63	-1.710	1.854	-0.098	0.19413	1	0.850	0.364
18 X71	1.103	2.408	0.059	0.13149	1	0.210	0.650
19 X91	7.779	2.813	0.384	0.11368	1	7.648	0.010
Out	**Part. Corr.**						
2 X0	-0.030	.	.	0.77023	1	0.027	0.871
6 X21	0.044	.	.	0.15410	1	0.056	0.815
8 X23	-0.013	.	.	0.18533	1	0.005	0.943
14 X42	0.025	.	.	0.25406	1	0.018	0.894

Step # 5 R = 0.966 R-Square = 0.934
Term removed: X71

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
3 X12	10.063	2.746	0.490	0.11959	1	13.429	0.001
4 X13	4.407	2.835	0.130	0.30446	1	2.417	0.130
5 X15	4.310	1.521	0.219	0.35717	1	8.027	0.008
7 X22	5.847	1.913	0.311	0.20649	1	9.346	0.005
9 X24	-8.435	3.598	-0.219	0.24461	1	5.495	0.026
10 X32	-1.696	2.373	-0.084	0.15558	1	0.511	0.480
11 X33	-3.555	2.459	-0.189	0.12492	1	2.091	0.158
12 X34	4.187	1.670	0.241	0.23232	1	6.287	0.018
13 X35	-1.476	1.712	-0.075	0.28230	1	0.743	0.395
15 X52	3.354	2.451	0.171	0.13782	1	1.873	0.181
16 X62	-3.346	3.249	-0.140	0.11500	1	1.060	0.311
17 X63	-1.865	1.799	-0.107	0.20088	1	1.075	0.308
19 X91	8.284	2.554	0.409	0.13436	1	10.521	0.003
Out	**Part. Corr.**						
2 X0	-0.030	.	.	0.77026	1	0.027	0.872
6 X21	0.061	.	.	0.16198	1	0.112	0.740
8 X23	-0.039	.	.	0.20699	1	0.047	0.830
14 X42	0.009	.	.	0.26315	1	0.002	0.962
18 X71	0.083	.	.	0.13149	1	0.210	0.650

Step # 6 R = 0.966 R-Square = 0.933
Term removed: X32

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
3 X12	10.580	2.628	0.515	0.12853	1	16.203	0.000
4 X13	4.004	2.756	0.118	0.31701	1	2.110	0.156
5 X15	4.034	1.460	0.205	0.38185	1	7.633	0.009
7 X22	5.205	1.676	0.277	0.26479	1	9.647	0.004
9 X24	-7.465	3.307	-0.194	0.28519	1	5.096	0.031
11 X33	-3.826	2.411	-0.204	0.12795	1	2.518	0.122
12 X34	4.174	1.657	0.240	0.23234	1	6.347	0.017
13 X35	-1.697	1.671	-0.086	0.29179	1	1.031	0.318
15 X52	2.870	2.337	0.146	0.14922	1	1.508	0.228
16 X62	-3.045	3.197	-0.128	0.11696	1	0.907	0.348

17	X63	-1.572	1.738	-0.090	0.21190	1	0.818	0.373
19	X81	7.102	1.930	0.351	0.23157	1	13.532	0.001

Out		Part. Corr.						
2	X0	0.011	.	.	0.85244	1	0.004	0.949
6	X21	0.068	.	.	0.16249	1	0.142	0.709
8	X23	-0.073	.	.	0.22410	1	0.165	0.687
10	X32	-0.127	.	.	0.15558	1	0.511	0.480
14	X42	0.017	.	.	0.26418	1	0.009	0.927
18	X71	0.071	.	.	0.13261	1	0.155	0.696

Step # 7 R = 0.965 R-Square = 0.931
Term removed: X63

Effect		Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In								
1	Constant							
3	X12	9.910	2.515	0.483	0.13963	1	15.529	0.000
4	X13	4.009	2.749	0.119	0.31701	1	2.127	0.154
5	X15	3.860	1.443	0.196	0.38857	1	7.152	0.012
7	X22	4.923	1.642	0.262	0.27433	1	8.988	0.005
9	X24	-6.879	3.234	-0.179	0.29657	1	4.525	0.041
11	X33	-3.487	2.375	-0.186	0.13111	1	2.155	0.152
12	X34	3.746	1.583	0.215	0.25304	1	5.597	0.024
13	X35	-1.845	1.659	-0.094	0.29462	1	1.237	0.274
15	X52	1.695	1.937	0.086	0.21596	1	0.765	0.388
16	X62	-1.835	2.896	-0.077	0.14180	1	0.402	0.531
19	X81	6.503	1.808	0.321	0.26245	1	12.930	0.001

Out		Part. Corr.						
2	X0	-0.001	.	.	0.85794	1	0.000	0.994
6	X21	0.104	.	.	0.17335	1	0.351	0.558
8	X23	-0.074	.	.	0.22414	1	0.176	0.678
10	X32	-0.086	.	.	0.16411	1	0.241	0.627
14	X42	0.052	.	.	0.27896	1	0.088	0.769
17	X63	-0.158	.	.	0.21190	1	0.818	0.373
18	X71	0.101	.	.	0.13859	1	0.330	0.570

Step # 8 R = 0.964 R-Square = 0.930
Term removed: X62

Effect		Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In								
1	Constant							
3	X12	9.136	2.179	0.445	0.18270	1	17.579	0.000
4	X13	3.702	2.682	0.109	0.32719	1	1.905	0.177
5	X15	3.624	1.382	0.184	0.41624	1	6.875	0.013
7	X22	4.539	1.513	0.242	0.31748	1	9.002	0.005
9	X24	-6.982	3.201	-0.182	0.29733	1	4.758	0.036
11	X33	-3.113	2.280	-0.166	0.13973	1	1.864	0.181
12	X34	4.236	1.369	0.243	0.33248	1	9.575	0.004
13	X35	-2.161	1.568	-0.110	0.32391	1	1.899	0.177
15	X52	0.963	1.543	0.049	0.33464	1	0.390	0.536
19	X81	6.488	1.792	0.321	0.26249	1	13.104	0.001

Out		Part. Corr.						
2	X0	-0.013	.	.	0.86723	1	0.005	0.942
6	X21	0.065	.	.	0.19167	1	0.138	0.713
8	X23	-0.095	.	.	0.23462	1	0.301	0.587
10	X32	-0.082	.	.	0.16431	1	0.223	0.640
14	X42	0.081	.	.	0.30272	1	0.216	0.645
16	X62	-0.110	.	.	0.14180	1	0.402	0.531
17	X63	-0.097	.	.	0.25692	1	0.311	0.581

18 X71	0.115	.	.	0.14131	1	0.439	0.512

Step # 9 R = 0.964 R-Square = 0.929
Term removed: X52

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
3 X12	8.899	2.127	0.434	0.18841	1	17.505	0.000
4 X13	4.134	2.569	0.122	0.35048	1	2.590	0.117
5 X15	3.579	1.368	0.182	0.41738	1	6.843	0.013
7 X22	4.646	1.490	0.247	0.32164	1	9.726	0.004
9 X24	-6.924	3.172	-0.180	0.29758	1	4.766	0.036
11 X33	-2.352	1.910	-0.125	0.19564	1	1.515	0.227
12 X34	4.272	1.356	0.246	0.33306	1	9.927	0.003
13 X35	-1.877	1.487	-0.095	0.35362	1	1.592	0.215
19 X81	6.054	1.638	0.299	0.30888	1	13.665	0.001
Out	**Part. Corr.**						
2 X0	0.004	.	.	0.88839	1	0.001	0.982
6 X21	0.077	.	.	0.19478	1	0.203	0.655
8 X23	-0.080	.	.	0.23867	1	0.218	0.644
10 X32	-0.059	.	.	0.17112	1	0.117	0.734
14 X42	0.065	.	.	0.30824	1	0.145	0.705
15 X52	0.106	.	.	0.33464	1	0.390	0.536
16 X62	-0.024	.	.	0.21973	1	0.020	0.889
17 X63	-0.044	.	.	0.30797	1	0.067	0.797
18 X71	0.110	.	.	0.14149	1	0.418	0.522

Step # 10 R = 0.962 R-Square = 0.926
Term removed: X33

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
3 X12	7.846	1.961	0.382	0.22478	1	16.004	0.000
4 X13	4.258	2.585	0.126	0.35103	1	2.713	0.108
5 X15	3.804	1.366	0.194	0.42497	1	7.760	0.008
7 X22	3.861	1.356	0.206	0.39388	1	8.108	0.007
9 X24	-7.013	3.194	-0.182	0.29773	1	4.822	0.035
12 X34	3.983	1.345	0.229	0.34333	1	8.771	0.005
13 X35	-2.118	1.485	-0.108	0.35988	1	2.035	0.162
19 X81	5.732	1.628	0.283	0.31696	1	12.394	0.001
Out	**Part. Corr.**						
2 X0	0.014	.	.	0.89072	1	0.007	0.933
6 X21	0.023	.	.	0.20725	1	0.019	0.892
8 X23	-0.034	.	.	0.24928	1	0.042	0.840
10 X32	-0.123	.	.	0.19366	1	0.542	0.466
11 X33	-0.204	.	.	0.19564	1	1.515	0.227
14 X42	0.143	.	.	0.37377	1	0.734	0.397
15 X52	-0.021	.	.	0.46854	1	0.015	0.903
16 X62	-0.050	.	.	0.22361	1	0.089	0.767
17 X63	-0.085	.	.	0.32210	1	0.256	0.616
18 X71	0.204	.	.	0.20752	1	1.520	0.226

Step # 11 R = 0.960 R-Square = 0.922
Term removed: X35

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							

1 Constant							
3 X12	7.787	1.988	0.379	0.22488	1	15.343	0.000
4 X13	2.790	2.404	0.083	0.41717	1	1.347	0.253
5 X15	2.866	1.213	0.146	0.55342	1	5.578	0.024
7 X22	4.155	1.359	0.221	0.40318	1	9.350	0.004
9 X24	-5.818	3.124	-0.151	0.31975	1	3.467	0.071
12 X34	3.256	1.262	0.187	0.40105	1	6.658	0.014
19 X81	5.548	1.646	0.274	0.31896	1	11.367	0.002
Out	Part. Corr.						
2 X0	0.011	.	.	0.89085	1	0.004	0.947
6 X21	0.040	.	.	0.20844	1	0.058	0.812
8 X23	-0.070	.	.	0.25589	1	0.178	0.675
10 X32	-0.173	.	.	0.20592	1	1.110	0.299
11 X33	-0.227	.	.	0.19910	1	1.955	0.171
13 X35	-0.231	.	.	0.35988	1	2.035	0.162
14 X42	0.139	.	.	0.37377	1	0.713	0.404
15 X52	-0.092	.	.	0.51935	1	0.304	0.585
16 X62	-0.142	.	.	0.27145	1	0.736	0.397
17 X63	-0.108	.	.	0.32626	1	0.429	0.517
18 X71	0.171	.	.	0.21028	1	1.080	0.306

Step # 12 R = 0.959 R-Square = 0.919
Term removed: X13

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
3 X12	7.583	1.989	0.369	0.22665	1	14.531	0.000
5 X15	3.146	1.194	0.160	0.57628	1	6.938	0.012
7 X22	4.577	1.315	0.244	0.43439	1	12.116	0.001
9 X24	-3.748	2.577	-0.097	0.47430	1	2.115	0.154
12 X34	2.973	1.244	0.171	0.41662	1	5.714	0.022
19 X81	5.642	1.651	0.279	0.31973	1	11.677	0.002
Out	Part. Corr.						
2 X0	0.024	.	.	0.99500	1	0.021	0.886
4 X13	0.187	.	.	0.41717	1	1.347	0.253
6 X21	0.065	.	.	0.21267	1	0.159	0.693
8 X23	-0.015	.	.	0.27644	1	0.009	0.926
10 X32	-0.100	.	.	0.22992	1	0.376	0.544
11 X33	-0.220	.	.	0.19914	1	1.885	0.178
13 X35	-0.134	.	.	0.42769	1	0.674	0.417
14 X42	0.134	.	.	0.37387	1	0.675	0.417
15 X52	-0.023	.	.	0.58214	1	0.020	0.888
16 X62	-0.044	.	.	0.33381	1	0.073	0.789
17 X63	-0.092	.	.	0.32825	1	0.313	0.579
18 X71	0.188	.	.	0.21320	1	1.361	0.251

Step # 13 R = 0.956 R-Square = 0.915
Term removed: X24

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
3 X12	6.681	1.917	0.325	0.25108	1	12.147	0.001
5 X15	2.674	1.166	0.136	0.62227	1	5.261	0.027
7 X22	4.748	1.328	0.253	0.43786	1	12.774	0.001
12 X34	3.180	1.253	0.183	0.42219	1	6.443	0.015
19 X81	5.013	1.616	0.248	0.34332	1	9.622	0.004
Out	Part. Corr.						

2 X0	0.008	.	.	0.89884	1	0.002	0.961
4 X13	0.019	.	.	0.61882	1	0.013	0.909
6 X21	0.136	.	.	0.23870	1	0.714	0.403
8 X23	-0.010	.	.	0.27656	1	0.004	0.951
9 X24	-0.230	.	.	0.47430	1	2.115	0.154
10 X32	-0.045	.	.	0.24124	1	0.079	0.780
11 X33	-0.213	.	.	0.19915	1	1.808	0.187
13 X35	-0.124	.	.	0.42800	1	0.593	0.446
14 X42	0.187	.	.	0.40269	1	1.376	0.248
15 X52	-0.061	.	.	0.59935	1	0.144	0.707
16 X62	-0.095	.	.	0.35263	1	0.347	0.560
17 X63	-0.045	.	.	0.34001	1	0.077	0.783
18 X71	0.212	.	.	0.21695	1	1.787	0.189

Dep Var: PPF N: 45 Multiple R: 0.956 Squared multiple R: 0.915

Adjusted squared multiple R: 0.904 Standard error of estimate: 2.730

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	74.589	0.925	0.000	.	80.615	0.000
X12	6.681	1.917	0.325	0.251	3.485	0.001
X15	2.674	1.166	0.136	0.622	2.294	0.027
X22	4.748	1.328	0.253	0.438	3.574	0.001
X34	3.180	1.253	0.183	0.422	2.538	0.015
X81	5.013	1.616	0.248	0.343	3.102	0.004

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	3113.041	5	622.608	83.549	0.000
Residual	290.628	39	7.452		

Appendix 5b

Detailed Project Data

Backward Stepping

F=2 to enter

Step # 0 R = 0.967 R-Square = 0.934

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	-0.068	0.488	-0.008	0.71017	1	0.020	0.890
3 X12	9.599	4.573	0.468	0.05092	1	4.407	0.046
4 X13	4.290	3.117	0.127	0.29731	1	1.895	0.180
5 X15	3.960	2.118	0.201	0.21760	1	3.496	0.073
6 X21	0.500	2.807	0.026	0.11868	1	0.032	0.860
7 X22	5.658	2.478	0.301	0.14517	1	5.212	0.031
8 X23	-0.015	2.697	-0.001	0.15353	1	0.000	0.996
9 X24	-7.843	4.409	-0.204	0.19249	1	3.166	0.087
10 X32	-1.870	2.975	-0.092	0.11691	1	0.395	0.535
11 X33	-2.990	3.914	-0.159	0.05820	1	0.584	0.452
12 X34	3.422	2.610	0.197	0.11229	1	1.719	0.201
13 X35	-1.606	2.148	-0.082	0.21191	1	0.559	0.461
14 X42	0.067	1.998	0.004	0.19151	1	0.001	0.974
15 X52	3.187	2.800	0.162	0.12462	1	1.295	0.266
16 X62	-3.097	4.459	-0.130	0.07209	1	0.482	0.493
17 X63	-1.595	2.081	-0.091	0.17726	1	0.587	0.451
18 X71	1.001	2.837	0.054	0.10905	1	0.124	0.727
19 X81	7.659	3.418	0.378	0.08855	1	5.020	0.034
Out	Part. Corr.						
none							

Dependent Variable PPF
Minimum tolerance for entry into model = 0.000000
Backward stepwise regression with F-to-Enter=2.000 and F-to-Remove=1.900
Step # 1 R = 0.967 R-Square = 0.934
Term removed: X23

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	-0.069	0.460	-0.008	0.76878	1	0.022	0.882
3 X12	9.590	4.140	0.467	0.05981	1	5.365	0.028
4 X13	4.289	3.049	0.127	0.29915	1	1.978	0.171
5 X15	3.957	2.015	0.201	0.23138	1	3.855	0.060
6 X21	0.504	2.653	0.026	0.12793	1	0.036	0.851
7 X22	5.660	2.399	0.301	0.14922	1	5.568	0.026
9 X24	-7.841	4.309	-0.204	0.19396	1	3.311	0.080
10 X32	-1.876	2.683	-0.093	0.13841	1	0.489	0.490
11 X33	-2.987	3.803	-0.159	0.05936	1	0.617	0.439
12 X34	3.418	2.423	0.196	0.12548	1	1.990	0.170
13 X35	-1.605	2.106	-0.082	0.21222	1	0.581	0.452
14 X42	0.064	1.969	0.004	0.21076	1	0.001	0.973
15 X52	3.189	2.716	0.162	0.12756	1	1.378	0.251
16 X62	-3.105	4.149	-0.130	0.08019	1	0.560	0.461
17 X63	-1.595	2.040	-0.091	0.17762	1	0.611	0.441
18 X71	1.004	2.715	0.054	0.11462	1	0.137	0.714
19 X81	7.663	3.245	0.379	0.09461	1	5.576	0.026
Out	Part. Corr.						
8 X23	-0.001	.	.	0.15353	1	0.000	0.996

Step # 2 R = 0.967 R-Square = 0.934
Term removed: X42

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	-0.069	0.452	-0.008	0.76951	1	0.024	0.879
3 X12	9.684	3.013	0.472	0.10888	1	10.329	0.003
4 X13	4.294	2.991	0.127	0.29984	1	2.061	0.162
5 X15	3.987	1.782	0.203	0.28557	1	5.008	0.033
6 X21	0.541	2.375	0.028	0.15396	1	0.052	0.821
7 X22	5.698	2.083	0.303	0.19083	1	7.483	0.011
9 X24	-7.857	4.206	-0.204	0.19629	1	3.489	0.072
10 X32	-1.879	2.634	-0.093	0.13849	1	0.509	0.482
11 X33	-3.055	3.174	-0.163	0.08222	1	0.927	0.344
12 X34	3.428	2.359	0.197	0.12764	1	2.112	0.157
13 X35	-1.579	1.921	-0.080	0.24585	1	0.675	0.418
15 X52	3.209	2.605	0.163	0.13370	1	1.517	0.228
16 X62	-3.172	3.584	-0.133	0.10361	1	0.783	0.384
17 X63	-1.609	1.965	-0.092	0.18474	1	0.670	0.420
18 X71	0.977	2.553	0.052	0.12507	1	0.147	0.705
19 X81	7.649	3.158	0.378	0.09637	1	5.867	0.022
Out	**Part. Corr.**						
8 X23	0.001	.	.	0.16896	1	0.000	0.996
14 X42	0.007	.	.	0.21076	1	0.001	0.973

Step # 3 R = 0.967 R-Square = 0.934
Term removed: X0

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
3 X12	9.706	2.959	0.473	0.10912	1	10.760	0.003
4 X13	4.265	2.934	0.126	0.30103	1	2.113	0.157
5 X15	3.985	1.751	0.203	0.28558	1	5.178	0.030
6 X21	0.552	2.333	0.029	0.15410	1	0.056	0.815
7 X22	5.638	2.011	0.300	0.19789	1	7.861	0.009
9 X24	-7.791	4.114	-0.203	0.19830	1	3.588	0.068
10 X32	-1.753	2.461	-0.087	0.15332	1	0.507	0.482
11 X33	-3.046	3.119	-0.162	0.08225	1	0.954	0.337
12 X34	3.441	2.317	0.198	0.12780	1	2.205	0.148
13 X35	-1.574	1.888	-0.080	0.24592	1	0.695	0.411
15 X52	3.169	2.549	0.161	0.13501	1	1.546	0.224
16 X62	-3.224	3.507	-0.135	0.10455	1	0.845	0.366
17 X63	-1.609	1.931	-0.092	0.18474	1	0.694	0.412
18 X71	0.972	2.509	0.052	0.12509	1	0.150	0.701
19 X81	7.542	3.028	0.373	0.10127	1	6.203	0.019
Out	**Part. Corr.**						
2 X0	-0.029	.	.	0.76951	1	0.024	0.879
8 X23	-0.006	.	.	0.18080	1	0.001	0.973
14 X42	0.007	.	.	0.21096	1	0.002	0.969

Step # 4 R = 0.966 R-Square = 0.934
Term removed: X21

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
3 X12	9.673	2.909	0.471	0.10937	1	11.059	0.002
4 X13	4.325	2.877	0.128	0.30327	1	2.259	0.143
5 X15	4.151	1.580	0.211	0.33981	1	6.901	0.013
7 X22	5.686	1.969	0.303	0.19993	1	8.340	0.007
9 X24	-8.196	3.682	-0.213	0.23972	1	4.955	0.034

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
10 X32	-1.798	2.415	-0.089	0.15426	1	0.555	0.462
11 X33	-2.837	2.944	-0.151	0.08945	1	0.929	0.343
12 X34	3.493	2.270	0.201	0.12896	1	2.367	0.134
13 X35	-1.689	1.796	-0.086	0.26339	1	0.885	0.354
15 X52	3.202	2.505	0.163	0.13541	1	1.634	0.211
16 X62	-3.035	3.361	-0.127	0.11031	1	0.816	0.374
17 X63	-1.710	1.854	-0.098	0.19413	1	0.850	0.364
18 X71	1.103	2.408	0.059	0.13149	1	0.210	0.650
19 X81	7.779	2.813	0.384	0.11368	1	7.648	0.010

Out	Part. Corr.						
2 X0	-0.030	.	.	0.77023	1	0.027	0.871
6 X21	0.044	.	.	0.15410	1	0.056	0.815
8 X23	-0.013	.	.	0.18533	1	0.005	0.943
14 X42	0.025	.	.	0.25406	1	0.018	0.894

Step # 5 R = 0.966 R-Square = 0.934
Term removed: X71

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
3 X12	10.063	2.746	0.490	0.11959	1	13.429	0.001
4 X13	4.407	2.835	0.130	0.30446	1	2.417	0.130
5 X15	4.310	1.521	0.219	0.35717	1	8.027	0.008
7 X22	5.847	1.913	0.311	0.20649	1	9.346	0.005
9 X24	-8.435	3.598	-0.219	0.24461	1	5.495	0.026
10 X32	-1.696	2.373	-0.084	0.15558	1	0.511	0.480
11 X33	-3.555	2.459	-0.189	0.12492	1	2.091	0.158
12 X34	4.187	1.670	0.241	0.23232	1	6.287	0.018
13 X35	-1.476	1.712	-0.075	0.28230	1	0.743	0.395
15 X52	3.354	2.451	0.171	0.13782	1	1.873	0.181
16 X62	-3.346	3.249	-0.140	0.11500	1	1.060	0.311
17 X63	-1.865	1.799	-0.107	0.20088	1	1.075	0.308
19 X81	8.284	2.554	0.409	0.13436	1	10.521	0.003

Out	Part. Corr.						
2 X0	-0.030	.	.	0.77026	1	0.027	0.872
6 X21	0.061	.	.	0.16198	1	0.112	0.740
8 X23	-0.039	.	.	0.20699	1	0.047	0.830
14 X42	0.009	.	.	0.26315	1	0.002	0.962
18 X71	0.083	.	.	0.13149	1	0.210	0.650

Step # 6 R = 0.966 R-Square = 0.933
Term removed: X32

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
3 X12	10.580	2.628	0.515	0.12853	1	16.203	0.000
4 X13	4.004	2.756	0.118	0.31701	1	2.110	0.156
5 X15	4.034	1.460	0.205	0.38185	1	7.633	0.009
7 X22	5.205	1.676	0.277	0.26479	1	9.647	0.004
9 X24	-7.465	3.307	-0.194	0.28519	1	5.096	0.031
11 X33	-3.826	2.411	-0.204	0.12795	1	2.518	0.122
12 X34	4.174	1.657	0.240	0.23234	1	6.347	0.017
13 X35	-1.697	1.671	-0.086	0.29179	1	1.031	0.318
15 X52	2.870	2.337	0.146	0.14922	1	1.508	0.228
16 X62	-3.045	3.197	-0.128	0.11696	1	0.907	0.348
17 X63	-1.572	1.738	-0.090	0.21190	1	0.818	0.373
19 X81	7.102	1.930	0.351	0.23157	1	13.532	0.001

Out Part. Corr.

2 X0	0.011	.	.	0.85244	1	0.004	0.949
6 X21	0.068	.	.	0.16249	1	0.142	0.709
8 X23	-0.073	.	.	0.22410	1	0.165	0.687
10 X32	-0.127	.	.	0.15558	1	0.511	0.490
14 X42	0.017	.	.	0.26418	1	0.009	0.927
18 X71	0.071	.	.	0.13261	1	0.155	0.696

Step # 7 R = 0.965 R-Square = 0.931
Term removed: X63

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
3 X12	9.910	2.515	0.493	0.13963	1	15.529	0.000
4 X13	4.009	2.749	0.119	0.31701	1	2.127	0.154
5 X15	3.860	1.443	0.196	0.38857	1	7.152	0.012
7 X22	4.923	1.642	0.262	0.27433	1	8.988	0.005
9 X24	-6.879	3.234	-0.179	0.29657	1	4.525	0.041
11 X33	-3.487	2.375	-0.186	0.13111	1	2.155	0.152
12 X34	3.746	1.583	0.215	0.25304	1	5.597	0.024
13 X35	-1.845	1.659	-0.094	0.29462	1	1.237	0.274
15 X52	1.695	1.937	0.086	0.21596	1	0.765	0.388
16 X62	-1.835	2.896	-0.077	0.14180	1	0.402	0.531
19 X81	6.503	1.808	0.321	0.26245	1	12.930	0.001
Out	Part. Corr.						
2 X0	-0.001	.	.	0.85794	1	0.000	0.994
6 X21	0.104	.	.	0.17335	1	0.351	0.559
8 X23	-0.074	.	.	0.22414	1	0.176	0.678
10 X32	-0.086	.	.	0.16411	1	0.241	0.627
14 X42	0.052	.	.	0.27996	1	0.088	0.769
17 X63	-0.158	.	.	0.21190	1	0.818	0.373
18 X71	0.101	.	.	0.13859	1	0.330	0.570

Step # 8 R = 0.964 R-Square = 0.930
Term removed: X62

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
3 X12	9.136	2.179	0.445	0.18270	1	17.579	0.000
4 X13	3.702	2.682	0.109	0.32719	1	1.905	0.177
5 X15	3.624	1.382	0.184	0.41624	1	6.875	0.013
7 X22	4.539	1.513	0.242	0.31748	1	9.002	0.005
9 X24	-6.982	3.201	-0.182	0.29733	1	4.758	0.036
11 X33	-3.113	2.280	-0.166	0.13973	1	1.864	0.181
12 X34	4.236	1.369	0.243	0.33248	1	9.575	0.004
13 X35	-2.161	1.568	-0.110	0.32391	1	1.899	0.177
15 X52	0.963	1.543	0.049	0.33464	1	0.390	0.536
19 X81	6.488	1.792	0.321	0.26249	1	13.104	0.001
Out	Part. Corr.						
2 X0	-0.013	.	.	0.86723	1	0.005	0.942
6 X21	0.065	.	.	0.19167	1	0.138	0.713
8 X23	-0.095	.	.	0.23462	1	0.301	0.587
10 X32	-0.082	.	.	0.16431	1	0.223	0.640
14 X42	0.081	.	.	0.30272	1	0.216	0.645
16 X62	-0.110	.	.	0.14180	1	0.402	0.531
17 X63	-0.097	.	.	0.25692	1	0.311	0.581
18 X71	0.115	.	.	0.14131	1	0.439	0.512

Step # 9 R = 0.964 R-Square = 0.929
Term removed: X52

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
3 X12	8.899	2.127	0.434	0.18841	1	17.505	0.000
4 X13	4.134	2.569	0.122	0.35048	1	2.590	0.117
5 X15	3.579	1.368	0.182	0.41738	1	6.843	0.013
7 X22	4.646	1.490	0.247	0.32164	1	9.726	0.004
9 X24	-6.924	3.172	-0.180	0.29758	1	4.766	0.036
11 X33	-2.352	1.910	-0.125	0.19564	1	1.515	0.227
12 X34	4.272	1.356	0.246	0.33306	1	9.927	0.003
13 X35	-1.877	1.487	-0.095	0.35362	1	1.592	0.215
19 X81	6.054	1.638	0.299	0.30888	1	13.665	0.001
Out	Part. Corr.						
2 X0	0.004	.	.	0.88839	1	0.001	0.982
6 X21	0.077	.	.	0.19478	1	0.203	0.655
8 X23	-0.080	.	.	0.23867	1	0.218	0.644
10 X32	-0.059	.	.	0.17112	1	0.117	0.734
14 X42	0.065	.	.	0.30824	1	0.145	0.705
15 X52	0.106	.	.	0.33464	1	0.390	0.536
16 X62	-0.024	.	.	0.21973	1	0.020	0.889
17 X63	-0.044	.	.	0.30797	1	0.067	0.797
18 X71	0.110	.	.	0.14149	1	0.418	0.522

Step # 10 R = 0.962 R-Square = 0.926
Term removed: X33

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
3 X12	7.846	1.961	0.382	0.22478	1	16.004	0.000
4 X13	4.258	2.585	0.126	0.35103	1	2.713	0.108
5 X15	3.804	1.366	0.194	0.42497	1	7.760	0.008
7 X22	3.861	1.356	0.206	0.39388	1	8.108	0.007
9 X24	-7.013	3.194	-0.182	0.29773	1	4.822	0.035
12 X34	3.983	1.345	0.229	0.34333	1	8.771	0.005
13 X35	-2.118	1.485	-0.108	0.35988	1	2.035	0.162
19 X81	5.732	1.628	0.283	0.31696	1	12.394	0.001
Out	Part. Corr.						
2 X0	0.014	.	.	0.89072	1	0.007	0.933
6 X21	0.023	.	.	0.20725	1	0.019	0.892
8 X23	-0.034	.	.	0.24928	1	0.042	0.840
10 X32	-0.123	.	.	0.19366	1	0.542	0.466
11 X33	-0.204	.	.	0.19564	1	1.515	0.227
14 X42	0.143	.	.	0.37377	1	0.734	0.397
15 X52	-0.021	.	.	0.46854	1	0.015	0.903
16 X62	-0.050	.	.	0.22361	1	0.089	0.767
17 X63	-0.085	.	.	0.32210	1	0.256	0.616
18 X71	0.204	.	.	0.20752	1	1.520	0.226

Dep Var: PPF N: 45 Multiple R: 0.962 Squared multiple R: 0.926

Adjusted squared multiple R: 0.910 Standard error of estimate: 2.643

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	76.666	1.793	0.000	.	42.750	0.000

X12	7.846	1.961	0.382	0.225	4.001	0.000
X13	4.258	2.585	0.126	0.351	1.647	0.108
X15	3.804	1.366	0.194	0.425	2.786	0.008
X22	3.861	1.356	0.206	0.394	2.847	0.007
X24	-7.013	3.194	-0.182	0.298	-2.196	0.035
X34	3.983	1.345	0.229	0.343	2.962	0.005
X35	-2.118	1.485	-0.108	0.360	-1.426	0.162
X81	5.732	1.628	0.283	0.317	3.520	0.001

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	3152.243	8	394.030	56.419	0.000
Residual	251.426	36	6.984		

Appendix 5c

Detailed Project Data

Backward Stepping

Force 18 variables into the model

Step # 0 R = 0.967 R-Square = 0.934

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X12	9.599	4.573	0.468	0.05092	1	4.407	0.046
3 X13	4.290	3.117	0.127	0.29731	1	1.895	0.180
4 X15	3.960	2.118	0.201	0.21760	1	3.496	0.073
5 X0	-0.068	0.488	-0.008	0.71017	1	0.020	0.890
6 X21	0.500	2.807	0.026	0.11868	1	0.032	0.860
7 X22	5.658	2.478	0.301	0.14517	1	5.212	0.031
8 X23	-0.015	2.697	-0.001	0.15353	1	0.000	0.996
9 X24	-7.843	4.408	-0.204	0.19248	1	3.166	0.087
10 X32	-1.870	2.975	-0.092	0.11691	1	0.395	0.535
11 X33	-2.990	3.914	-0.159	0.05820	1	0.584	0.452
12 X34	3.422	2.610	0.197	0.11229	1	1.719	0.201
13 X35	-1.606	2.148	-0.082	0.21191	1	0.559	0.461
14 X42	0.067	1.998	0.004	0.19151	1	0.001	0.974
15 X52	3.187	2.800	0.162	0.12462	1	1.295	0.266
16 X62	-3.097	4.459	-0.130	0.07209	1	0.482	0.493
17 X63	-1.595	2.081	-0.091	0.17726	1	0.587	0.451
18 X71	1.001	2.837	0.054	0.10905	1	0.124	0.727
19 X81	7.659	3.418	0.378	0.08855	1	5.020	0.034

Out	Part. Corr.
none	

Dependent Variable PPF
Minimum tolerance for entry into model = 0.000000
Backward stepwise regression with F-to-Enter=4.000 and F-to-Remove=3.900
Backward stepwise with first 19 variables forced in model.
F-to-Enter=4.000 and F-to-Remove=3.900 Max # steps= 38
Nothing to do!

Dep Var: PPF N: 45 Multiple R: 0.967 Squared multiple R: 0.934

Adjusted squared multiple R: 0.889 Standard error of estimate: 2.933

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	77.048	2.301	0.000	.	33.484	0.000
X12	9.599	4.573	0.468	0.051	2.099	0.046
X13	4.290	3.117	0.127	0.297	1.376	0.180
X15	3.960	2.118	0.201	0.218	1.870	0.073
X0	-0.068	0.488	-0.008	0.710	-0.140	0.890
X21	0.500	2.807	0.026	0.119	0.178	0.860
X22	5.658	2.478	0.301	0.145	2.283	0.031
X23	-0.015	2.697	-0.001	0.154	-0.005	0.996
X24	-7.843	4.408	-0.204	0.192	-1.779	0.087
X32	-1.870	2.975	-0.092	0.117	-0.629	0.535
X33	-2.990	3.914	-0.159	0.058	-0.764	0.452
X34	3.422	2.610	0.197	0.112	1.311	0.201
X35	-1.606	2.148	-0.082	0.212	-0.748	0.461
X42	0.067	1.998	0.004	0.192	0.033	0.974
X52	3.187	2.800	0.162	0.125	1.138	0.266
X62	-3.097	4.459	-0.130	0.072	-0.695	0.493
X63	-1.595	2.081	-0.091	0.177	-0.766	0.451
X71	1.001	2.837	0.054	0.109	0.353	0.727
X81	7.659	3.418	0.378	0.089	2.240	0.034

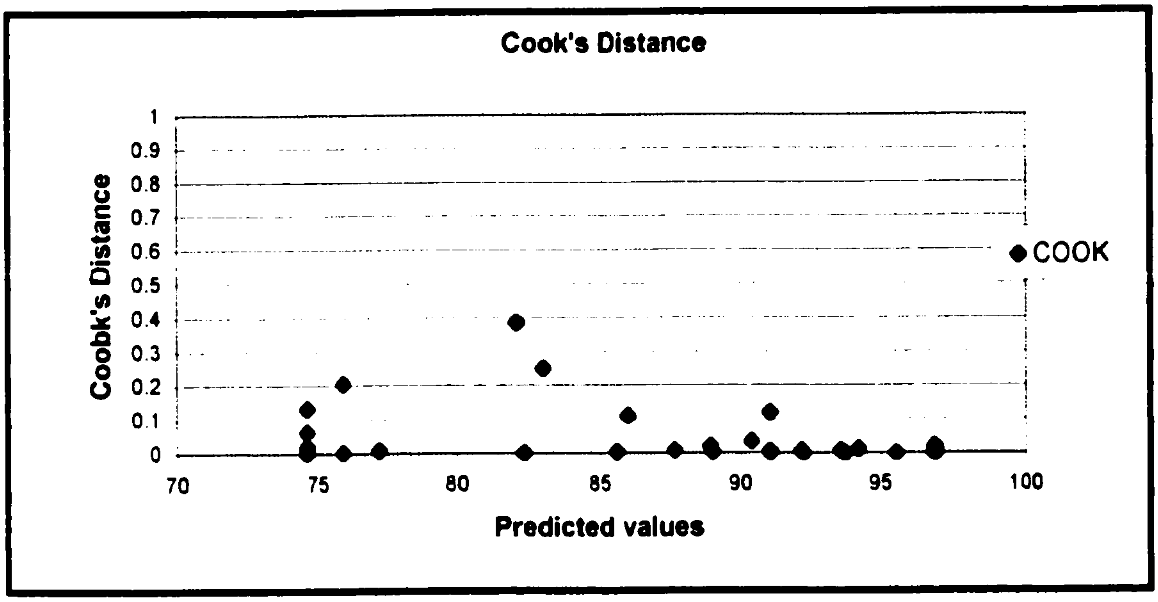
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	3180.062	18	176.670	20.542	0.000
Residual	223.606	26	8.600		

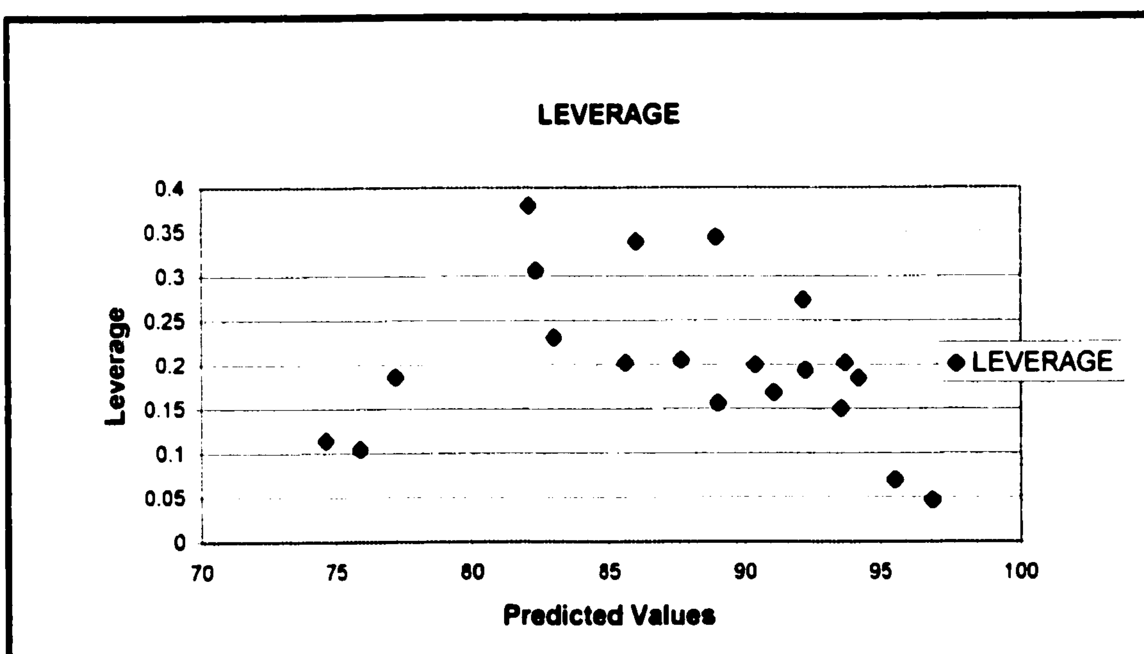
Appendix 5d

Residuals Plots

No.	PREDICTION	RESIDUAL	LEVERAGE	COOK
1	92.13706522	-0.857065217	0.272704791	0.00847
2	82.0111472	4.188852797	0.379623805	0.387088
3	75.92625316	-8.386253165	0.105045303	0.206294
4	88.95674216	1.063257839	0.343521727	0.020154
5	91.03057075	-0.530570754	0.168840749	0.001539
6	96.88493744	2.38506256	0.046966435	0.006579
7	96.88493744	1.68506256	0.046966435	0.003284
8	96.88493744	1.75506256	0.046966435	0.003562
9	96.88493744	2.46506256	0.046966435	0.007028
10	91.03057075	-1.110570754	0.168840749	0.006742
11	90.36432447	-2.224324475	0.199750223	0.034515
12	91.03057075	-4.720570754	0.168840749	0.121807
13	75.92625316	1.133746835	0.105045303	0.00377
14	94.21089381	1.399106191	0.185289531	0.012221
15	77.26327498	1.22672502	0.186402011	0.009478
16	96.88493744	-4.26493744	0.046966435	0.021036
17	96.88493744	-1.93493744	0.046966435	0.00433
18	87.69028084	1.079719156	0.205289824	0.008475
19	86.01768339	1.892316609	0.338865386	0.111625
20	82.27616234	-0.266162342	0.306770864	0.001011
21	96.88493744	-1.66493744	0.046966435	0.003206
22	96.88493744	-0.63493744	0.046966435	0.000466
23	96.88493744	0.08506256	0.046966435	8.37E-06
24	74.58923135	-6.389231349	0.114881804	0.133882
25	96.88493744	-0.38493744	0.046966435	0.000171
26	95.54791562	-0.017915625	0.070531378	5.86E-07
27	74.58923135	-2.489231349	0.114881804	0.020321
28	96.88493744	1.09506256	0.046966435	0.001387
29	95.54791562	-0.017915625	0.070531378	5.86E-07
30	74.58923135	0.610768651	0.114881804	0.001223
31	96.88493744	2.49506256	0.046966435	0.0072
32	96.88493744	1.18506256	0.046966435	0.001624
33	85.61645225	0.783547748	0.201883603	0.004352
34	74.58923135	1.260768651	0.114881804	0.005213
35	96.88493744	-1.03493744	0.046966435	0.001239
36	96.88493744	-1.72493744	0.046966435	0.003441
37	93.54464753	-1.344647531	0.15061254	0.008442
38	96.88493744	-0.27493744	0.046966435	8.74E-05
39	96.88493744	-0.28493744	0.046966435	9.39E-05
40	74.58923135	2.560768651	0.114881804	0.021506
41	92.20762572	-0.107625715	0.193637187	7.71E-05
42	89.02730266	0.772697341	0.156923419	0.002948
43	82.94240862	5.357591379	0.231108708	0.250958
44	93.70461438	-0.204614384	0.202220555	0.000298
45	74.58923135	4.390768651	0.114881804	0.063227



Cook's Distance
Coobk's Distance
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
70
75
80
85
90
95
100
Predicted values
COOK



LEVERAGE
Leverage
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
70
75
80
85
90
95
100
Predicted Values
LEVERAGE

Appendix 6

Detailed Project Data

Forward Stepping

Step # 0 R = 0.000 R-Square = 0.000

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
Out	Part. Corr.						
2 X0	0.241	.	.	1.00000	1	2.642	0.111
3 X12	0.883	.	.	1.00000	1	152.680	0.000
4 X13	0.524	.	.	1.00000	1	16.234	0.000
5 X15	0.571	.	.	1.00000	1	20.755	0.000
6 X21	0.840	.	.	1.00000	1	102.746	0.000
7 X22	0.799	.	.	1.00000	1	75.904	0.000
8 X23	0.725	.	.	1.00000	1	47.666	0.000
9 X24	0.590	.	.	1.00000	1	22.943	0.000
10 X32	0.743	.	.	1.00000	1	53.107	0.000
11 X33	0.808	.	.	1.00000	1	81.014	0.000
12 X34	0.773	.	.	1.00000	1	63.753	0.000
13 X35	0.533	.	.	1.00000	1	17.061	0.000
14 X38	0.095	.	.	1.00000	1	0.394	0.533
15 X42	0.686	.	.	1.00000	1	38.226	0.000
16 X52	0.523	.	.	1.00000	1	16.213	0.000
17 X62	0.684	.	.	1.00000	1	37.870	0.000
18 X63	0.718	.	.	1.00000	1	45.718	0.000
19 X71	0.764	.	.	1.00000	1	60.221	0.000
20 X81	0.833	.	.	1.00000	1	97.396	0.000

Dependent Variable PPF
Minimum tolerance for entry into model = 0.000000
Forward stepwise regression with F-to-Enter=4.000 and F-to-Remove=3.900
Step # 1 R = 0.883 R-Square = 0.780
Term entered: X12

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
3 X12	18.132	1.467	0.883	1.00000	1	152.680	0.000
Out	Part. Corr.						
2 X0	0.005	.	.	0.92717	1	0.001	0.975
4 X13	0.235	.	.	0.76605	1	2.447	0.125
5 X15	0.512	.	.	0.84285	1	14.929	0.000
6 X21	0.585	.	.	0.44884	1	21.895	0.000
7 X22	0.471	.	.	0.45953	1	11.957	0.001
8 X23	0.207	.	.	0.44034	1	1.872	0.178
9 X24	0.045	.	.	0.57802	1	0.085	0.772
10 X32	0.560	.	.	0.63421	1	19.206	0.000
11 X33	0.237	.	.	0.28011	1	2.498	0.121
12 X34	0.515	.	.	0.54748	1	15.150	0.000
13 X35	0.360	.	.	0.81429	1	6.257	0.016
14 X38	-0.019	.	.	0.98607	1	0.015	0.902
15 X42	0.337	.	.	0.59183	1	5.395	0.025
16 X52	0.221	.	.	0.75966	1	2.153	0.150
17 X62	0.211	.	.	0.51800	1	1.949	0.170
18 X63	0.393			0.57053	1	7.650	0.008

```
 19 X71                0.601        .         .    0.62479   1  23.767   0.000
 20 X81                0.474        .         .    0.37925   1  12.198   0.001
--------------------------------------------------------------------------------

Step # 2 R =  0.927 R-Square =  0.860
Term entered: X71

Effect              Coefficient   Std Error  Std Coef     Tol.  df        F      'P'

In
___
  1 Constant
  3 X12               13.649        1.501      0.665 0.62479   1  82.677   0.000
 19 X71                6.644        1.363      0.357 0.62479   1  23.767   0.000

Out                 Part. Corr.
___
  2 X0                 0.072        .         .    0.92005   1   0.216   0.645
  4 X13                0.195        .         .    0.75236   1   1.618   0.211
  5 X15                0.258        .         .    0.56902   1   2.925   0.095
  6 X21                0.439        .         .    0.35639   1   9.784   0.003
  7 X22                0.516        .         .    0.45492   1  14.900   0.000
  8 X23                0.117        .         .    0.42431   1   0.570   0.454
  9 X24               -0.026        .         .    0.57115   1   0.027   0.870
 10 X32                0.438        .         .    0.53415   1   9.745   0.003
 11 X33                0.325        .         .    0.27972   1   4.841   0.033
 12 X34                0.154        .         .    0.26954   1   1.000   0.323
 13 X35                0.030        .         .    0.55349   1   0.037   0.848
 14 X38               -0.023        .         .    0.98607   1   0.022   0.883
 15 X42                0.175        .         .    0.52204   1   1.288   0.263
 16 X52                0.228        .         .    0.75652   1   2.258   0.141
 17 X62                0.223        .         .    0.51644   1   2.139   0.151
 18 X63                0.220        .         .    0.48693   1   2.085   0.156
 20 X81                0.321        .         .    0.31945   1   4.722   0.036
--------------------------------------------------------------------------------

Step # 3 R =  0.947 R-Square =  0.897
Term entered: X22

Effect              Coefficient   Std Error  Std Coef     Tol.  df        F      'P'

In
___
  1 Constant
  3 X12                9.632        1.666      0.469 0.38102   1  33.416   0.000
  7 X22                5.387        1.396      0.287 0.45492   1  14.900   0.000
 19 X71                6.185        1.187      0.332 0.61852   1  27.136   0.000

Out                 Part. Corr.
___
  2 X0                 0.014        .         .    0.90756   1   0.008   0.928
  4 X13                0.140        .         .    0.73596   1   0.800   0.377
  5 X15                0.300        .         .    0.56902   1   3.965   0.053
  6 X21                0.303        .         .    0.30327   1   4.052   0.051
  8 X23                0.060        .         .    0.41731   1   0.144   0.707
  9 X24                0.014        .         .    0.56809   1   0.008   0.930
 10 X32                0.219        .         .    0.37558   1   2.006   0.164
 11 X33                0.104        .         .    0.21603   1   0.441   0.510
 12 X34                0.077        .         .    0.26143   1   0.237   0.629
 13 X35                0.032        .         .    0.55347   1   0.040   0.843
 14 X38               -0.035        .         .    0.98588   1   0.050   0.824
 15 X42                0.114        .         .    0.51014   1   0.527   0.472
 16 X52                0.057        .         .    0.66190   1   0.132   0.719
 17 X62                0.057        .         .    0.45578   1   0.130   0.721
 18 X63                0.106        .         .    0.45486   1   0.452   0.505
 20 X81                0.333        .         .    0.31782   1   4.992   0.031
--------------------------------------------------------------------------------

Step # 4 R =  0.953 R-Square =  0.908
Term entered: X81

Effect              Coefficient   Std Error  Std Coef     Tol.  df        F      'P'
```

In								
1	Constant							
3	X12	7.462	1.864	0.364	0.27756	1	16.034	0.000
7	X22	5.174	1.336	0.275	0.45260	1	15.008	0.000
19	X71	5.110	1.231	0.274	0.52410	1	17.225	0.000
20	X81	3.836	1.717	0.190	0.31782	1	4.992	0.031

Out		Part. Corr.						
2	X0	-0.007	.	.	0.90395	1	0.002	0.965
4	X13	0.065	.	.	0.69310	1	0.166	0.686
5	X15	0.289	.	.	0.56460	1	3.541	0.067
6	X21	0.222	.	.	0.27327	1	2.018	0.163
8	X23	0.165	.	.	0.38664	1	1.097	0.301
9	X24	-0.101	.	.	0.51205	1	0.403	0.529
10	X32	0.046	.	.	0.26266	1	0.081	0.778
11	X33	0.029	.	.	0.20435	1	0.034	0.855
12	X34	0.188	.	.	0.24080	1	1.433	0.238
13	X35	0.024	.	.	0.55310	1	0.023	0.880
14	X38	-0.077	.	.	0.97384	1	0.233	0.632
15	X42	0.236	.	.	0.46520	1	2.309	0.137
16	X52	0.103	.	.	0.65281	1	0.417	0.522
17	X62	0.039	.	.	0.45405	1	0.058	0.811
18	X63	0.099	.	.	0.45426	1	0.389	0.537

Dep Var: PPF   N: 45   Multiple R: 0.953   Squared multiple R: 0.908

Adjusted squared multiple R: 0.899   Standard error of estimate: 2.790

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	74.938	0.868	0.000	.	86.305	0.000
X12	7.462	1.864	0.364	0.278	4.004	0.000
X22	5.174	1.336	0.275	0.453	3.874	0.000
X71	5.110	1.231	0.274	0.524	4.150	0.000
X81	3.836	1.717	0.190	0.318	2.234	0.031

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	3092.205	4	773.051	99.280	0.000
Residual	311.463	40	7.787		

Appendix 7

Summarized Project Data

Backward Stepping

Step # 0 R = 0.949 R-Square = 0.900

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 LP	4.116	1.080	0.524	0.14641	1	14.523	0.001
3 X21	2.795	2.000	0.145	0.25613	1	1.952	0.171
4 LS	3.422	0.915	0.447	0.19385	1	13.994	0.001
5 LC	-0.301	0.675	-0.040	0.35141	1	0.199	0.658
6 LQ	-1.383	0.708	-0.183	0.31469	1	3.812	0.059
7 LCOM	-2.408	1.042	-0.261	0.21727	1	5.337	0.027
8 LSAF	1.162	0.825	0.158	0.22049	1	1.983	0.168
9 X81	3.207	1.993	0.158	0.28558	1	2.588	0.116
Out	Part. Corr.						
none							

Dependent Variable PPF
Minimum tolerance for entry into model = 0.000000
Backward stepwise regression with F-to-Enter=4.000 and F-to-Remove=3.900
Step # 1 R = 0.949 R-Square = 0.900
Term removed: LC

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 LP	3.921	0.977	0.499	0.17514	1	16.111	0.000
3 X21	2.769	1.978	0.144	0.25634	1	1.960	0.170
4 LS	3.401	0.904	0.444	0.19437	1	14.166	0.001
6 LQ	-1.323	0.688	-0.175	0.32645	1	3.699	0.062
7 LCOM	-2.448	1.027	-0.265	0.21891	1	5.681	0.022
8 LSAF	1.071	0.791	0.146	0.23469	1	1.834	0.184
9 X81	3.339	1.950	0.165	0.29206	1	2.934	0.095
Out	Part. Corr.						
5 LC	-0.074	.	.	0.35141	1	0.199	0.658

Step # 2 R = 0.946 R-Square = 0.895
Term removed: LSAF

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 LP	3.860	0.986	0.492	0.17551	1	15.312	0.000
3 X21	2.778	1.999	0.144	0.25634	1	1.930	0.173
4 LS	3.483	0.911	0.455	0.19526	1	14.612	0.000
6 LQ	-0.895	0.618	-0.119	0.41366	1	2.100	0.156
7 LCOM	-1.905	0.956	-0.206	0.25832	1	3.971	0.054
9 X81	3.979	1.912	0.197	0.31026	1	4.330	0.044
Out	Part. Corr.						
5 LC	-0.017	.	.	0.37404	1	0.010	0.919
8 LSAF	0.217	.	.	0.23469	1	1.834	0.184

Step # 3 R = 0.943 R-Square = 0.889
Term removed: X21

In

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
1 Constant							
2 LP	4.302	0.945	0.548	0.19582	1	20.720	0.000
4 LS	3.772	0.898	0.493	0.20600	1	17.659	0.000
6 LQ	-0.875	0.625	-0.116	0.41389	1	1.960	0.169
7 LCOM	-1.922	0.967	-0.208	0.25837	1	3.951	0.054
9 X81	4.831	1.832	0.239	0.34589	1	6.951	0.012

Out

Effect	Part. Corr.						
3 X21	0.220	.	.	0.25634	1	1.930	0.173
5 LC	-0.010	.	.	0.37435	1	0.004	0.951
8 LSAF	0.213	.	.	0.23469	1	1.801	0.188

Step # 4 R = 0.940 R-Square = 0.884
Term removed: LQ

In

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
1 Constant							
2 LP	3.573	0.798	0.455	0.28096	1	20.033	0.000
4 LS	3.831	0.907	0.501	0.20645	1	17.826	0.000
7 LCOM	-2.099	0.970	-0.227	0.26284	1	4.680	0.037
9 X81	5.282	1.826	0.261	0.35688	1	8.371	0.006

Out

Effect	Part. Corr.						
3 X21	0.209	.	.	0.25649	1	1.787	0.189
5 LC	0.008	.	.	0.37693	1	0.003	0.959
6 LQ	-0.219	.	.	0.41389	1	1.960	0.169
8 LSAF	0.084	.	.	0.29744	1	0.276	0.602

Dep Var: PPF N: 45 Multiple R: 0.940 Squared multiple R: 0.884

Adjusted squared multiple R: 0.872 Standard error of estimate: 3.144

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	67.062	1.914	0.000	.	35.028	0.000
LP	3.573	0.798	0.455	0.281	4.476	0.000
LS	3.831	0.907	0.501	0.206	4.222	0.000
LCOM	-2.099	0.970	-0.227	0.263	-2.163	0.037
X81	5.282	1.826	0.261	0.357	2.893	0.006

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	3008.281	4	752.070	76.084	0.000
Residual	395.387	40	9.885		

Appendix 8

Summarised Project Data

Forward Stepping

```
Step # 0 R =  0.000 R-Square =  0.000

Effect              Coefficient   Std Error  Std Coef     Tol.  df         F      'P'

In
___
  1 Constant

Out                 Part. Corr.
___
  2 LP                    0.848         .          .   1.00000   1 110.125    0.000
  3 X21                   0.840         .          .   1.00000   1 102.746    0.000
  4 LS                    0.875         .          .   1.00000   1 140.176    0.000
  5 LC                    0.664         .          .   1.00000   1  33.963    0.000
  6 LQ                    0.527         .          .   1.00000   1  16.548    0.000
  7 LCOM                  0.693         .          .   1.00000   1  39.653    0.000
  8 LSAF                  0.723         .          .   1.00000   1  47.014    0.000
  9 X81                   0.833         .          .   1.00000   1  97.396    0.000
-------------------------------------------------------------------------------


Dependent Variable PPF
Minimum tolerance for entry into model = 0.000000
Forward stepwise regression with F-to-Enter=4.000 and F-to-Remove=3.900
Step # 1 R =  0.875 R-Square =  0.765
Term entered: LS

Effect              Coefficient   Std Error  Std Coef     Tol.  df         F      'P'

In
___
  1 Constant
  4 LS                    6.693       0.565      0.875 1.00000   1 140.176    0.000

Out                 Part. Corr.
___
  2 LP                    0.544         .          .   0.38901   1  17.614    0.000
  3 X21                   0.498         .          .   0.37395   1  13.830    0.001
  5 LC                    0.221         .          .   0.55304   1   2.147    0.150
  6 LQ                    0.126         .          .   0.70408   1   0.679    0.415
  7 LCOM                 -0.050         .          .   0.34698   1   0.105    0.747
  8 LSAF                  0.227         .          .   0.44976   1   2.285    0.139
  9 X81                   0.507         .          .   0.40040   1  14.551    0.000
-------------------------------------------------------------------------------

Step # 2 R =  0.914 R-Square =  0.835
Term entered: LP

Effect              Coefficient   Std Error  Std Coef     Tol.  df         F      'P'

In
___
  1 Constant
  2 LP                    3.316       0.790      0.422 0.38901   1  17.614    0.000
  4 LS                    4.168       0.770      0.545 0.38901   1  29.314    0.000

Out                 Part. Corr.
___
  3 X21                   0.322         .          .   0.28834   1   4.756    0.035
  5 LC                   -0.099         .          .   0.39514   1   0.402    0.530
  6 LQ                   -0.311         .          .   0.44026   1   4.399    0.042
  7 LCOM                 -0.388         .          .   0.27834   1   7.271    0.010
  8 LSAF                 -0.028         .          .   0.35606   1   0.032    0.858
  9 X81                   0.464         .          .   0.37793   1  11.258    0.002
-------------------------------------------------------------------------------

Step # 3 R =  0.933 R-Square =  0.870
Term entered: X81

Effect              Coefficient   Std Error  Std Coef     Tol.  df         F      'P'

In
___
  1 Constant
```

	Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
2	LP	2.736	0.729	0.348	0.36718	1	14.089	0.001
4	LS	2.790	0.803	0.365	0.28729	1	12.070	0.001
9	X81	6.214	1.852	0.307	0.37793	1	11.258	0.002
Out		Part. Corr.						
3	X21	0.201	.	.	0.25651	1	1.690	0.201
5	LC	-0.051	.	.	0.38991	1	0.106	0.747
6	LQ	-0.247	.	.	0.42105	1	2.609	0.114
7	LCOM	-0.324	.	.	0.26284	1	4.680	0.037
8	LSAF	-0.058	.	.	0.35518	1	0.134	0.716

Step # 4 R = 0.940 R-Square = 0.884
Term entered: LCOM

Effect		Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In								
1	Constant							
2	LP	3.573	0.798	0.455	0.28096	1	20.033	0.000
4	LS	3.831	0.907	0.501	0.20645	1	17.826	0.000
7	LCOM	-2.099	0.970	-0.227	0.26284	1	4.680	0.037
9	X81	5.282	1.826	0.261	0.35688	1	8.371	0.006
Out		Part. Corr.						
3	X21	0.209	.	.	0.25649	1	1.787	0.189
5	LC	0.008	.	.	0.37693	1	0.003	0.959
6	LQ	-0.219	.	.	0.41389	1	1.960	0.169
8	LSAF	0.084	.	.	0.29744	1	0.276	0.602

Dep Var: PPF N: 45 Multiple R: 0.940 Squared multiple R: 0.884

Adjusted squared multiple R: 0.872 Standard error of estimate: 3.144

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	67.062	1.914	0.000	.	35.028	0.000
LP	3.573	0.798	0.455	0.281	4.476	0.000
LS	3.831	0.907	0.501	0.206	4.222	0.000
LCOM	-2.099	0.970	-0.227	0.263	-2.163	0.037
X81	5.282	1.826	0.261	0.357	2.893	0.006

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	3008.281	4	752.070	76.084	0.000
Residual	395.387	40	9.885		

Appendix 9

Schedule Performance

Backward Stepping

Step # 0 R = 0.924 R-Square = 0.855

Effect		Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In								
1	Constant							
2	X0	-2.102	0.713	-0.262	0.71017	1	8.687	0.007
3	X12	23.723	6.680	1.177	0.05092	1	12.610	0.001
4	X13	0.203	4.554	0.006	0.29731	1	0.002	0.965
5	X15	7.987	3.094	0.414	0.21760	1	6.662	0.016
6	X21	7.697	4.100	0.407	0.11868	1	3.524	0.072
7	X22	1.416	3.621	0.077	0.14517	1	0.153	0.699
8	X23	-3.230	3.940	-0.156	0.15353	1	0.672	0.420
9	X24	14.790	6.439	0.391	0.19248	1	5.275	0.030
10	X32	9.812	4.346	0.494	0.11691	1	5.097	0.033
11	X33	-18.865	5.719	-1.022	0.05820	1	10.882	0.003
12	X34	1.534	3.813	0.090	0.11229	1	0.162	0.691
13	X35	8.873	3.137	0.459	0.21191	1	7.999	0.009
14	X42	0.366	2.920	0.021	0.19151	1	0.016	0.901
15	X52	2.321	4.091	0.120	0.12462	1	0.322	0.575
16	X62	-15.922	6.515	-0.681	0.07209	1	5.973	0.022
17	X63	1.666	3.041	0.097	0.17726	1	0.300	0.589
18	X71	-13.790	4.145	-0.753	0.10905	1	11.071	0.003
19	X81	-2.419	4.994	-0.122	0.08855	1	0.235	0.632
Out		Part. Corr.						
	none							

Dependent Variable WSPF
Minimum tolerance for entry into model = 0.000000
Backward stepwise with Alpha-to-Enter=0.150 and Alpha-to-Remove=0.150

Step # 1 R = 0.924 R-Square = 0.855
Term removed: X13

Effect		Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In								
1	Constant							
2	X0	-2.101	0.699	-0.261	0.71130	1	9.024	0.006
3	X12	23.695	6.528	1.175	0.05136	1	13.177	0.001
5	X15	7.964	2.994	0.413	0.22387	1	7.076	0.013
6	X21	7.712	4.011	0.408	0.11942	1	3.696	0.065
7	X22	1.416	3.553	0.077	0.14517	1	0.159	0.693
8	X23	-3.217	3.855	-0.156	0.15449	1	0.696	0.411
9	X24	14.952	5.211	0.396	0.28310	1	8.235	0.008
10	X32	9.843	4.211	0.495	0.11996	1	5.464	0.027
11	X33	-18.879	5.604	-1.023	0.05837	1	11.349	0.002
12	X34	1.502	3.674	0.088	0.11645	1	0.167	0.686
13	X35	8.894	3.046	0.460	0.21649	1	8.524	0.007
14	X42	0.369	2.864	0.022	0.19161	1	0.017	0.899
15	X52	2.322	4.015	0.120	0.12462	1	0.335	0.568
16	X62	-15.885	6.341	-0.679	0.07327	1	6.275	0.019
17	X63	1.676	2.976	0.093	0.17827	1	0.317	0.578
18	X71	-13.777	4.058	-0.753	0.10957	1	11.529	0.002
19	X81	-2.436	4.888	-0.123	0.08904	1	0.248	0.622
Out		Part. Corr.						
4	X13	0.009	.	.	0.29731	1	0.002	0.965

Step # 2 R = 0.924 R-Square = 0.855
Term removed: X42

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							

1 Constant							
2 X0	-2.111	0.683	-0.263	0.72015	1	9.559	0.004
3 X12	24.094	5.646	1.195	0.06625	1	18.213	0.000
5 X15	8.091	2.776	0.419	0.25123	1	8.495	0.007
6 X21	7.950	3.494	0.421	0.15184	1	5.176	0.031
7 X22	1.640	3.045	0.089	0.19079	1	0.290	0.594
8 X23	-3.065	3.606	-0.148	0.17032	1	0.722	0.403
9 X24	14.900	5.102	0.394	0.28485	1	8.527	0.007
10 X32	9.768	4.097	0.491	0.12229	1	5.686	0.024
11 X33	-19.208	4.895	-1.041	0.07380	1	15.396	0.001
12 X34	1.509	3.609	0.088	0.11648	1	0.175	0.679
13 X35	9.039	2.778	0.468	0.25109	1	10.585	0.003
15 X52	2.450	3.821	0.127	0.13279	1	0.411	0.527
16 X62	-16.315	5.292	-0.697	0.10149	1	9.503	0.005
17 X63	1.600	2.864	0.093	0.18565	1	0.312	0.581
18 X71	-13.882	3.904	-0.758	0.11419	1	12.644	0.001
19 X81	-2.467	4.795	-0.124	0.08926	1	0.265	0.611

Out	Part. Corr.						
4 X13	0.009	.	.	0.29745	1	0.002	0.962
14 X42	0.025	.	.	0.19161	1	0.017	0.899

Step # 3 R = 0.924 R-Square = 0.854
Term removed: X34

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	-2.148	0.667	-0.267	0.73246	1	10.361	0.003
3 X12	23.607	5.445	1.171	0.06919	1	18.795	0.000
5 X15	7.962	2.719	0.412	0.25436	1	8.573	0.007
6 X21	8.131	3.418	0.430	0.15421	1	5.660	0.024
7 X22	1.674	3.000	0.091	0.19093	1	0.311	0.581
8 X23	-2.557	3.347	-0.124	0.19213	1	0.584	0.451
9 X24	15.280	4.949	0.404	0.29422	1	9.534	0.004
10 X32	9.404	3.945	0.473	0.12809	1	5.681	0.024
11 X33	-18.337	4.366	-0.994	0.09015	1	17.640	0.000
13 X35	9.087	2.736	0.470	0.25151	1	11.029	0.002
15 X52	2.458	3.766	0.127	0.13279	1	0.426	0.519
16 X62	-16.738	5.120	-0.716	0.10534	1	10.686	0.003
17 X63	1.979	2.678	0.116	0.20638	1	0.546	0.466
18 X71	-12.795	2.871	-0.699	0.20522	1	19.869	0.000
19 X81	-2.835	4.646	-0.143	0.09238	1	0.372	0.546

Out	Part. Corr.						
4 X13	-0.006	.	.	0.30343	1	0.001	0.976
12 X34	0.079	.	.	0.11648	1	0.175	0.679
14 X42	0.026	.	.	0.19165	1	0.019	0.892

Step # 4 R = 0.923 R-Square = 0.852
Term removed: X22

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	-2.079	0.648	-0.259	0.75892	1	10.288	0.003
3 X12	23.667	5.381	1.174	0.06922	1	19.343	0.000
5 X15	7.646	2.629	0.396	0.26588	1	8.459	0.007
6 X21	8.335	3.359	0.441	0.15598	1	6.157	0.019
8 X23	-2.578	3.308	-0.125	0.19215	1	0.607	0.442
9 X24	15.641	4.850	0.414	0.29931	1	10.401	0.003
10 X32	10.423	3.457	0.524	0.16303	1	9.091	0.005
11 X33	-17.649	4.140	-0.957	0.09797	1	18.176	0.000
13 X35	8.577	2.549	0.444	0.28309	1	11.320	0.002
15 X52	1.740	3.498	0.090	0.15035	1	0.247	0.623
16 X62	-15.657	4.685	-0.669	0.12295	1	11.169	0.002
17 X63	2.466	2.502	0.144	0.23089	1	0.971	0.332
18 X71	12.470	2.778	0.681	0.21406	1	20.146	0.000

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 19 X81                 -3.851       4.225      -0.194 0.10914   1    0.831    0.369

Out                 Part. Corr.

  4 X13                 -0.005         .           .   0.30846   1    0.001    0.980
  7 X22                  0.103         .           .   0.19093   1    0.311    0.581
 12 X34                  0.081         .           .   0.11656   1    0.192    0.665
 14 X42                  0.073         .           .   0.25200   1    0.155    0.697
-------------------------------------------------------------------------------

Step # 5 R =  0.922 R-Square =  0.851
Term removed: X52

Effect              Coefficient   Std Error  Std Coef    Tol.  df        F     'P'

In

  1 Constant
  2 X0                  -2.060       0.639      -0.256 0.76147   1   10.390    0.003
  3 X12                 22.924       5.106       1.137 0.07501   1   20.154    0.000
  5 X15                  7.387       2.545       0.383 0.27678   1    8.423    0.007
  6 X21                  8.351       3.318       0.442 0.15599   1    6.335    0.017
  8 X23                 -2.722       3.255      -0.132 0.19364   1    0.699    0.409
  9 X24                 16.219       4.651       0.429 0.31756   1   12.161    0.001
 10 X32                 10.719       3.364       0.539 0.16799   1   10.153    0.003
 11 X33                -16.894       3.805      -0.916 0.11316   1   19.717    0.000
 13 X35                  8.639       2.515       0.447 0.28375   1   11.795    0.002
 16 X62                -14.219       3.642      -0.608 0.19851   1   15.243    0.000
 17 X63                  3.176       2.030       0.185 0.34232   1    2.448    0.128
 18 X71                -12.396       2.740      -0.677 0.21467   1   20.462    0.000
 19 X81                 -4.784       3.739      -0.241 0.13594   1    1.637    0.210

Out                 Part. Corr.

  4 X13                 -0.004         .           .   0.30849   1    0.000    0.982
  7 X22                  0.066         .           .   0.21617   1    0.129    0.722
 12 X34                  0.080         .           .   0.11656   1    0.195    0.662
 14 X42                  0.078         .           .   0.25290   1    0.183    0.672
 15 X52                  0.090         .           .   0.15035   1    0.247    0.623
-------------------------------------------------------------------------------

Step # 6 R =  0.921 R-Square =  0.847
Term removed: X23

Effect              Coefficient   Std Error  Std Coef    Tol.  df        F     'P'

In

  1 Constant
  2 X0                  -2.183       0.619      -0.272 0.80418   1   12.441    0.001
  3 X12                 20.116       3.829       0.998 0.13213   1   27.598    0.000
  5 X15                  6.544       2.326       0.339 0.32828   1    7.914    0.008
  6 X21                  8.669       3.280       0.459 0.15808   1    6.985    0.013
  9 X24                 16.396       4.624       0.434 0.31822   1   12.573    0.001
 10 X32                  9.648       3.096       0.485 0.19647   1    9.712    0.004
 11 X33                -15.965       3.622      -0.865 0.12371   1   19.432    0.000
 13 X35                  8.376       2.484       0.434 0.28826   1   11.371    0.002
 16 X62                -14.657       3.587      -0.627 0.20270   1   16.695    0.000
 17 X63                  3.051       2.015       0.178 0.34418   1    2.293    0.140
 18 X71                -12.135       2.710      -0.663 0.21750   1   20.056    0.000
 19 X81                 -3.490       3.388      -0.176 0.16404   1    1.061    0.311

Out                 Part. Corr.

  4 X13                 -0.008         .           .   0.30868   1    0.002    0.966
  7 X22                  0.062         .           .   0.21625   1    0.119    0.732
  8 X23                 -0.149         .           .   0.19364   1    0.699    0.409
 12 X34                  0.025         .           .   0.13160   1    0.019    0.892
 14 X42                  0.032         .           .   0.27437   1    0.033    0.858
 15 X52                  0.102         .           .   0.15150   1    0.326    0.572
-------------------------------------------------------------------------------

Step # 7 R =  0.918 R-Square =  0.842
Term removed: X81

Effect              Coefficient   Std Error  Std Coef    Tol.  df        F     'P'
```

In

1 Constant							
2 X0	-2.301	0.609	-0.286	0.83251	1	14.278	0.001
3 X12	18.619	3.546	0.924	0.15437	1	27.572	0.000
5 X15	6.923	2.299	0.359	0.33669	1	9.067	0.005
6 X21	7.576	3.107	0.401	0.17656	1	5.947	0.020
9 X24	14.038	4.022	0.372	0.42149	1	12.186	0.001
10 X32	7.929	2.610	0.399	0.27685	1	9.227	0.005
11 X33	-15.186	3.545	-0.823	0.12935	1	18.350	0.000
13 X35	8.219	2.481	0.426	0.28934	1	10.971	0.002
16 X62	-13.306	3.342	-0.569	0.23399	1	15.854	0.000
17 X63	2.919	2.013	0.171	0.34557	1	2.104	0.156
18 X71	-12.121	2.712	-0.662	0.21750	1	19.975	0.000
Out	**Part. Corr.**						
4 X13	0.006	.	.	0.31037	1	0.001	0.975
7 X22	0.112	.	.	0.23751	1	0.404	0.529
8 X23	-0.059	.	.	0.23366	1	0.111	0.741
12 X34	0.089	.	.	0.15252	1	0.254	0.618
14 X42	0.104	.	.	0.33318	1	0.351	0.558
15 X52	0.170	.	.	0.18977	1	0.954	0.336
19 X81	-0.179	.	.	0.16404	1	1.061	0.311

Step # 8 R = 0.912 R-Square = 0.832
Term removed: X63

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	-2.205	0.615	-0.274	0.84246	1	12.851	0.001
3 X12	18.950	3.596	0.940	0.15501	1	27.777	0.000
5 X15	7.310	2.320	0.379	0.34130	1	9.927	0.003
6 X21	6.723	3.100	0.356	0.18313	1	4.704	0.037
9 X24	12.909	3.994	0.339	0.44111	1	10.282	0.003
10 X32	8.003	2.652	0.403	0.27696	1	9.107	0.005
11 X33	-13.016	3.266	-0.705	0.15737	1	15.885	0.000
13 X35	8.568	2.510	0.444	0.29208	1	11.655	0.002
16 X62	-13.598	3.389	-0.581	0.23485	1	16.096	0.000
18 X71	-10.994	2.640	-0.601	0.23697	1	17.339	0.000
Out	**Part. Corr.**						
4 X13	0.011	.	.	0.31052	1	0.004	0.951
7 X22	0.140	.	.	0.24170	1	0.656	0.424
8 X23	-0.047	.	.	0.23406	1	0.073	0.789
12 X34	0.168	.	.	0.17507	1	0.961	0.334
14 X42	0.102	.	.	0.33318	1	0.344	0.561
15 X52	0.266	.	.	0.25516	1	2.518	0.122
17 X63	0.245	.	.	0.34557	1	2.104	0.156
19 X81	-0.158	.	.	0.16470	1	0.843	0.365

Step # 8 R = 0.919 R-Square = 0.844
Term entered: X52

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	-2.217	0.602	-0.276	0.84232	1	13.571	0.001
3 X12	21.793	3.948	1.081	0.12308	1	30.471	0.000
5 X15	7.600	2.277	0.394	0.33909	1	11.137	0.002
6 X21	7.763	3.103	0.411	0.17496	1	6.259	0.017
9 X24	13.477	3.931	0.357	0.43603	1	11.755	0.002
10 X32	8.410	2.607	0.423	0.27428	1	10.404	0.003
11 X33	-16.598	3.912	-0.900	0.10497	1	17.999	0.000
13 X35	8.355	2.459	0.433	0.29121	1	11.544	0.002
15 X52	4.168	2.627	0.216	0.25516	1	2.518	0.122
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

18 X71	-11.832	2.637	-0.646	0.22745	1	20.139	0.000

Out	Part. Corr.						
4 X13	-0.001	.	.	0.30992	1	0.000	0.996
7 X22	0.164	.	.	0.24059	1	0.884	0.354
8 X23	-0.082	.	.	0.23071	1	0.219	0.643
12 X34	0.098	.	.	0.16005	1	0.310	0.582
14 X42	0.055	.	.	0.32158	1	0.096	0.758
17 X63	0.132	.	.	0.25702	1	0.571	0.455
19 X81	-0.070	.	.	0.14402	1	0.159	0.692

Dep Var: WSPF N: 45 Multiple R: 0.919 Squared multiple R: 0.844

Adjusted squared multiple R: 0.792 Standard error of estimate: 3.937

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	14.534	2.802	0.000	.	5.187	0.000
X0	-2.217	0.602	-0.276	0.842	-3.684	0.001
X12	21.793	3.948	1.081	0.123	5.520	0.000
X15	7.600	2.277	0.394	0.339	3.337	0.002
X21	7.763	3.103	0.411	0.175	2.502	0.017
X24	13.477	3.931	0.357	0.436	3.429	0.002
X32	8.410	2.607	0.423	0.274	3.226	0.003
X33	-16.598	3.912	-0.900	0.105	-4.243	0.000
X35	8.355	2.459	0.433	0.291	3.398	0.002
X52	4.168	2.627	0.216	0.255	1.587	0.122
X62	-17.628	4.177	-0.754	0.148	-4.220	0.000
X71	-11.832	2.637	-0.646	0.227	-4.488	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	2771.918	11	251.993	16.262	0.000
Residual	511.374	33	15.496		

Appendix 10

Cost Performance

Backward Stepping

Step # 0 R = 0.707 R-Square = 0.499

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	2.062	0.883	0.384	0.71017	1	5.451	0.028
3 X12	-12.985	8.272	-0.965	0.05092	1	2.464	0.129
4 X13	-0.607	5.638	-0.027	0.29731	1	0.012	0.915
5 X15	-7.319	3.831	-0.568	0.21760	1	3.649	0.067
6 X21	0.216	5.077	0.017	0.11868	1	0.002	0.966
7 X22	-9.841	4.484	-0.799	0.14517	1	4.817	0.037
8 X23	-2.694	4.879	-0.196	0.15353	1	0.305	0.586
9 X24	7.492	7.973	0.297	0.19248	1	0.883	0.356
10 X32	7.080	5.382	0.534	0.11691	1	1.730	0.200
11 X33	14.180	7.081	1.152	0.05820	1	4.010	0.056
12 X34	-7.841	4.721	-0.688	0.11229	1	2.758	0.109
13 X35	-6.069	3.885	-0.471	0.21191	1	2.441	0.130
14 X42	7.458	3.615	0.654	0.19151	1	4.256	0.049
15 X52	-4.494	5.066	-0.349	0.12462	1	0.787	0.383
16 X62	12.536	8.067	0.803	0.07209	1	2.415	0.132
17 X63	2.547	3.765	0.223	0.17726	1	0.457	0.505
18 X71	13.980	5.132	1.145	0.10905	1	7.421	0.011
19 X81	-7.324	6.184	-0.552	0.08855	1	1.402	0.247

Out	Part. Corr.
none	

Dependent Variable WCPF
Minimum tolerance for entry into model = 0.000000
Backward stepwise with Alpha-to-Enter=0.150 and Alpha-to-Remove=0.150

Step # 1 R = 0.707 R-Square = 0.499
Term removed: X21

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	2.064	0.865	0.385	0.71275	1	5.693	0.024
3 X12	-13.045	7.998	-0.970	0.05245	1	2.660	0.115
4 X13	-0.588	5.516	-0.027	0.29916	1	0.011	0.916
5 X15	-7.286	3.680	-0.566	0.22710	1	3.919	0.058
7 X22	-9.869	4.352	-0.802	0.14835	1	5.141	0.032
8 X23	-2.749	4.612	-0.200	0.16550	1	0.355	0.556
9 X24	7.376	7.351	0.293	0.21808	1	1.007	0.325
10 X32	7.091	5.276	0.535	0.11718	1	1.806	0.190
11 X33	14.294	6.433	1.161	0.06791	1	4.937	0.035
12 X34	-7.818	4.602	-0.686	0.11380	1	2.886	0.101
13 X35	-6.130	3.546	-0.476	0.24488	1	2.988	0.095
14 X42	7.529	3.152	0.660	0.24257	1	5.704	0.024
15 X52	-4.510	4.957	-0.350	0.12535	1	0.828	0.371
16 X62	12.684	7.137	0.813	0.08868	1	3.158	0.087
17 X63	2.531	3.677	0.222	0.17903	1	0.474	0.497
18 X71	14.031	4.897	1.149	0.11533	1	8.209	0.008
19 X81	-7.255	5.859	-0.547	0.09500	1	1.533	0.226

Out Part. Corr.

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
6 X21	0.008	.	.	0.11868	1	0.002	0.966

Step # 2 R = 0.706 R-Square = 0.499
Term removed: X13

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	2.060	0.849	0.384	0.71418	1	5.890	0.022
3 X12	-12.953	7.810	-0.963	0.05306	1	2.751	0.108
5 X15	-7.225	3.571	-0.561	0.23269	1	4.093	0.053
7 X22	-9.864	4.275	-0.801	0.14836	1	5.325	0.029
8 X23	-2.779	4.522	-0.202	0.16609	1	0.378	0.544
9 X24	6.925	5.906	0.275	0.32595	1	1.375	0.251
10 X32	6.998	5.112	0.528	0.12040	1	1.874	0.182
11 X33	14.312	6.316	1.163	0.06795	1	5.134	0.031
12 X34	-7.729	4.445	-0.678	0.11769	1	3.023	0.093
13 X35	-6.177	3.456	-0.479	0.24882	1	3.196	0.085
14 X42	7.507	3.090	0.658	0.24361	1	5.903	0.022
15 X52	-4.510	4.869	-0.350	0.12535	1	0.858	0.362
16 X62	12.548	6.897	0.804	0.09161	1	3.310	0.080
17 X63	2.504	3.603	0.219	0.17987	1	0.493	0.493
18 X71	13.984	4.790	1.145	0.11627	1	8.521	0.007
19 X81	-7.220	5.746	-0.545	0.09530	1	1.579	0.219
Out	Part. Corr.						
4 X13	-0.021	.	.	0.29916	1	0.011	0.916
6 X21	0.007	.	.	0.11942	1	0.001	0.972

Step # 3 R = 0.702 R-Square = 0.492
Term removed: X23

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	1.917	0.808	0.358	0.77206	1	5.636	0.024
3 X12	-15.121	6.893	-1.124	0.06666	1	4.812	0.036
5 X15	-7.650	3.466	-0.594	0.24178	1	4.873	0.035
7 X22	-9.516	4.191	-0.773	0.15101	1	5.155	0.031
9 X24	6.748	5.835	0.268	0.32673	1	1.337	0.257
10 X32	5.703	4.606	0.430	0.14508	1	1.533	0.226
11 X33	15.372	6.011	1.249	0.07344	1	6.541	0.016
12 X34	-8.551	4.193	-0.750	0.12943	1	4.159	0.051
13 X35	-6.337	3.409	-0.492	0.25024	1	3.456	0.073
14 X42	7.101	2.986	0.623	0.25527	1	5.656	0.024
15 X52	-4.100	4.771	-0.318	0.12775	1	0.739	0.397
16 X62	11.501	6.611	0.737	0.09757	1	3.026	0.093
17 X63	2.329	3.553	0.204	0.18099	1	0.430	0.517
18 X71	14.863	4.522	1.217	0.12767	1	10.803	0.003
19 X81	-5.977	5.320	-0.451	0.10877	1	1.262	0.270
Out	Part. Corr.						
4 X13	-0.027	.	.	0.30024	1	0.021	0.886
6 X21	0.037	.	.	0.12839	1	0.038	0.846
8 X23	-0.115	.	.	0.16609	1	0.378	0.544

Step # 4 R = 0.696 R-Square = 0.485
Term removed: X63

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
1 Constant							
2 X0	1.919	0.800	0.358	0.77206	1	5.751	0.023
3 X12	-13.542	6.397	-1.007	0.07593	1	4.481	0.043
5 X15	-6.936	3.258	-0.539	0.26834	1	4.531	0.042
7 X22	-8.506	3.860	-0.691	0.17463	1	4.854	0.035
9 X24	5.373	5.393	0.213	0.37517	1	0.993	0.327
10 X32	5.127	4.479	0.387	0.15057	1	1.310	0.261
11 X33	14.244	5.704	1.157	0.07999	1	6.236	0.018
12 X34	-7.595	3.894	-0.666	0.14725	1	3.805	0.060
13 X35	-5.790	3.273	-0.449	0.26621	1	3.129	0.087
14 X42	6.582	2.851	0.577	0.27456	1	5.329	0.028
15 X52	-2.182	3.732	-0.169	0.20474	1	0.342	0.563
16 X62	9.320	5.659	0.597	0.13062	1	2.712	0.110
18 X71	14.213	4.370	1.164	0.13412	1	10.578	0.003
19 X81	-4.559	4.814	-0.344	0.13032	1	0.897	0.351

Out	Part. Corr.						
4 X13	-0.018	.	.	0.30183	1	0.010	0.923
6 X21	0.023	.	.	0.13001	1	0.015	0.903
8 X23	-0.105	.	.	0.16714	1	0.321	0.575
17 X63	0.121	.	.	0.18099	1	0.430	0.517

Step # 5 R = 0.692 R-Square = 0.479
Term removed: X52

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	1.857	0.784	0.346	0.78583	1	5.601	0.024
3 X12	-12.434	6.045	-0.924	0.08323	1	4.231	0.048
5 X15	-6.483	3.131	-0.503	0.28439	1	4.287	0.047
7 X22	-7.990	3.718	-0.649	0.18425	1	4.618	0.040
9 X24	4.945	5.286	0.196	0.38223	1	0.875	0.357
10 X32	4.555	4.324	0.344	0.15809	1	1.110	0.300
11 X33	12.764	5.057	1.037	0.09960	1	6.371	0.017
12 X34	-8.093	3.759	-0.710	0.15466	1	4.637	0.039
13 X35	-5.789	3.239	-0.449	0.26621	1	3.196	0.084
14 X42	6.460	2.813	0.567	0.27604	1	5.272	0.029
16 X62	7.388	4.545	0.473	0.19824	1	2.643	0.114
18 X71	14.108	4.320	1.155	0.13435	1	10.667	0.003
19 X81	-3.557	4.450	-0.268	0.14924	1	0.639	0.430

Out	Part. Corr.						
4 X13	-0.023	.	.	0.30246	1	0.016	0.901
6 X21	0.037	.	.	0.13237	1	0.041	0.842
8 X23	-0.091	.	.	0.16927	1	0.253	0.619
15 X52	-0.106	.	.	0.20474	1	0.342	0.563
17 X63	0.030	.	.	0.29009	1	0.027	0.871

Step # 6 R = 0.684 R-Square = 0.468
Term removed: X81

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	1.726	0.763	0.322	0.82152	1	5.118	0.031
3 X12	-14.384	5.499	-1.069	0.09944	1	6.843	0.013
5 X15	-6.602	3.110	-0.513	0.28503	1	4.507	0.042
7 X22	-7.531	3.653	-0.612	0.18875	1	4.251	0.047
9 X24	3.452	4.917	0.137	0.43675	1	0.493	0.488
10 X32	2.715	3.639	0.205	0.22064	1	0.557	0.461
11 X33	12.432	5.012	1.010	0.10028	1	6.154	0.019
12 X34	-7.223	3.577	-0.634	0.16882	1	4.078	0.052

13 X35	-5.665	3.216	-0.440	0.26682	1	3.102	0.088
14 X42	6.804	2.764	0.597	0.28266	1	6.057	0.019
16 X62	8.363	4.353	0.536	0.21363	1	3.691	0.064
18 X71	12.985	4.062	1.063	0.15023	1	10.221	0.003

Out	Part. Corr.						
4 X13	-0.011	.	.	0.30432	1	0.004	0.949
6 X21	-0.022	.	.	0.15659	1	0.016	0.901
8 X23	-0.038	.	.	0.19074	1	0.044	0.835
15 X52	-0.048	.	.	0.23446	1	0.070	0.793
17 X63	0.009	.	.	0.29599	1	0.003	0.960
19 X81	-0.142	.	.	0.14924	1	0.639	0.430

Step # 7 R = 0.678 R-Square = 0.460
Term removed: X24

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	1.726	0.757	0.322	0.82152	1	5.199	0.029
3 X12	-12.995	5.091	-0.966	0.11425	1	6.516	0.016
5 X15	-5.864	2.904	-0.455	0.32182	1	4.077	0.052
7 X22	-7.509	3.625	-0.610	0.18876	1	4.292	0.046
10 X32	2.524	3.601	0.190	0.22188	1	0.491	0.488
11 X33	12.228	4.964	0.993	0.10062	1	6.067	0.019
12 X34	-7.255	3.549	-0.636	0.16885	1	4.179	0.049
13 X35	-5.774	3.188	-0.448	0.26745	1	3.281	0.079
14 X42	6.242	2.625	0.548	0.30856	1	5.652	0.023
16 X62	8.788	4.277	0.563	0.21786	1	4.221	0.048
18 X71	13.035	4.030	1.067	0.15029	1	10.462	0.003
Out	Part. Corr.						
4 X13	0.065	.	.	0.47896	1	0.137	0.714
6 X21	-0.050	.	.	0.16516	1	0.079	0.780
8 X23	-0.052	.	.	0.19350	1	0.086	0.771
9 X24	0.123	.	.	0.43675	1	0.493	0.488
15 X52	-0.047	.	.	0.23446	1	0.071	0.792
17 X63	-0.013	.	.	0.30585	1	0.006	0.941
19 X81	-0.088	.	.	0.17052	1	0.252	0.619

Step # 8 R = 0.672 R-Square = 0.452
Term removed: X32

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	1.610	0.733	0.300	0.86311	1	4.823	0.035
3 X12	-13.944	4.870	-1.037	0.12295	1	8.197	0.007
5 X15	-5.631	2.863	-0.437	0.32608	1	3.867	0.057
7 X22	-6.590	3.354	-0.535	0.21716	1	3.861	0.058
11 X33	13.738	4.439	1.116	0.12396	1	9.578	0.004
12 X34	-8.128	3.299	-0.713	0.19256	1	6.071	0.019
13 X35	-5.451	3.131	-0.423	0.27315	1	3.032	0.091
14 X42	6.158	2.603	0.540	0.30920	1	5.596	0.024
16 X62	9.073	4.226	0.581	0.21984	1	4.609	0.039
18 X71	14.195	3.647	1.162	0.18076	1	15.151	0.000
Out	Part. Corr.						
4 X13	0.078	.	.	0.48539	1	0.204	0.655
6 X21	-0.026	.	.	0.17114	1	0.022	0.883
8 X23	-0.018	.	.	0.20787	1	0.010	0.919
9 X24	0.113	.	.	0.43920	1	0.426	0.519
10 X32	0.121	.	.	0.22188	1	0.491	0.488

15 X52	-0.044	.	.	0.23458	1	0.063	0.803
17 X63	-0.004	.	.	0.30769	1	0.000	0.983
19 X81	-0.017	.	.	0.22470	1	0.010	0.923

Dep Var: WCPF N: 45 Multiple R: 0.672 Squared multiple R: 0.452

Adjusted squared multiple R: 0.291 Standard error of estimate: 4.854

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	23.493	2.102	0.000	.	11.177	0.000
X0	1.610	0.733	0.300	0.863	2.196	0.035
X12	-13.944	4.870	-1.037	0.123	-2.863	0.007
X15	-5.631	2.863	-0.437	0.326	-1.967	0.057
X22	-6.590	3.354	-0.535	0.217	-1.965	0.058
X33	13.738	4.439	1.116	0.124	3.095	0.004
X34	-8.128	3.299	-0.713	0.193	-2.464	0.019
X35	-5.451	3.131	-0.423	0.273	-1.741	0.091
X42	6.158	2.603	0.540	0.309	2.366	0.024
X62	9.073	4.226	0.581	0.220	2.147	0.039
X71	14.195	3.647	1.162	0.181	3.892	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	660.293	10	66.029	2.803	0.012
Residual	800.987	34	23.558		

Appendix 11

Quality Performance

Backward Stepping

Step # 0 R = 0.697 R-Square = 0.485

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	-0.028	1.341	-0.003	0.71017	1	0.000	0.984
3 X12	-1.139	12.563	-0.057	0.05092	1	0.008	0.928
4 X13	4.694	8.563	0.141	0.29731	1	0.300	0.588
5 X15	3.292	5.819	0.171	0.21760	1	0.320	0.576
6 X21	-7.414	7.711	-0.393	0.11868	1	0.924	0.345
7 X22	14.083	6.809	0.764	0.14517	1	4.277	0.049
8 X23	5.909	7.410	0.286	0.15353	1	0.636	0.432
9 X24	-30.124	12.109	-0.798	0.19248	1	6.189	0.020
10 X32	-18.762	8.174	-0.945	0.11691	1	5.269	0.030
11 X33	1.695	10.755	0.092	0.05820	1	0.025	0.876
12 X34	9.730	7.171	0.570	0.11229	1	1.841	0.186
13 X35	-4.410	5.900	-0.228	0.21191	1	0.559	0.462
14 X42	-7.757	5.491	-0.454	0.19151	1	1.996	0.170
15 X52	5.359	7.694	0.278	0.12462	1	0.485	0.492
16 X62	0.289	12.251	0.012	0.07209	1	0.001	0.981
17 X63	-5.807	5.718	-0.339	0.17726	1	1.031	0.319
18 X71	0.811	7.794	0.044	0.10905	1	0.011	0.918
19 X81	17.401	9.392	0.876	0.08855	1	3.433	0.075

Out	Part. Corr.
none	

Dependent Variable WQPF
Minimum tolerance for entry into model = 0.000000
Backward stepwise with Alpha-to-Enter=0.150 and Alpha-to-Remove=0.150

Step # 0 R = 0.697 R-Square = 0.485

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
2 X0	-0.028	1.341	-0.003	0.71017	1	0.000	0.984
3 X12	-1.139	12.563	-0.057	0.05092	1	0.008	0.928
4 X13	4.694	8.563	0.141	0.29731	1	0.300	0.588
5 X15	3.292	5.819	0.171	0.21760	1	0.320	0.576
6 X21	-7.414	7.711	-0.393	0.11868	1	0.924	0.345
7 X22	14.083	6.809	0.764	0.14517	1	4.277	0.049
8 X23	5.909	7.410	0.286	0.15353	1	0.636	0.432
9 X24	-30.124	12.109	-0.798	0.19248	1	6.189	0.020
10 X32	-18.762	8.174	-0.945	0.11691	1	5.269	0.030
11 X33	1.695	10.755	0.092	0.05820	1	0.025	0.876
12 X34	9.730	7.171	0.570	0.11229	1	1.841	0.186
13 X35	-4.410	5.900	-0.228	0.21191	1	0.559	0.462
14 X42	-7.757	5.491	-0.454	0.19151	1	1.996	0.170
15 X52	5.359	7.694	0.278	0.12462	1	0.485	0.492
16 X62	0.289	12.251	0.012	0.07209	1	0.001	0.981
17 X63	-5.807	5.718	-0.339	0.17726	1	1.031	0.319
18 X71	0.811	7.794	0.044	0.10905	1	0.011	0.918
19 X81	17.401	9.392	0.876	0.08855	1	3.433	0.075

Out	Part. Corr.
none	

Step # 1 R = 0.697 R-Square = 0.485
Term removed: X0

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
1 Constant							
3 X12	-1.107	12.241	-0.055	0.05165	1	0.008	0.929
4 X13	4.687	8.397	0.141	0.29778	1	0.312	0.581
5 X15	3.298	5.703	0.171	0.21812	1	0.334	0.568
6 X21	-7.423	7.553	-0.393	0.11911	1	0.966	0.334
7 X22	14.052	6.522	0.762	0.15237	1	4.642	0.040
8 X23	5.867	6.989	0.284	0.16620	1	0.705	0.409
9 X24	-30.106	11.850	-0.797	0.19357	1	6.455	0.017
10 X32	-18.697	7.406	-0.941	0.13714	1	6.373	0.018
11 X33	1.693	10.553	0.092	0.05820	1	0.026	0.874
12 X34	9.747	6.988	0.571	0.11385	1	1.945	0.174
13 X35	-4.411	5.790	-0.229	0.21191	1	0.580	0.453
14 X42	-7.744	5.354	-0.454	0.19393	1	2.092	0.160
15 X52	5.337	7.476	0.276	0.12710	1	0.510	0.481
16 X62	0.295	12.019	0.013	0.07213	1	0.001	0.981
17 X63	-5.805	5.611	-0.339	0.17731	1	1.070	0.310
18 X71	0.801	7.633	0.044	0.10949	1	0.011	0.917
19 X81	17.349	8.878	0.873	0.09543	1	3.819	0.061

Out	Part. Corr.						
2 X0	-0.004	.	.	0.71017	1	0.000	0.984

Step # 2 R = 0.697 R-Square = 0.485
Term removed: X62

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
3 X12	-0.971	10.710	-0.048	0.06506	1	0.008	0.928
4 X13	4.713	8.180	0.142	0.30258	1	0.332	0.569
5 X15	3.336	5.397	0.173	0.23490	1	0.382	0.542
6 X21	-7.343	6.689	-0.389	0.14643	1	1.205	0.282
7 X22	14.139	5.391	0.767	0.21507	1	6.878	0.014
8 X23	5.922	6.494	0.287	0.18564	1	0.832	0.370
9 X24	-30.109	11.635	-0.797	0.19360	1	6.696	0.015
10 X32	-18.729	7.154	-0.943	0.14171	1	6.853	0.014
11 X33	1.577	9.270	0.086	0.07274	1	0.029	0.866
12 X34	9.726	6.809	0.570	0.11563	1	2.040	0.164
13 X35	-4.341	4.961	-0.225	0.27840	1	0.766	0.389
14 X42	-7.813	4.470	-0.458	0.26828	1	3.055	0.091
15 X52	5.459	5.472	0.283	0.22882	1	0.995	0.327
17 X63	-5.862	5.018	-0.343	0.21373	1	1.364	0.253
18 X71	0.754	7.262	0.041	0.11666	1	0.011	0.918
19 X81	17.377	8.644	0.875	0.09707	1	4.041	0.054

Out	Part. Corr.						
2 X0	-0.004	.	.	0.71061	1	0.000	0.983
16 X62	0.005	.	.	0.07213	1	0.001	0.981

Step # 3 R = 0.696 R-Square = 0.485
Term removed: X12

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
4 X13	4.747	8.030	0.143	0.30322	1	0.349	0.559
5 X15	3.528	4.878	0.183	0.27768	1	0.523	0.475
6 X21	-7.356	6.573	-0.390	0.14649	1	1.252	0.272
7 X22	14.139	5.298	0.767	0.21507	1	7.122	0.012
8 X23	5.561	5.044	0.270	0.29719	1	1.216	0.279
9 X24	-30.331	11.180	-0.803	0.20254	1	7.361	0.011
10 X32	-18.452	6.354	-0.929	0.17350	1	8.432	0.007
11 X33	1.048	7.073	0.057	0.12067	1	0.022	0.883
12 X34	9.899	6.425	0.580	0.12545	1	2.374	0.134
13 X35	-4.281	4.831	-0.222	0.28352	1	0.785	0.383
14 X42	-7.950	4.137	-0.466	0.30251	1	3.692	0.065
15 X52	5.494	5.364	0.285	0.22996	1	1.049	0.314
17 X63	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
18 X71	0.501	6.586	0.027	0.13695	1	0.006	0.940
19 X81	17.124	8.039	0.862	0.10841	1	4.538	0.042
Out	**Part. Corr.**						
2 X0	-0.002	.	.	0.72600	1	0.000	0.993
3 X12	-0.017	.	.	0.06506	1	0.008	0.928
16 X62	-0.004	.	.	0.09086	1	0.000	0.985

Step # 4 R = 0.696 R-Square = 0.485
Term removed: X71

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
4 X13	4.763	7.893	0.144	0.30343	1	0.364	0.551
5 X15	3.552	4.786	0.184	0.27889	1	0.551	0.464
6 X21	-7.270	6.367	-0.385	0.15092	1	1.304	0.263
7 X22	14.191	5.165	0.770	0.21879	1	7.549	0.010
8 X23	5.518	4.928	0.267	0.30104	1	1.254	0.272
9 X24	-30.334	10.993	-0.803	0.20254	1	7.615	0.010
10 X32	-18.423	6.237	-0.928	0.17410	1	8.724	0.006
11 X33	0.789	6.100	0.043	0.15684	1	0.017	0.898
12 X34	10.232	4.621	0.599	0.23443	1	4.902	0.035
13 X35	-4.189	4.600	-0.217	0.30232	1	0.829	0.370
14 X42	-7.938	4.065	-0.465	0.30291	1	3.813	0.060
15 X52	5.467	5.263	0.283	0.23098	1	1.079	0.307
17 X63	-5.916	4.826	-0.346	0.21580	1	1.503	0.230
19 X81	17.319	7.490	0.872	0.12074	1	5.347	0.029
Out	**Part. Corr.**						
2 X0	-0.001	.	.	0.72620	1	0.000	0.994
3 X12	-0.010	.	.	0.07638	1	0.003	0.956
16 X62	-0.004	.	.	0.09117	1	0.001	0.981
18 X71	0.014	.	.	0.13695	1	0.006	0.940

Step # 5 R = 0.696 R-Square = 0.485
Term removed: X33

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
4 X13	4.519	7.541	0.136	0.32188	1	0.359	0.553
5 X15	3.411	4.585	0.177	0.29421	1	0.553	0.463
6 X21	-7.049	6.036	-0.373	0.16264	1	1.364	0.252
7 X22	14.384	4.867	0.780	0.23861	1	8.735	0.006
8 X23	5.612	4.796	0.272	0.30776	1	1.369	0.251
9 X24	-30.037	10.578	-0.796	0.21181	1	8.063	0.009
10 X32	-18.396	6.134	-0.926	0.17429	1	8.994	0.005
12 X34	10.305	4.513	0.604	0.23801	1	5.214	0.029
13 X35	-4.193	4.526	-0.217	0.30233	1	0.858	0.361
14 X42	-8.016	3.956	-0.469	0.30972	1	4.106	0.051
15 X52	5.675	4.929	0.294	0.25491	1	1.326	0.258
17 X63	-5.861	4.730	-0.343	0.21749	1	1.535	0.225
19 X81	17.489	7.256	0.881	0.12456	1	5.809	0.022
Out	**Part. Corr.**						
2 X0	-0.004	.	.	0.73550	1	0.000	0.982
3 X12	0.004	.	.	0.10801	1	0.000	0.982
11 X33	0.024	.	.	0.15684	1	0.017	0.898
16 X62	-0.009	.	.	0.09487	1	0.002	0.961
18 X71	0.001	.	.	0.17800	1	0.000	0.995

Step # 6 R = 0.692 R-Square = 0.479
Term removed: X13

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'

In

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
1 Constant							
5 X15	3.181	4.523	0.165	0.29629	1	0.494	0.487
6 X21	-6.687	5.945	-0.354	0.16428	1	1.265	0.269
7 X22	14.478	4.815	0.785	0.23886	1	9.040	0.005
8 X23	5.934	4.718	0.288	0.31167	1	1.582	0.218
9 X24	-26.555	8.750	-0.703	0.30330	1	9.210	0.005
10 X32	-17.763	5.982	-0.894	0.17963	1	8.818	0.006
12 X34	9.486	4.258	0.556	0.26206	1	4.964	0.033
13 X35	-3.453	4.311	-0.179	0.32664	1	0.642	0.429
14 X42	-8.119	3.913	-0.475	0.31030	1	4.305	0.046
15 X52	5.860	4.870	0.304	0.25591	1	1.448	0.238
17 X63	-5.864	4.683	-0.343	0.21750	1	1.568	0.220
19 X81	17.006	7.139	0.856	0.12612	1	5.675	0.023

Out

Effect	Part. Corr.			Tol.	df	F	'P'
2 X0	0.004	.	.	0.73937	1	0.000	0.984
3 X12	-0.013	.	.	0.11083	1	0.005	0.942
4 X13	0.107	.	.	0.32188	1	0.359	0.553
11 X33	-0.003	.	.	0.16638	1	0.000	0.988
16 X62	0.006	.	.	0.09674	1	0.001	0.973
18 X71	0.016	.	.	0.18160	1	0.008	0.929

Step # 7 R = 0.686 R-Square = 0.471
Term removed: X15

In

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
1 Constant							
6 X21	-5.169	5.497	-0.274	0.18922	1	0.884	0.354
7 X22	13.276	4.467	0.720	0.27330	1	8.832	0.005
8 X23	6.328	4.648	0.307	0.31612	1	1.853	0.183
9 X24	-24.067	7.942	-0.637	0.36260	1	9.184	0.005
10 X32	-16.516	5.669	-0.832	0.19693	1	8.488	0.006
12 X34	9.349	4.220	0.548	0.26261	1	4.907	0.034
13 X35	-2.302	3.957	-0.119	0.38168	1	0.338	0.565
14 X42	-7.648	3.825	-0.448	0.31967	1	3.997	0.054
15 X52	4.894	4.636	0.254	0.27806	1	1.114	0.299
17 X63	-5.215	4.556	-0.305	0.22629	1	1.311	0.261
19 X81	15.320	6.672	0.771	0.14215	1	5.272	0.028

Out

Effect	Part. Corr.			Tol.	df	F	'P'
2 X0	0.006	.	.	0.73971	1	0.001	0.972
3 X12	-0.061	.	.	0.13116	1	0.118	0.734
4 X13	0.095	.	.	0.32415	1	0.294	0.591
5 X15	0.123	.	.	0.29629	1	0.494	0.487
11 X33	-0.028	.	.	0.17360	1	0.025	0.876
16 X62	0.019	.	.	0.09782	1	0.011	0.915
18 X71	0.035	.	.	0.18619	1	0.040	0.844

Step # 8 R = 0.682 R-Square = 0.465
Term removed: X35

In

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
1 Constant							
6 X21	-5.104	5.442	-0.270	0.18930	1	0.880	0.355
7 X22	14.454	3.943	0.784	0.34399	1	13.439	0.001
8 X23	5.937	4.555	0.288	0.32289	1	1.699	0.201
9 X24	-24.389	7.845	-0.646	0.36436	1	9.665	0.004
10 X32	-17.648	5.272	-0.889	0.22325	1	11.206	0.002
12 X34	8.783	4.067	0.514	0.27736	1	4.665	0.038
14 X42	-8.089	3.712	-0.474	0.33279	1	4.748	0.036
15 X52	4.287	4.473	0.222	0.29288	1	0.918	0.345
17 X63	-5.250	4.511	-0.307	0.22633	1	1.355	0.253
19 X81	15.384	6.606	0.775	0.14310	1	5.422	0.026

Out	Part. Corr.						
2 X0	0.001	.	.	0.74166	1	0.000	0.995
3 X12	-0.035	.	.	0.13845	1	0.042	0.840
4 X13	0.065	.	.	0.34797	1	0.141	0.709
5 X15	0.075	.	.	0.34621	1	0.188	0.667
11 X33	-0.011	.	.	0.17815	1	0.004	0.949
13 X35	-0.101	.	.	0.38168	1	0.338	0.565
16 X62	-0.033	.	.	0.12904	1	0.036	0.850
18 X71	-0.001	.	.	0.21011	1	0.000	0.995

Step # 9 R = 0.672 R-Square = 0.451
Term removed: X21

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
7 X22	13.818	3.877	0.749	0.35447	1	12.700	0.001
8 X23	6.440	4.515	0.312	0.32744	1	2.035	0.163
9 X24	-22.377	7.533	-0.593	0.39380	1	8.824	0.005
10 X32	-18.002	5.250	-0.906	0.22440	1	11.759	0.002
12 X34	7.721	3.899	0.452	0.30067	1	3.922	0.056
14 X42	-9.506	3.386	-0.557	0.39878	1	7.883	0.008
15 X52	2.646	4.110	0.137	0.34581	1	0.414	0.524
17 X63	-3.994	4.300	-0.233	0.24820	1	0.863	0.359
19 X81	12.192	5.652	0.614	0.19359	1	4.653	0.038
Out	Part. Corr.						
2 X0	-0.006	.	.	0.74298	1	0.001	0.974
3 X12	-0.044	.	.	0.13887	1	0.065	0.800
4 X13	0.054	.	.	0.34953	1	0.098	0.756
5 X15	0.017	.	.	0.38927	1	0.010	0.920
6 X21	-0.159	.	.	0.18930	1	0.880	0.355
11 X33	-0.039	.	.	0.18404	1	0.053	0.820
13 X35	-0.096	.	.	0.38184	1	0.317	0.577
16 X62	-0.089	.	.	0.14910	1	0.270	0.607
18 X71	-0.015	.	.	0.21177	1	0.008	0.930

Step # 10 R = 0.667 R-Square = 0.445
Term removed: X52

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
7 X22	14.144	3.813	0.767	0.36064	1	13.762	0.001
8 X23	6.952	4.408	0.337	0.33793	1	2.487	0.124
9 X24	-20.588	6.944	-0.545	0.45590	1	8.790	0.005
10 X32	-16.552	4.703	-0.833	0.27503	1	12.385	0.001
12 X34	7.520	3.855	0.440	0.30261	1	3.806	0.059
14 X42	-9.935	3.292	-0.582	0.41490	1	9.108	0.005
17 X63	-2.670	3.746	-0.156	0.32178	1	0.508	0.481
19 X81	10.392	4.872	0.523	0.25625	1	4.549	0.040
Out	Part. Corr.						
2 X0	0.016	.	.	0.77243	1	0.009	0.927
3 X12	-0.024	.	.	0.14325	1	0.020	0.888
4 X13	0.073	.	.	0.36218	1	0.186	0.669
5 X15	0.011	.	.	0.39045	1	0.004	0.947
6 X21	-0.103	.	.	0.22350	1	0.375	0.544
11 X33	0.007	.	.	0.21824	1	0.002	0.968
13 X35	-0.067	.	.	0.40422	1	0.160	0.692
15 X52	0.108	.	.	0.34581	1	0.414	0.524
16 X62	0.009	.	.	0.27800	1	0.003	0.957
18 X71	-0.031	.	.	0.21637	1	0.033	0.857

Step # 11 R = 0.661 R-Square = 0.437

Term removed: X63

Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In							
1 Constant							
7 X22	13.573	3.703	0.736	0.37727	1	13.437	0.001
8 X23	6.605	4.352	0.320	0.34210	1	2.303	0.138
9 X24	-19.640	6.770	-0.520	0.47323	1	8.416	0.006
10 X32	-16.498	4.671	-0.831	0.27510	1	12.475	0.001
12 X34	5.894	3.086	0.345	0.46581	1	3.647	0.064
14 X42	-9.563	3.229	-0.560	0.42557	1	8.773	0.005
19 X81	9.600	4.712	0.483	0.27033	1	4.150	0.049
Out	Part. Corr.						
2 X0	0.008	.	.	0.77530	1	0.002	0.960
3 X12	-0.035	.	.	0.14459	1	0.044	0.835
4 X13	0.065	.	.	0.36359	1	0.151	0.699
5 X15	0.003	.	.	0.39220	1	0.000	0.985
6 X21	-0.088	.	.	0.22635	1	0.283	0.598
11 X33	-0.017	.	.	0.22725	1	0.010	0.920
13 X35	-0.084	.	.	0.41335	1	0.255	0.617
15 X52	0.038	.	.	0.44833	1	0.052	0.821
16 X62	0.005	.	.	0.27826	1	0.001	0.974
17 X63	-0.118	.	.	0.32178	1	0.508	0.481
18 X71	-0.012	.	.	0.22136	1	0.006	0.941

Dep Var: WQPF N: 45 Multiple R: 0.661 Squared multiple R: 0.437

Adjusted squared multiple R: 0.330 Standard error of estimate: 7.063

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	41.003	4.770	0.000	.	8.596	0.000
X22	13.573	3.703	0.736	0.377	3.666	0.001
X23	6.605	4.352	0.320	0.342	1.518	0.138
X24	-19.640	6.770	-0.520	0.473	-2.901	0.006
X32	-16.498	4.671	-0.831	0.275	-3.532	0.001
X34	5.894	3.086	0.345	0.466	1.910	0.064
X42	-9.563	3.229	-0.560	0.426	-2.962	0.005
X81	9.600	4.712	0.483	0.270	2.037	0.049

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	1432.647	7	204.664	4.102	0.002
Residual	1845.876	37	49.889		

Appendix 12

Predicted PPF

Neural Network 1

1	Actual(1)	Network(1)	Act-Net(1)
2	91.279998779297	94.737030029297	-3.457031250000
3	86.199996948242	86.438346862793	-0.238349914551
4	67.540000915527	74.340301513672	-6.800300598145
5	90.019996643066	94.737030029297	-4.717033386230
6	90.500000000000	90.633392333984	-0.133392333984
7	99.269996643066	94.737030029297	4.532966613770
8	98.569999694824	94.737030029297	3.832969665527
9	98.639999389648	94.737030029297	3.902969360352
10	99.349998474121	94.737030029297	4.612968444824
11	89.919998168945	94.734977722168	-4.814979553223
12	88.139999389648	88.319007873535	-0.179008483887
13	86.309997558594	86.270057678223	0.039939880371
14	77.059997558594	76.628105163574	0.431892395020
15	95.610000610352	94.737030029297	0.872970581055
16	78.489997863770	78.294097900391	0.195899963379
17	92.620002746582	92.713272094727	-0.093269348145
18	94.949996948242	94.559425354004	0.390571594238
19	88.769996643066	88.830421447754	-0.060424804688
20	87.910003662109	94.729843139648	-6.819839477539
21	82.010002136230	82.154907226563	-0.144905090332
22	95.220001220703	94.736946105957	0.483055114746
23	96.250000000000	94.718185424805	1.531814575195
24	96.970001220703	94.718185424805	2.251815795898
25	68.199996948242	67.818603515625	0.381393432617
26	96.500000000000	94.737030029297	1.762969970703
27	95.529998779297	94.717071533203	0.812927246094
28	72.099998474121	72.484611511230	-0.384613037109
29	97.980003356934	94.718185424805	3.261817932129
30	95.529998779297	94.717071533203	0.812927246094
31	75.199996948242	74.375488281250	0.824508666992
32	99.379997253418	94.737030029297	4.642967224121
33	98.069999694824	94.737030029297	3.332969665527
34	86.400001525879	86.606475830078	-0.206474304199
35	75.849998474121	76.140228271484	-0.290229797363
36	95.849998474121	94.718185424805	1.131813049316
37	95.160003662109	94.718185424805	0.441818237305
38	92.199996948242	94.677314758301	-2.477317810059
39	96.610000610352	94.737030029297	1.872970581055
40	96.599998474121	94.718185424805	1.881813049316
41	77.150001525879	77.562042236328	-0.412040710449
42	92.099998474121	94.737030029297	-2.637031555176
43	89.800003051758	94.737030029297	-4.937026977539
44	88.300003051758	94.736946105957	-6.436943054199
45	93.500000000000	93.410125732422	0.089874267578
46	78.980003356934	80.951126098633	-1.971122741699
47	87.889999389648	94.735877990723	-6.845878601074
48	73.599998474121	80.983917236328	-7.383918762207
49	89.769996643066	94.737030029297	-4.967033386230
50	88.830001831055	94.737030029297	-5.907028198242
51	80.699996948242	80.755798339844	-0.055801391602
52	88.139999389648	94.736953735352	-6.596954345703
53	88.099998474121	88.246536254883	-0.146537780762
54	87.559997558594	82.894592285156	4.665405273438
55	79.500000000000	80.983917236328	-1.483917236328

Appendix 13

Predicted PPF

Neural Network 2

	A	B	C
1	Actual(1)	Network(1)	Act-Net(1)
2	91.279998779297	88.931579589844	2.348419189453
3	86.199996948242	86.445899963379	-0.245903015137
4	67.540000915527	74.737960815430	-7.197959899902
5	90.019996643066	88.825965881348	1.194030761719
6	90.500000000000	90.212852478027	0.287147521973
7	99.269996643066	90.450080871582	8.819915771484
8	98.569999694824	90.394142150879	8.175857543945
9	98.639999389648	90.436599731445	8.203399658203
10	99.349998474121	90.401840209961	8.948158264160
11	89.919998168945	90.303970336914	-0.383972167969
12	88.139999389648	90.217636108398	-2.077636718750
13	86.309997558594	90.643661499023	-4.333663940430
14	77.059997558594	75.058700561523	2.001296997070
15	95.610000610352	90.132110595703	5.477890014648
16	78.489997863770	75.058700561523	3.431297302246
17	92.620002746582	90.123153686523	2.496849060059
18	94.949996948242	90.162422180176	4.787574768066
19	88.769996643066	90.180870056152	-1.410873413086
20	87.910003662109	78.541854858398	9.368148803711
21	82.010002136230	83.755737304688	-1.745735168457
22	95.220001220703	90.477325439453	4.742675781250
23	96.250000000000	90.693099975586	5.556900024414
24	96.970001220703	90.996566772461	5.973434448242
25	68.199996948242	73.672111511230	-5.472114562988
26	96.500000000000	90.412986755371	6.087013244629
27	95.529998779297	90.135169982910	5.394828796387
28	72.099998474121	73.572250366211	-1.472251892090
29	97.980003356934	90.175468444824	7.804534912109
30	95.529998779297	90.120056152344	5.409942626953
31	75.199996948242	73.466880798340	1.733116149902
32	99.379997253418	90.436851501465	8.943145751953
33	98.069999694824	90.334060668945	7.735939025879
34	86.400001525879	88.584770202637	-2.184768676758
35	75.849998474121	73.583465576172	2.266532897949
36	95.849998474121	90.412986755371	5.437011718750
37	95.160003662109	90.248855590820	4.911148071289
38	92.199996948242	90.240989685059	1.959007263184
39	96.610000610352	90.019065856934	6.590934753418
40	96.599998474121	90.228630065918	6.371368408203
41	77.150001525879	73.632987976074	3.517013549805
42	92.099998474121	90.153625488281	1.946372985840
43	89.800003051758	90.249198913574	-0.449195861816
44	88.300003051758	86.503768920898	1.796234130859
45	93.500000000000	90.939567565918	2.560432434082
46	78.980003356934	74.358802795410	4.621200561523
47	87.889999389648	90.551551818848	-2.661552429199
48	73.599998474121	73.735572814941	-0.135574340820
49	89.769996643066	90.182075500488	-0.412078857422
50	88.830001831055	90.182716369629	-1.352714538574
51	80.699996948242	77.004875183105	3.695121765137
52	88.139999389648	88.158958435059	-0.018959045410
53	88.099998474121	90.637481689453	-2.537483215332
54	87.559997558594	90.238410949707	-2.678413391113
55	79.500000000000	73.843307495117	5.656692504883

Appendix 14

Predicted Cost Performance

Neural Network

	A	B	C
1	Actual(1)	Network(1)	Act-Net(1)
2	36.560001373291	31.195325851440	5.364675521851
3	30.860000610352	31.197257995605	-0.337257385254
4	27.899999618530	28.364355087280	-0.464355468750
5	29.370000839233	33.151309967041	-3.781309127808
6	26.219999313354	35.097785949707	-8.877786636353
7	34.270000457764	30.819259643555	3.450740814209
8	32.639999389648	30.819259643555	1.820739746094
9	32.639999389648	30.819259643555	1.820739746094
10	34.619998931885	30.819259643555	3.800739288330
11	40.000000000000	33.910717010498	6.089282989502
12	30.590000152588	31.677846908569	-1.087846755381
13	26.489999771118	32.915218353271	-6.425218582153
14	26.489999771118	28.532991409302	-2.042991638184
15	22.979999542236	31.406120300293	-8.426120758057
16	26.549999237061	28.778970718384	-2.228971481323
17	29.969999313354	34.387199401855	-4.417200088501
18	31.649999618530	30.839033126831	0.810966491699
19	41.900001525879	31.626741409302	10.273260116577
20	26.909999847412	29.610734939575	-2.700735092163
21	26.309999465942	29.592823028564	-3.282823562622
22	25.709999084473	30.888141632080	-5.178142547607
23	31.500000000000	31.051723480225	0.448276519775
24	22.000000000000	31.051723480225	-9.051723480225
25	28.950000762939	29.059728622437	-0.109727859497
26	34.299999237061	30.868946075439	3.431053161621
27	33.599998474121	30.856510162354	2.743488311768
28	28.350000381470	28.438989639282	-0.088989257813
29	33.250000000000	31.051723480225	2.198276519775
30	33.599998474121	30.856510162354	2.743488311768
31	28.250000000000	28.619615554810	-0.369615554810
32	34.650001525879	30.819259643555	3.830741882324
33	34.650001525879	30.819259643555	3.830741882324
34	33.250000000000	34.112968444824	-0.862968444824
35	28.350000381470	28.870988845825	-0.520988464355
36	34.299999237061	31.051723480225	3.248275756836
37	18.799999237061	31.051723480225	-12.251724243164
38	17.399999618530	30.881986618042	-13.481986999512
39	29.100000381470	30.819259643555	-1.719259262085
40	19.600000381470	31.051723480225	-11.451723098755
41	26.600000381470	28.551803588867	-1.951803207397
42	38.400001525879	34.686927795410	3.713073730469
43	36.400001525879	33.789066314697	2.610935211182
44	24.000000000000	28.830839157104	-4.830839157104
45	26.700000762939	33.394279479980	-6.694278717041
46	15.380000114441	28.773342132568	-13.393342018127
47	18.659999847412	33.120166778564	-14.460166931152
48	30.399999618530	29.112262725830	1.287736892700
49	29.299999237061	34.348888397217	-5.048889160156
50	29.250000000000	33.513111114502	-4.263111114502
51	24.450000762939	29.423292160034	-4.973291397095
52	19.049999237061	33.005737304688	-13.955738067627
53	30.930000305176	35.109249114990	-4.179248809814
54	35.840000152588	31.233501434326	4.606498718262
55	54.869998931885	29.112262725830	25.757736206055

Appendix 15

Predicted Schedule Performance

Neural Network

	A	B	C
1	Actual(1)	Network(1)	Act-Net(1)
2	35.000000000000	34.788379669189	0.211620330811
3	22.340000152588	32.210582733154	-9.870582580566
4	14.989999771118	24.698078155518	-9.708078384399
5	41 650001525879	32.071689605713	9.578311920166
6	34.279998779297	32.186084747314	2.093914031982
7	35.000000000000	34.204483032227	0.795516967773
8	33.000000000000	34.204483032227	-1.204483032227
9	33.000000000000	34.204483032227	-1.204483032227
10	40.000000000000	34.204483032227	5.795516967773
11	30 000000000000	31 971199035645	-1.971199035645
12	24.750000000000	29.787439346313	-5.037439346313
13	30.000000000000	32.193592071533	-2.193592071533
14	30.750000000000	31 997430801392	-1.247430801392
15	23.329999923706	34.593139648438	-11 263139724731
16	32.099998474121	25.701843261719	6.398155212402
17	26.010000228882	32.759700775146	-6 749700546265
18	30.459999084473	35.498413085938	-5.038414001465
19	17.139999389648	31.471675872803	-14.331676483154
20	12.500000000000	22.898801803589	-10.398801803589
21	37.500000000000	35.619834899902	1 880165100098
22	35.000000000000	34.635009765625	0.364990234375
23	40.000000000000	34.806262963971	5.193737030029
24	40.000000000000	34.806262969971	5.193737030029
25	16.000000000000	25.057859420776	-9.057859420776
26	32.200000762939	33.427730560303	-1.227729797363
27	32.200000762939	35.078384399414	-2.878383636475
28	20.000000000000	25.350294113159	-5 350294113159
29	35.000000000000	34.806262969971	0.193737030029
30	32.200000762939	35.078384399414	-2.878383636475
31	23.200000762939	25.140565872192	-1.940565109253
32	35.000000000000	34.204483032227	0.795516967773
33	33.599998474121	34.204483032227	-0.604484558105
34	23.450000762939	32.435752868652	-8.985752105713
35	23.500000000000	24.956726074219	-1 456726074219
36	31 850000381470	34.806262969971	-2.956262588501
37	36.799999237061	34.806262969971	1 993736267090
38	35.599998474121	36.174022674561	-0.574024200439
39	37.599998474121	34.204483032227	3.395515441895
40	37.200000762939	34.806262969971	2.393737792969
41	26.799999237061	25.538455963135	1.261543273926
42	24.000000000000	34.784492492676	-10.784492492676
43	24.000000000000	26.655261993408	-2.655261993408
44	14.800000190735	24.403194427490	-9.603194236755
45	47.000000000000	36.153198242188	10.846801757813
46	6.659999847412	24.819242477417	-18.159242630005
47	24.989999771118	23.320232391357	1.669767379761
48	24.799999237061	24.943782806396	-0.143783569336
49	41.669998168945	34.234207153320	7.435791015625
50	31.079999923706	33.336055755615	-2.256055831909
51	33.500000000000	24.536542892456	8.963457107544
52	41.650001525879	35.758941650391	5.891059875488
[illegible]	42.299999237061	31.394319534302	10.905679702759
[illegible]	33.319999694824	32.885841369629	0.434158325195
[illegible]	8.500000000000	24.943782806396	-16.443782806396

Appendix 16

Predicted Quality Performance

Neural Network

	A	B	C
1	Actual(1)	Network(1)	Act-Net(1)
2	19.719999313354	22.354412078857	-2.634412765503
3	33.000000000000	33.224636077881	-0.224636077881
4	24.649999618530	22.740537643433	1.909461975098
5	19.000000000000	22.792518615723	-3.792518615723
6	30.000000000000	34.757724761963	-4.757724761963
7	30.000000000000	23.425825119019	6.574174880981
8	32.930000305176	23.425825119019	9.504175186157
9	33.000000000000	23.425825119019	9.574174880981
10	24.729999542236	23.425825119019	1.304174423218
11	19.920000076294	22.519554138184	-2.599554061890
12	32.799999237061	31.100255966187	1.699743270874
13	29.819999694824	30.219413757324	-0.399414062500
14	19.819999694824	22.829978942871	-3.009979248047
15	49.299999237061	30.525476455688	18.774522781372
16	19.840000152588	22.463733673096	-2.623733520508
17	36.639999389648	16.910041809082	19.729957580566
18	32.840000152588	21.306516647339	11.533483505249
19	29.729999542236	38.541965484619	-8.811965942383
20	48.500000000000	50.280944824219	-1.780944824219
21	18.200000762939	22.470607757568	-4.270606994629
22	34.509998321533	25.192493438721	9.317504882813
23	24.750000000000	26.774101257324	-2.024101257324
24	34.970001220703	26.774101257324	8.195899963379
25	23.250000000000	29.272230148315	-6.022230148315
26	30.000000000000	21.814931869507	8.185068130493
27	29.729999542236	18.682975769043	11.047023773193
28	23.750000000000	25.284303665161	-1.534303665161
29	29.729999542236	26.774101257324	2.955898284912
30	29.729999542236	18.682975769043	11.047023773193
31	23.750000000000	26.094444274902	-2.344444274902
32	29.729999542236	23.425825119019	6.304174423218
33	29.819999694824	23.425825119019	6.394174575806
34	29.700000762939	28.865880966187	0.834119796753
35	24.000000000000	27.060411453247	-3.060411453247
36	29.700000762939	26.774101257324	2.925899505615
37	39.560001373291	26.774101257324	12.785900115967
38	39.200000762939	26.200527191162	12.999473571777
39	29.909999847412	23.425825119019	6.484174728394
40	39.799999237061	26.774101257324	13.025897979736
41	23.750000000000	22.766906738281	0.983093261719
42	29.700000762939	23.005037307739	6.694963455200
43	29.399999618530	28.736576080322	0.663423538208
44	49.500000000000	49.115070343018	0.384929656982
45	19.799999237061	22.462738037109	-2.662738800049
46	56.939998626709	19.630588531494	37.309410095215
47	44.240001678467	22.461702346802	21.778299331665
48	18.399999618530	22.134300231934	-3.734300613403
49	18.799999237061	27.155385971069	-8.355386734009
50	28.500000000000	30.178276062012	-1.678276062012
51	22.750000000000	14.869999885559	7.880000114441
52	27.440000534058	14.869999885559	12.570000648499
53	14.869999885559	35.621738433838	-20.751738548279
54	18.399999618530	22.722478866577	-4.322479248047
55	16.129999160767	22.134300231934	-6.004301071167