Validation of the Project Definition Rating Index (PDRI) for MIT Building Projects

by

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ABSTRACT

The thesis presents the work performed to validate the managerial tool called Project Definition Rating Index (PDRI). An improved methodology is presented. This new methodology produces much better linear correlation results between PDRI scores and Cost performance of the projects ($R^2 = 0.957$) than previous validation efforts.

The projects used for validation purposes have been developed by MIT for its Capital Project effort that started officially in the year 2000. While the results are recommended to be applied to future MIT projects, the author explains how the PDRI works thus facilitating future validation tasks.

In the process, the author proposes a modified version of the weights of the PDRI scoring sheet that better adjusts to the definition principles of the tool.

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1 INTRODUCTION

In the field of Construction Management, research has taken many forms and directions. Sometimes authors conclude their works with best practice guidelines and sometimes they develop managerial tools. In all cases the success of their work depends on the adoption of these guidelines and managerial tools by the construction industry, which not always happens.

Managerial tools for the construction industry have been developed many times for proprietary purposes by the construction companies. The reason behind it is that most of them use sensible information based on the experience gained through the exercise of their business. The fact that private companies are reluctant to release data based on their performance makes it difficult for universities to lead research to develop tools based on expertise. However there are times in which university researchers are able to develop their sought managerial tools. But even research leaders face the problem of collecting enough data for their studies, added with the difficulties faced while retrieving data from actual work sites and projects. Construction companies confirm the accuracy of findings and estimates rather than giving their own data for academic use (Slaughter 1999).

When the purpose of the research is to gather empirical data and study it, every effort should be made to treat that data with the maximum care. Other researchers have already stated how difficult it is to collect the empirical data. Good statistical studies can yet be made with small amounts of data, but special care needs to be taken.

1.1 JUSTIFICATION

In many other fields of science it is common to see the industry leaders supporting applied research and development done in universities, or even suggesting the directive lines for such investigation efforts. This yields to large leaps in the state of knowledge of those fields. In the quest for applied research, the enterprises, and the private sector in general, have a lot to say. They are behind the everyday success or failure of the economic related activity of their given discipline. Thus, they know in first hand what their needs are to make businesses work better. They can tell investigators in which direction should the efforts be focused to improve operative results. In Construction Management this phenomenon seldom happens, and it is the researchers' responsibility to build momentum around these few examples of industry input.

This reflexion should not alienate, in any case, the thoughts of those who rather believe that one of the main functions of a researcher is to set the development lines of his/her field and to decide in which direction to push the borders of knowledge. There are different research goals and different ways to accomplish them.

This document presents results of applied investigation done as an extension of previous researchers' work and contributes to the diffusion of knowledge. At the same time it brings new ideas to develop a theoretic ground for the managerial tool studied and establishes a discussion around it.

1.2 PROJECT SCOPE DEFINITION

Different authors have identified the vital importance of performing well the tasks to be done during the development of the project. This should be taken into account ever since the start of the pre-planning process because it has a great impact on the outcome of the project. The cause is that since the cost of these preliminary tasks is reduced compared to the overall cost of the project, and the impact on the outcome is big, it pays off to spend some more on these planning tasks in order to ensure a satisfactory development of the project during subsequent phases (Neale and Neale 1989, Cho 2000, Best and de Valence 1999, Pinkerton 2003). In fact, one of the main reasons for which projects have cost overruns is that changes occur during construction. There are scope changes requested by the different parts involved in the project (i.e. end users, owner, architect, or even the contractor attending to market driven forces). These scope changes reflect the uncertainty that reigns during the early stages of a project, and the different objectives each party has for the project. Behind these changes are either a lack of definition of the items subject to change, or a poor idea of how the project had to be handled. Included in this last item we can find: the expected use of the building, the architectural design, management of the risks faced, the delivery method chosen, or the documentation and deliverables required.

Having well defined guidelines on how to define building projects should be a common objective within organizations. It is crucial that there is a deep discussion around all of the aspects about the project undertaken, but this discussion could, many times, go on and on.

How much is enough? What items should be stressed? The Project Definition Rating Index is a tool that provides a way to follow the planning process of a building project and answers these questions in an easy and effective way.

1.3 THESIS OBJECTIVES

The first purpose of the dissertation is to develop specific guidelines that complement the managerial tool called "Project Definition Rating Index (PDRI) for Building Projects". More specifically, these guidelines are directed for the use of the Massachusetts Institute of Technology (MIT). The development of these guidelines can be understood as a validation process that will make the PDRI useful for MIT as an organization that will undertake more projects in the future. Taking advantage of one of the largest capital efforts ever taken by the MIT, in which its campus is evolving and changing at a pace hard to cope with, this thesis wants to collect, at least at a basic level, the experience gained through this effort. It is a firm purpose of this essay to bring new knowledge on how to perform the planning of building projects.

The second goal of the thesis is to enlarge the database of projects used to validate the PDRI. As of the year 2000, the Research Team 155 of the Construction Industry Institute had used a total of 33 projects to validate the PDRI for building projects. Since this is a small sample to represent the United States construction industry as a whole, Cho (2000) recommends to increase the size of the sample to improve the validation process. He also suggests that particular organizations could benchmark the PDRI and enhance its accuracy. In this sense the objective is twofold: on one side the document provides new input for validation purposes trying to use a sample representative of MIT's building projects, and on the other side the thesis follows Cho's recommendation and uses internal knowledge for the benefit of the organization. This thesis contributes with 6 new projects undertaken by MIT and drawn from the recent capital effort it is undertaking, and that represents more than $1 billion that will be invested in 10 different buildings for the campus. This investment is planned to be done during a period of 10 years.

The third purpose of the thesis is to better understand the working principles of the PDRI. This will permit performing a critical analysis of its function for project managers' use. From a better understanding and the analysis of the data obtained the author expresses the objective of improving the PDRI model.

1.4 ORGANIZATION OF THE THESIS

In the following chapters of this document the author explains all the steps that guided the presented work to its completion. In chapter 2 the author introduces the background that motivates the research effort and puts the reader into a position to understand the context of the research. A special part of this chapter takes care of explaining the previous investigation on which the present one is based. The first part of the chapter focuses down starting at the organization that generated the PDRI for building projects and the roots of the PDRI. It finishes explaining, at a low level of detail, the development of the PDRI and the corresponding validation previously done. The second part of the chapter also scales down from the organization for which the PDRI for building projects is being validated, MIT, to the particular investment effort that motivates this research.

In chapter 3 the author explains the methodology used for collecting the necessary data. Each project used for the statistical analysis is described, and the chapter also includes a description of one project that was not included into the analysis and the arguments that supported this decision. There is an overview of the tools used for collecting the data and the procedure is also described. The last part of the chapter explains how the empirical data is manipulated, according to the basic principles and assumptions of the PDRI and following standard statistical procedures.

Chapter 4 reviews the results of the recollection of data and proceeds to analyze them as described in chapter 3. Every step is explained and reasoned. At the end of the chapter the author discusses in depth the findings and provides a theoretical explanation of the empirical findings. All being embedded into the general original framework of the PDRI for building projects.

Chapter 5 reviews the accomplishment of the objectives expressed in chapter 1 and presents the conclusions of the research. In this chapter, recommendations for future research may also be found.

2 BACKGROUND

This chapter describes the origins of the Project Definition Rating Index for building projects, while it also provides an introduction to the generation of the tool based on the thesis of Chung-Suk Cho (2000) and starts a light discussion of the decisions made.

The second part of the chapter introduces the nature of the data that will be used for the study of this thesis: the Capital Project of the Massachusetts Institute of Technology. Finally, the chapter introduces the motivations of the author to conduct this thesis and the problems it intends to solve.

2.1 THE CONSTRUCTION INDUSTRY INSTITUTE

The Construction Industry Institute (CII) is an organization that involves members that are either contractors or owners in the construction business, and has partnerships with several American universities. The main goal of the CII is to develop best practices for the construction industry to improve the business effectiveness. By having involved representatives of the different sides in the industry, they ensure participation.

The Project Definition Rating Index for industrial projects is one of the different research topics that was promoted by the CII in order to improve the scope definition level of industrial projects (Dumont, Gibson and Fish, 1997). After realizing the good reception that the construction industry gave to this newly developed tool, and acknowledging the need of a similar tool for building projects, a new research team was formed with the purpose of adapting the tool to building projects (Cho, Furman and Gibson, 1999). This kind of projects was not included in the application range of the previous work. Therefore it was felt that a new research team should be formed in order to develop a similar tool focused on building projects.

This new team collected the experience gained in the previous effort and restarted the process of developing –defining, weighting and validating– another PDRI. It is surprising that even in such a particular organization as the CII is, in which more than 40 contractors and 40 owners are involved, only 33 different projects could be used for validation purposes of the building version of the PDRI (moreover when this study was promoted based on feedback from a very similar research and which was felt very useful). Taking into account that the organizations backing the CII include some of the largest owners and contractors in the United States, the potential database would be easily of hundreds of different projects for every single year. The fact that only 33 projects could be used shows the high difficulty researchers find in conducting their research in the field of construction management as the author already stated in the first chapter.

2.1.1 Project Definition Rating Index

The present essay is fundamentally based on previous research done jointly by the CII and the University of Texas at Austin. That work started in 1994 with the development of the Project Definition Rating Index (PDRI) for Industrial Projects (Gibson and Dumont, 1996).

2.1.1.1 The First Tool

The PDRI for Industrial Projects was the result of the efforts made by the research team 113-2 of the CII in a joint work with the University of Texas at Austin. This early effort to develop a managerial tool that was both useful and easy to use, was well received by the construction industry (Dumont, Gibson and Fish, 1997). The tool was developed using input from professionals in the construction industry who defined a list of 70 relevant elements in the scope definition process of an industrial project. These elements are relevant in the sense that the result of a project depends heavily on how well defined they are. The 70 elements were carefully described so that they were meaningful to the different construction professionals in the industry. The main feature is the fact that each of the 70 elements has a different weight in an attempt to specify the relative importance they have on the final project success. The weighting process benefited from the experience of over 50 professionals.

The philosophy of this tool is to allow project planners to easily determine the level of definition needed for each of the elements in the list. If a certain overall level of definition is attained, then project managers should be able to assess how successful the the project will be. This success will undoubtedly depend on the execution of the later stages of the project that involve a larger expenditure, but their preparation is done as part of the definition process. The later stages of the project referred to are: the development of construction documents, or complete design, and the construction of the actual project. The elements in the list will receive a different rating depending on their definition status at a given point in time. Having all the items added provides an overall rating for the project's level of definition at the point in time considered. The objective is to achieve a sufficient level of definition without putting an excessive effort on the pre-planning process in order to maximize the chances of a smooth development of the later stages of the project.

This industrial version of the tool was then validated using a total of 40 completed industrial projects. The validation process was intended to check whether the tool predicted accurately a greater success for the projects that received a better rating. However the linear correlation that the researchers probably expected wasn't experimentally observed (R^2 = 0.39). It is possible that using more projects for the validation process, would have yielded better results. To proceed with the validation then, the researchers separated the sample of projects into two different groups by setting a dividing score and compared results between the two groups of projects (Dumont, Gibson and Fish, 1997). By studying the performance of these 2 groups of projects they found that the projects with better PDRI scores (low) were more successful on average than projects with worse PDRI scores (high). Results from this division showed that the group of projects with low scores were completed with average reductions of 5% in cost and 1% in schedule. Besides, projects in the group with high scores had average increases of 14% in cost and 12% in schedule. At the same time the projects scoring below the dividing score had on average 6%

less amount of change orders than the projects scoring above the dividing score. This data is particularly interesting because change orders are one of the main sources of benefit for contractors given that the negotiation power of the owner is greatly reduced once construction is underway. Therefore, owners typically pay more than the market value for a change order than for well planned work.

2.1.1.2 PDRI For Building Projects: The Birth Of A Saga

Following the efforts of previous years, and encouraged by the acceptance of the PDRI for Industrial Projects (Cho and Gibson, 2001), the CII decided to develop a similar tool to address scope development of buildings. With the experience obtained in the process of developing the Industrial Projects version and based on that previous knowledge, the new CII-155 research team was created in 1998. According to Cho (2000), eventually a PDRI for Infrastructure projects might be developed by the CII. A brief description of the creation process of the PDRI for building projects follows.

2.1.2 The Development Of The PDRI

The PDRI for building projects consists of a list of 64 different elements most likely to be relevant in the success of the project. That is, during the planning phase of a project, those elements that require special attention to reduce the uncertainties about the outcome of the project.

2.1.2.1 Definition Process

Taking advantage of the knowledge gained after the development of the PDRI for industrial projects, researchers at the University of Texas continued the previous effort with a preliminary list of 75 elements. After 2 iterations and input from over 30 industry representatives, the list featured 71 elements. The research team 155 of the CII used this draft as starting point. Then, Cho (2000) used the expertise of the team members and a series of workshops with industry representatives to develop a final version of the list that included 64 elements in 11 different categories.

2.1.2.2 Weighting Process

For the list to be useful in the same terms as the industrial version was, the elements had to be weighted. That is, weights had to be assigned to each element to reflect the relative potential influence of the element to the project outcome. the process of assigning weights was done using input from more than 69 participants in a series of workshops held in 7 different cities across the United States.

The criteria that the participants were asked to use in order to weight the different elements was "the amount of contingency they deemed appropriate for an element when evaluating its current level definition considering that they were about to begin the development of construction documents. The levels of definition that were used for evaluating each element was Level 1 [Complete Definition] and 5 [Incomplete or Poor Definition]" (Cho 2000). The author recalls that the criteria used is exclusively economic and more specifically cost oriented. This poses the question on whether the tool is well designed to measure other aspects of a project that are not economic. Another aspect to pay attention to is that Cho (2000) collected weights only for the definition levels 1 and 5, and assumed that weights for the levels 2, 3, and 4 vary linearly. While this assumption seems well funded based on previous research (Gibson and Dumont, 1996), it also determines the behavior of the PDRI. There will be a deeper discussion on this topic in chapter 4.

After collecting the input from the workshops, Cho (2000) performed a statistical analysis with all the data and filtered out sets of data that skewed significantly the sample. In this process he eliminated 8 sets of data out of the 67 he had originally collected. With the 59 reminding sets of data input, Cho calculated the mean for each element and for the two levels of definition previously mentioned. After that, all the numbers were normalized to provide a level of coherence with the previous PDRI for Industrial Projects. That is, the sum of all the weights corresponding to a level of definition 5 had to result 1000, and performing the same operation for the definition level 1, 70. Therefore the range of the scores of the 2 PDRI tools would be the same. After that, all the numbers were rounded to the closest integer and the levels 2, 3, and 4 interpolated and rounded as well. The author recalls that rounding the interpolated numbers no longer necessarily maintains linearity of the weights.

2.1.2.3 Validation Process

The members of the research team 155 of the CII made an effort to demonstrate the usefulness of their newly developed tool. To accomplish this goal they conducted a validation process aimed to correlate PDRI scores with project success. The first problem they encountered was to decide which measure of success to use. After a review of the literature, they concluded that the most representative variables were: budget achievement, schedule achievement, design size achievement, and facility utilization achievement. This decision was heavily based on the experience collected during the previous researches done at the CII. But instead of combining them using the same formula to find a success index, the members of the team preferred to come up with a formula taking into account the correlations of the different success variables with the PDRI.

The CII research team (1999) conducted a survey of successful and unsuccessful projects among CII organization members. The survey consisted of a questionnaire that was sent to 68 chosen projects drawn from the CII database. 38 questionnaires were returned and only 33 of the returned could be used for validation purposes. The data collected in these questionnaires served to check whether the different variables had a correlation with the PDRI scores. Although a linear correlation factor was not computed for each variable considered, statistical significance proved that projects with lower PDRI scores showed better performance indexes than projects with higher PDRI scores.

In an effort to correlate PDRI scores with performance variables, the CII research team (1999) chose the previously mentioned 4 variables and grouped the project results in three different categories for each variable. The author recalls that grouping data reduces the information of the sample. The CII team, for example, decided to rate the project performance in each area with the discrete values 1, 3, and 5. Since the original variables were defined in a continuous scale, that means grouping the variables. Furthermore, the grouping criteria was selected completely arbitrarily, assigning the value of 3 or “at performance” to those values of the variables that differed no more than ±2% between the planned value and the actual value. And assigning 1 or 5 to values falling either below or above that interval. Once the data values were grouped, Cho (2000) computed the correlation coefficient between the PDRI scores and each of the performance variables. The best correlation found was $R^2 = 0.121$ which indicates a weak linear correlation.

Nevertheless, Cho was able to propose a linear project success equation that had a correlation factor of $R^2 = 0.1536$, by combining the three most heavily correlated performance variables with equal weights. With a curvilinear model he improved the correlation with $R^2 = 0.2313$, but it is still very little significant.

2.2 THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

The Massachusetts Institute of Technology (MIT) is a world wide renowned education institution committed to provide an education that excels in all fields of science, technology and other human sciences. MIT is a private university that houses over 900 faculty and 10,000 graduate and undergraduate students from all over the world. In addition, 47 alumni, faculty, researchers and staff have won Nobel prizes.

2.2.1 The MIT Capital Project

MIT has embarked in the mission of renovating its campus with a major capital investment on new and renovated building facilities. The Capital Project represents a total budget of $1.4 billion, 10 buildings (renovated and new) housing about one million state-of-the-art square feet, and several infrastructure facilities and landscape improvements. In addition most of the buildings are architecturally unique, continuing the MIT tradition of building a unique campus that fosters creation and innovation in every possible way. In fact at least three of the selected architects are Pritzker prize winners (ENR, 2003). This speaks of the quality and representativity of the projects everybody at MIT is talking about. This is an ongoing effort and a tremendous opportunity to learn and gain hands-on experience in many ways. Such a pool of unique building projects, representing an investment of $1 billion, happening at the same time can not go wasted in terms of learning. In this sense, MIT's Capital Project represents a unique opportunity to test theories and hypothesis since all the projects have common characteristics that make them easily comparable. They are all sponsored by the same owner. They are all built in the same campus and They will all be built within a short period of time, thus under comparable economic and environmental conditions. All these factors reduce the possibility of dispersion of the data caused by factors that are not directly related to the projects.

2.2.2 The MIT Department Of Facilities

The Department of Facilities of MIT manages the design, construction and maintenance of all the buildings owned by MIT. It works with a tight budget, and because funds for new construction come mainly from donations, all the decisions made are in some way influenced by the need to keep to the budget. However, since MIT is an educational institution that performs on a time basis, it needs some facilities at a due date, and the cost of not having the facility at the expected date can sometimes be prohibitive. Therefore, decisions are many times a complex issue at the Department of Facilities.

To prevent eventualities to the maximum extent, the department has adopted the policy of performing complete design of its buildings before starting construction. This has a double outcome. On one side it reduces the bids received for the work because of the higher level of detail provided to the subcontractors. On the other side it reduces the risk of cost overruns and schedule delays that come from incomplete definition because it ensures that all possible problems have been studied before embarking into construction.

2.2.3 The Media Laboratory Extension Project

One of the several buildings projected in the capital renovation of MIT is the extension of one of the most well known laboratories. The Media Laboratory (Media Lab) focus is to develop the technologies that sooner or later are to become part of our everyday lives. During the decades of the 1980's and 90's the research done at the Media Lab was recognized as the leading edge of this front. At the entrance to the 21st century the Media Lab wants to expand its facilities with a new building that will host seven research laboratories, display spaces, lecture and conference rooms, and a cafe (Maki and Associates, 2003). Among the unique features of this building the author recalls the custom made curtain wall that gives the building a special look by identifying the double deck laboratories with the exterior enclosure of the building.

The author started the focus of this thesis by studying the reasons that caused delays in the start of the construction of the building. Permission for starting construction has been delayed at least 3 times at the time of writing the present thesis (Fall 2003, Winter 2004, and Spring 2004). Additionally, the project had to be modified because the actual budget didn't meet early expectations of donations. A comprehensive process of value engineering then started to identify possible ways to significantly reduce the cost of the building.

After reviewing the assumptions for scope definition, the members of the planning team accepted that those assumptions could be modified without compromising the performance of the building nor the satisfaction of the customer but yet reducing the need of building mechanical system utilities. So much so, that a whole floor located in the basement could be removed from the design. That also meant that the depth of the slurry wall could be significantly reduced. For engineering interest, it is worth noting that the MIT campus is located next to the Charles River, upstream of the regulating dam that controls the water level of the river in relation to the Atlantic Ocean, and prevents the penetration of saline waters.

These changes in scope definition of the project, that are expected to ultimately free the path for construction of this new building, lead the author's interest to study the scope definition process of projects and find ways to guarantee their success. Having found in the literature the existence of a recently developed PDRI for building projects with apparently a lot of potential and backed by the CII, the author fell compelled to turn it into a useful tool for the use of the MIT. I expect its usage will prove useful to the Department of Facilities and other organizations that might find it appealing.

3 METHODOLOGY

The methodology the author uses for validating the PDRI for MIT building projects shares many aspects of the previous validation efforts made by Cho, Furman and Gibson (1999), Cho (2000), Cho and Gibson (2001). During those efforts, the process consisted of collecting data from various projects using an extensive questionnaire that was addressed to the people in the managing team of the projects. Similarly to what previous researchers had done (Cho, Furman and Gibson 1999), the author looked for available projects within the organization and that had been completed within a few years. That would ensure the possibility to collect the necessary objective and subjective data required in the questionnaires. The author used the same questionnaires described in Chapter 2 and addressed them to the project managers who were representing MIT during the development process through the Department of Facilities.

3.1 SAMPLE OF PROJECTS

As it was mentioned in the previous chapter, the MIT campus presents a unique opportunity to study the performance of building projects due to the major capital development underway. The MIT campus had not seen any major construction process for a period of 15 years (ENR, 2003) and now starts a period of heavy renovation and new construction that will span over 10 years, with a total of 10 new and renovated buildings that will cost about $1 billion. While total capital investment will reach over $1.4 billion. This is the next major building program since the 1970's in MIT (MIT News, 2002). The program officially started in the year 2000, and a total of 6 projects have been completed at the time of writing this paper. These projects are: the Stata Center, the Simmons Hall, the Zesiger Sports and Fitness Center, the Dreyfus Chemistry Building, 224 Albany Street Graduate Dormitory, and 70 Pacific Street Dormitory. The projects which either are under construction, or have not yet started the construction phase at the time of writing the thesis are: the Brain and Cognitive Sciences project, the Baker House, the East Campus project, and the Media Lab Extension.

The renovation of the existing Alumni Pool, and the renovation of Building E19 are examples of other minor construction projects which are not included in the Capital Project.

To have a sample that statistically represents the capital effort made by MIT, the author wanted to gather data from as many completed projects as possible. In order to accomplish this, the 6 completed projects mentioned above were surveyed. However, after an interview with the project manager for the Simmons Hall building, the author and the project manager agreed that this particular project was not suitable for a statistic study because its uniquenesses would skew the sample in excess. The author managed to keep the sample at 6 projects by eliminating the Simmons Hall project, and including the E19 renovation project into the study. At this point the author would have gladly included the Alumni Pool renovation as well, but it was not complete to provide the data needed.

Finally, the total amount of projects sampled represents a capital investment of more than $500 million, or 50% of the total investment in building construction for the MIT Capital Project. The sizes of these projects range from $8 million to $300 million.

3.1.1 Simmons Hall

Although not finally included in the sample, Simmons Hall is worth being described due to the uniqueness factors that make it not suitable for the study here presented. In many ways the building was born as an architectural experiment. With the purpose of housing 350 undergraduate students, and thus increasing the capacity of on campus housing up to the goal of bringing on campus all freshmen students, the architectural team was assigned the mission of creating an environment that would push and incentivize the creativeness of MIT students. As MIT president Dr. Charles Vest said at the dedication ceremony of the building: “[the building is] unlike anything on campus or elsewhere”.

Besides the structural shape of the building (see Figure 3.1) in which the architect challenges the spatial vision capabilities of residents and pedestrians with open holes, atriums and cantilever corners all over the building, the facade is unique in every sense and is what confers an open character to the building. Instead of showing standard size windows, the anodized aluminum facade features hundreds of tiny little windows that give the building a porosity appearance. Every single room in fact has 9 openable windows. This is not a regular building by any means, and even for the MIT standards it represents a milestone in the campus architecture. This was reflected in the construction process. For the construction of the facade the windows were mounted in sets on precast units; dozens of them were required, but they were not interchangeable. All these features along with many others added up to the singularity of this remarkable building.

Figure 3.1 View of the facade of Simmons Hall.

But besides all these facts, the most cumbersome thing that convinced the author of not using this project for the research was the assertion by its project director that while the first team of architects did a good job in conceptual design, the second team that implemented this design did a poor job understanding the needs of such a singular building and jeopardized the final outcome of the project.

Figure 3.2 Interior view of the Simmons Hall main lobby.

3.1.2 70 Pacific Street Dormitory

Also known by its residents as Sidney & Pacific because it is located at the corner of these two Cambridge streets, the building has become the hub of graduate residential life at MIT. The dorm houses over 700 students in one-room, two-room, and “double-quad” apartments (4 students in a two-bedroom apartment). Besides the basic amenities of these apartments such as individual bathrooms and kitchens, the building also offers common kitchens for every floor, a well assorted game room, gymnasium, courtyard, different common rooms for organizing activities, lounges, and study rooms.

Figure 3.3 View of the main entrance of 70 Pacific street.

The building is 9 stories high, has 412,000 ft^2, and MIT had to build it anew with tight restrictions on budget and schedule. In addition there were permitting problems that were finally solved with the gift from MIT to the city of Cambridge, of the park lying across Sidney street. This was exchanged for the building rights associated with the parcel that allowed to construct more densely in the dorm site.

3.1.3 Building E 19 Renovation

The renovation project of building E19 involved the complete renovation of the 5th floor of this 7 stories building into a research and laboratory space. The new floor with 20,000 ft^2 was to house the Picower Center for Learning and Memory that later on would move to the new Stata Center, and the McGovern Institute for Brain Research (MIBR). The existing space was occupied by the Office of the Controller. In addition, 3,000 ft^2 of existing vacant space in the 3rd floor were transformed into office and conference space for the headquarters of the MIBR.

Due to the research schedule needs of the new occupants, the project had to be designed and constructed in 7 months.

Figure 3.4 The Dreyfus Chemistry Building is located at the heart of the campus.

3.1.4 Dreyfus Chemistry Building

Also known as Building 18, because of the tradition at MIT to give numbers to everything. This building is a laboratory space for research in chemistry enclosed in a modernist shell designed by I. M. Pei in 1967 (see Figure 3.4). The research facility had to be completely renovated with all its systems replaced.

The project wasn't short on technical difficulties. But the main difficulty was caused by its users who didn't want to leave the building during its renovation. Therefore, the managers had to come up with a plan to refurbish the building while 2/3 of the building were occupied with all its systems running.

The building has a capacity of 264 occupants in 14 faculty groups and a total area of 132,000 gross ft^2. This project was granted the Merit Award for the Successful Construction, and the architect received the Research and Development Design of the Year Award.

3.1.5 224 Albany Street Graduate Dormitory

Talking about alias, here we have a good example. In MIT's nomenclature this building is called NW30, but due to its original use it is also known as "The Warehouse". The building was built in 1890 as an industrial warehouse and in the last years was used for storage space. The renovation of this building started in the year 2000 with the goal of converting it into a 120 single suite apartments using the 89,000 ft^2 available. These apartments are occupied by graduate students during the fall and spring semesters, and during the summer the apartments are offered to conference visitors.

Figure 3.5 224 Albany street is also known as "The Warehouse".

3.1.6 Zesiger Sports And Fitness Center

The new sports facility of MIT brings in a 11,000 ft^2 state-of-the-art gymnasium, an Olympic class pool, a training pool, 6 squash courts, a multi-activity court, administrative offices and a medical area. The building is built between and connects to 2 other existing buildings that also house sports facilities for the campus members. The project included the construction of the new 3 stories building of 125,000 ft^2, and the renovation of 37,000 ft^2 of existing space.

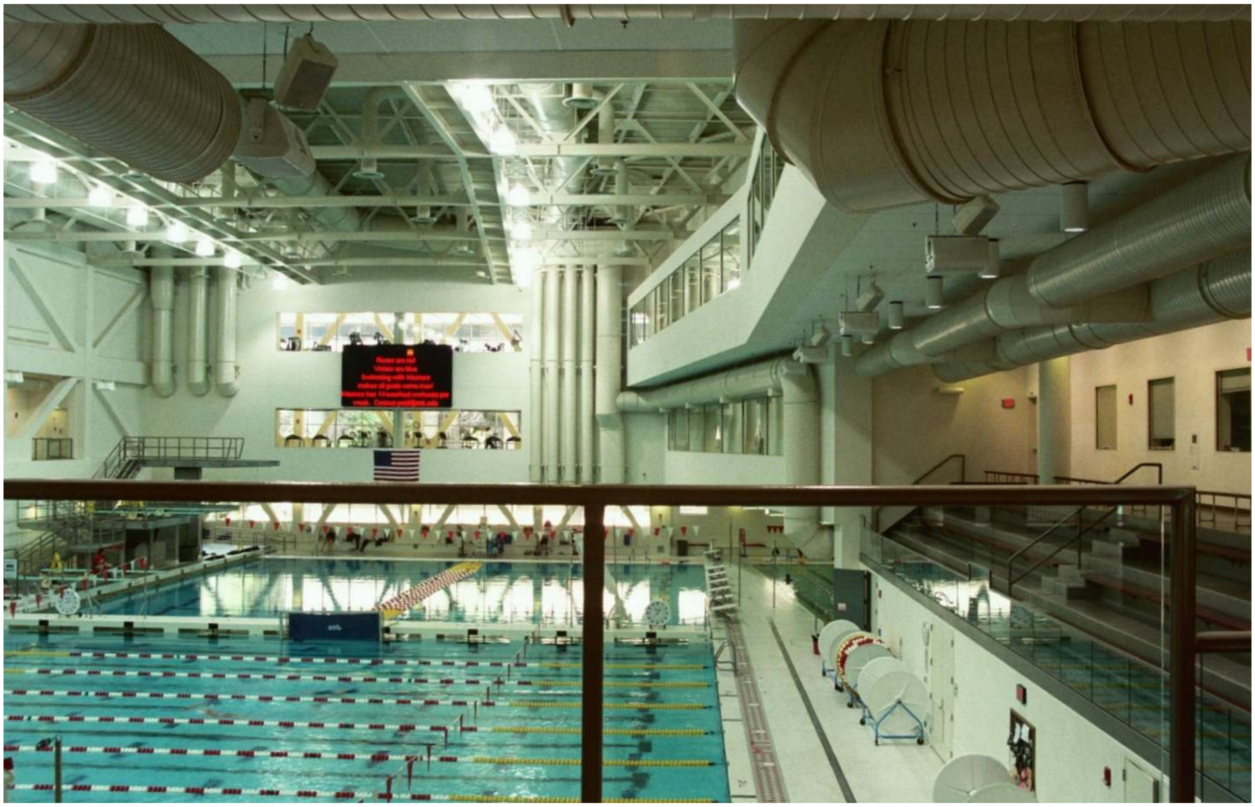


Figure 3.6 Interior view of the Zesiger Center facilities.

3.1.7 Stata Center

With a total of 716,000 ft^2 the Stata Center becomes one of the mammoths of the campus. It has been designed by the architect Frank Ghery, and this is the program's as well as the architect's largest project (ENR, 2003). This is a truly custom-built facility that houses the Laboratory for Computer Science, the Artificial Intelligence Laboratory, the Laboratory for Information and Decision Systems and the Linguistics and Philosophy faculty.

Although the project has recently been completed and new occupants are just moving in, the author considers really important to include this project to the database because of its size and representativity of what the MIT Capital Project is.

Figure 3.7 Two views of the Stata Center from Vassar Street.

3.2 THE QUESTIONNAIRE

The author used the same questionnaire that was used in previous research (Cho 2000). The reason for that decision is that the questionnaire that was developed for the CII was very generic thus applicable to a wide range of projects. Furthermore, it is very complete, so it collects all the necessary data to perform the validation analysis of the PDRI. The questionnaire can be viewed in Appendix B.

The questionnaire is divided into 9 different sections:

1. Project Background Information

2. General Project Information
3. Schedule Information
4. Cost Information
5. Change Information
6. Financial/Investment Information
7. Operating Information
8. Customer Satisfaction
9. Project Rating Information

Sections 1 and 2 gather the necessary data to understand the nature of the project, its purpose and its organizational structure. Sections 3, 4 and 5 ask for objective measures of success with several closed ended questions and an open ended question in sections 3 and 5. Sections 6, 7 and 8 ask for subjective measures of success using closed ended questions that evaluate success in a 5 degree scale, and open ended questions. Section 7 also asks for objective measures of success. Section 9 consists of the unweighted PDRI sheet which is to be completed by the managing staff of the project, based on the state of definition at the end of design development.

This questionnaire was based on the questionnaire developed for the industrial version of the PDRI (Dumont and Gibson, 1996) and modified accordingly to the needs of the building version (Cho, 2000).

3.2.1 Variables Used

Out of all the questions asked in the questionnaire only a handful proved relevant for performing the statistical analysis. The reasons for discarding most of the questions for statistical analysis is that the questions were not strictly applicable to the data available in the way they were formulated. Let's take the questions regarding cost information, for example. Not all the organizations use the same criteria to allocate the cost packets into the different groups. This translates into the difficulty that represents tracking every cost category and reorganize them into the groups suggested by the questionnaire. For this reason, from the cost breakdown information in question 4.1 of the questionnaire, only total project costs were considered for the analysis.

Some of the questions included in the questionnaire, are more geared towards providing the researchers a more accurate idea on the project characteristics and increasing their understanding of the project rather than providing data to be processed statistically. The main reason is that some questions are not accurate enough for that purpose. An example of this can be found in question 5.5 where respondents are asked to provide data on changes after project authorization that represent more than 1% of the project budget. The question doesn't specify whether respondents need to specify if there is more than one change meeting the criteria, thus it is not possible to track the specific nature of those changes.

Freeman and Beale (1992) found in a bibliographical review that the most cited measures of project success are technical performance efficiency of project execution (the ability to meet cost and schedule targets). Nonetheless, they proposed measuring success based on financial performance.

In any case this research does not intend to assert which is the most accurate or valid measure of project success, but rather to find out which one is most useful to understand PDRI scores.

In conclusion, the questions that were finally used for further statistical study were:

- Planned Construction Duration from 3.1
- Actual Construction Duration from 3.1
- Planned Total Project Costs from 4.1
- Actual Total Project Costs from 4.1
- Number of Change Orders from 5.1
- Subjective Financial Performance assessment from 6.1
- Subjective Original Intent Matching assessment from 8.1
- Subjective Success assessment from 8.2

The data collected from the four first questions had to be mathematically treated in order to remove the influence that the size of the projects would exercise over the sample. The operation performed was to subtract the planned value from the actual value and divide the result by the planned value. See expression below:

$$\frac{Actual\,Value - Planned\,Value}{Planned\,Value}$$

This operation yields a non dimensional value that can be either positive, negative, or zero. When the result is zero then there is no variation between the plans and the actual implementation of the project. When the result is positive, it means that there has been an increase in cost or in schedule, and the absolute value represents the percentage of the increase relative to the planned value. When the result is negative, it means that there has been a reduction in cost or in schedule, and the absolute value represents the percentage of the reduction relative to the planned value.

After performing this operation, the author obtains 6 different variables to measure project performance and find a relationship between PDRI scores and project success. The variables are listed in Table 3.1.

$$\mathit{Performance\ variable\ related\ to\ cost} = \frac{\mathit{Actual\ Total\ Project\ Costs} - \mathit{Planned\ Total\ Project\ Costs}}{\mathit{Planned\ Total\ Project\ Costs}}$$

$$\mathit{Performance\ variable\ realted\ to\ schedule} = \frac{\mathit{Actual\ Construction\ Duration} - \mathit{Planned\ Construction\ Duration}}{\mathit{Planned\ Construction\ Duration}}$$

$$\mathit{Performance\ variable\ realted\ to\ change\ orders} = \mathit{number\ of\ change\ orders}$$

$$\mathit{Performance\ variable\ realted\ to\ financial\ performance} = \mathit{subjective\ financial\ performance\ assessment}$$

$$\mathit{Performance\ variable\ realted\ to\ intent\ matching} = \mathit{subjective\ original\ intent\ matching\ assessment}$$

$$\mathit{Performance\ variable\ realted\ to\ success} = \mathit{subjective\ success\ assessment}$$

Table 3.1 Variables used for measuring project performance.

3.3 INTERVIEWS

The author worked closely with the Assistant Director of Facilities for Infrastructure and Special Projects of the Department of Facilities in MIT to identify potential projects to be used for the study and to contact the project leaders that would be interviewed to collect the necessary data for the study. As soon as the author was given the contact information for each of the project directors, an e-mail was sent to request an appointment for an interview.

The goal of the interviews was to present the objectives of the research to the project directors that were to provide the necessary data, and to introduce the questionnaire. In this way, the author was able to quickly dispel doubts on several questions and at the same time engaged the interviewees to help in the development of the research. In some interviews the project director showed satisfaction and immediately after browsing the questions said that he would gladly complete the questionnaire and send it back to the author. In other cases the project director would try to satisfy the data required on the spot as much as possible. However, in all cases some of the questions required checking the archives which always implied that the interview had to finish without thorough completion of the questionnaire.

In certain cases the questionnaire was returned to the author with some fields incomplete. If that happened the project director was immediately contacted by e-mail and asked to review the missing data. If he declared himself unable to provide the required information he would suggest another member of the managing team that would likely be able to provide the required information. In those particular situations, the data collection process slowed down considerably.

Another factor that slowed down data collection was the time constraints of the project directors. Because of the huge effort being made by the Department of Facilities, the time availability of its project directors is very little, so scheduling interviews was difficult.

Anecdotically the author recalls that for certain financial information that was not readily available to the staff in the Department of Facilities, the author approached a personal friend of his in the Office of Budget and Financial Planning of MIT to ask for that information in a more expedite manner. In exchange for this favors the author "bribed" his friend with a sailing ride in the Charles River.

3.4 STATISTICAL ANALYSIS

The first step is to analyze whether the data collected is statistically valid to be used in the study. For that purpose, and to represent the distribution of each set of data, the author uses box plots which provide a lot of information in a graphical manner. A box plot features different elements each has a very specific statistic meaning. The three central horizontal lines represent each: the first quartile, the median and the third quartile, which are respectively displayed from bottom to top. Outliers are represented as points out of the box. From the bottom and the top of the box may extend two horizontal lines representing the data points outside of the box that are not outliers. Outliers are data that lie beyond a distance from the box equal to 1.5 times the interquartile distance, or the distance between the first and third quartiles.

The correlation factor *r* is a statistic parameter that describes how consistent the linear correlation between two sets of data is. The two sets must have the same number of observations. The correlation factor values can vary between -1 and 1. When the absolute value of the correlation factor approaches 1, it means that there is evidence of a strong linear relationship between the two sets of data. On the contrary, when its value approaches 0, it cannot be inferred that a linear relation exists. A positive value implies that there is a direct relationship, that is, the higher the value in the first dataset, the higher the corresponding value in the second dataset. On the contrary, if the factor takes a negative value then there exists an inverse relationship, that is, the higher the value in the first dataset, the lower the corresponding value in the second dataset. A related statistic parameter to the correlation factor r is R^2, which is computed taking the square of r. This is used to argue the existence of a linear relationship, since the values now vary only between 0 and 1. Values of R^2 will always be lower than absolute values of r, making the evidence of a linear relationship more demanding.

The scatter plot is a statistic tool used to represent data graphically and to identify, in an easy way, relationships that numbers could otherwise hinder. It is normally used to represent 2 different sets of data and to show relationships between them.

The regression analysis is yet another statistical tool used when correlation between two or more sets of data exists. Its most common use is to infer the equation of the line that approximates the relationship between data. However it can also be used to infer equations that are not necessarily linear.

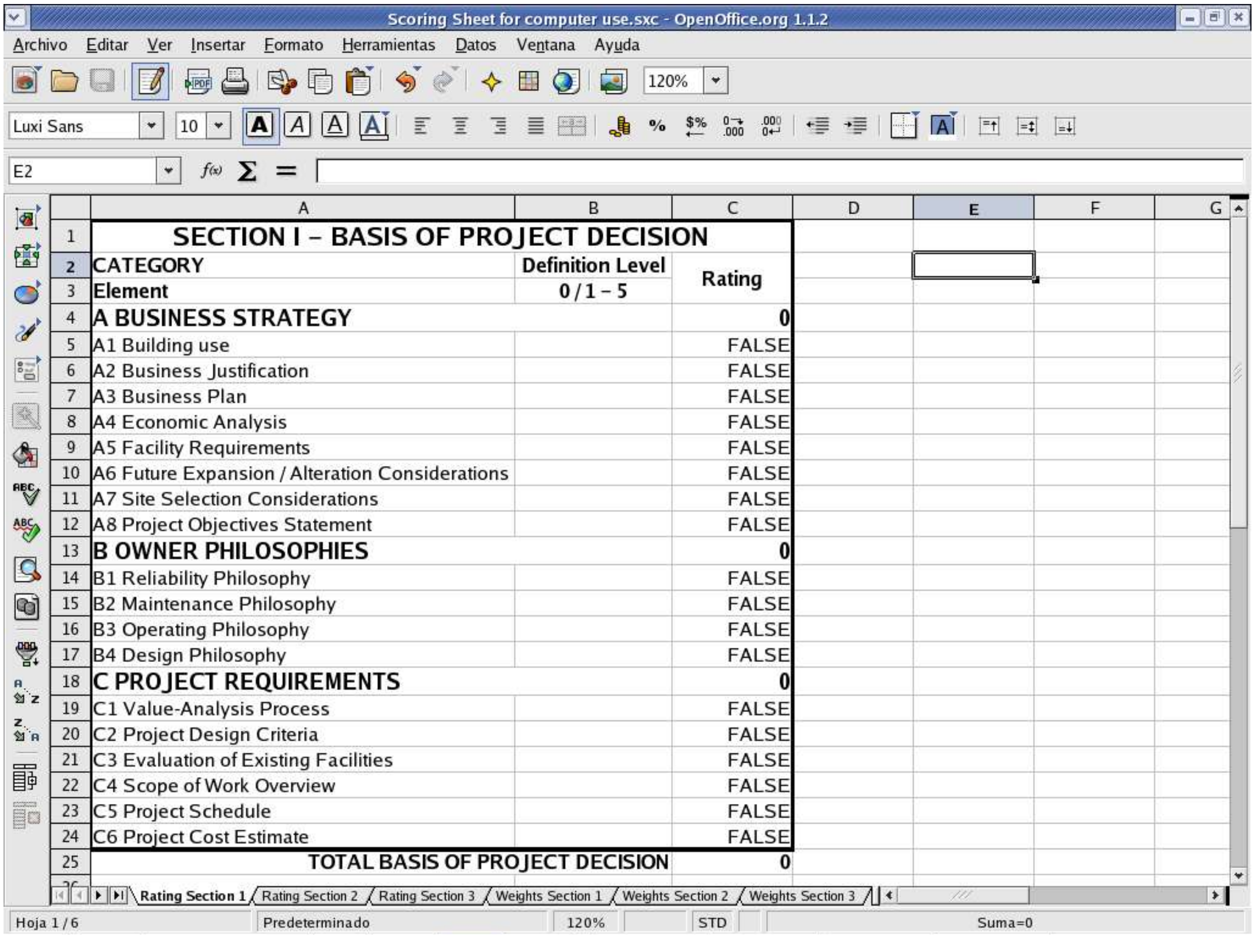
All the statistical operations and tools described above are done for this thesis using the software Maple 8 from Waterloo Maple Inc. in its version for Linux.

3.5 PROJECT RATING INFORMATION

In order to efficiently process the information from the unweighted score sheets for every project, the author designed a computer spreadsheet (see Figure 3.8) that automatically weighted the definition levels for each of the 64 different elements in the PDRI list. The spreadsheet is divided into 6 different tabs: 3 for entering definition data and 3 containing the weighting information. The 3 tabs for entering definition data are organized following the "Sections" structure of the PDRI elements list. The other 3 tabs with weight information are the corresponding tabs of the data input tabs. Therefore, Tab 1 is designed to enter the data for Section 1 of the PDRI; Tab 2, for Section 2; and Tab 3, for Section 3. Tab 4 is designed to contain the weight information for Section 1; Tab 5, for Section 2; and Tab 6, for Section 3.

It is worth noting that the only information included in the weight information tabs are the weights associated to definition levels 1 and 5 of each element. The author has conserved the original argument made by Cho (2000) concerning the existence of a linear relationship between the level of definition of each element and its corresponding weight. Thus, the spreadsheet interpolates linearly the corresponding value for every definition level without rounding the value. This differs from what Cho did in his research, and has implications. The most direct implication is that by rounding the interpolations for definition levels 2, 3 and 4, the model would no longer follow the assumption of linearity between definition levels and weights.

With this spreadsheet it is very easy to enter the numeric values of each definition level and get the corresponding weight instantaneously. In addition, the total score for every category and section is also automatically computed. Finally, the person entering the data can watch in real time how the total PDRI score changes as he introduces the data.



	A	B	C
1	SECTION I – BASIS OF PROJECT DECISION		
2	CATEGORY	Definition Level	Rating
3	Element	0 / 1 – 5	
4	A BUSINESS STRATEGY		0
5	A1 Building use		FALSE
6	A2 Business Justification		FALSE
7	A3 Business Plan		FALSE
8	A4 Economic Analysis		FALSE
9	A5 Facility Requirements		FALSE
10	A6 Future Expansion / Alteration Considerations		FALSE
11	A7 Site Selection Considerations		FALSE
12	A8 Project Objectives Statement		FALSE
13	B OWNER PHILOSOPHIES		0
14	B1 Reliability Philosophy		FALSE
15	B2 Maintenance Philosophy		FALSE
16	B3 Operating Philosophy		FALSE
17	B4 Design Philosophy		FALSE
18	C PROJECT REQUIREMENTS		0
19	C1 Value-Analysis Process		FALSE
20	C2 Project Design Criteria		FALSE
21	C3 Evaluation of Existing Facilities		FALSE
22	C4 Scope of Work Overview		FALSE
23	C5 Project Schedule		FALSE
24	C6 Project Cost Estimate		FALSE
25	TOTAL BASIS OF PROJECT DECISION		0

Figure 3.8 Snapshot of a blank spreadsheet developed to weight the elements of the PDRI (Tab 1).

The spreadsheet was edited using the open source and free software named Calc from OpenOffice.org 1.0.

3.6 SUMMARY

In this chapter the author has presented the methodology used for validating the PDRI for MIT building projects. The projects used for the sample have also been described. Justification for the projects not used has also been provided. The total number of projects used is 6:

- 3 research and laboratory spaces (building E19, the Dreyfus Chemistry Building and the Stata Center).
- 2 graduate dormitories (70 Pacific Street and 224 Albany Street).
- 1 recreational and athletic facility (Zesiger Sports and Fitness Center).

The sample objects can also be classified as either renovation or new construction. In this case we find that there are 3 representatives of each category. These 2 classifications give us an idea of how well balanced this sample representing the assets of MIT is. It also represents more than 50% in spending budget of the Capital Project buildings that MIT is constructing.

The chapter also introduces the questionnaire used to collect data on the projects from the sample. and how interviews are run for that purpose. Details on the difficulties encountered for that purpose are also shown. Even an anecdote is included adding a note of humour to the thesis.

Finally, the statistical and computer tools used for the analysis are presented and their use explained in detail. The next chapter presents the findings of the research and analyzes the results in a critical way.

4 RESULTS AND ANALYSIS

This chapter presents the results of the research and the analysis performed. It also compares this results to previous research.

4.1 RESULTS OVERVIEW

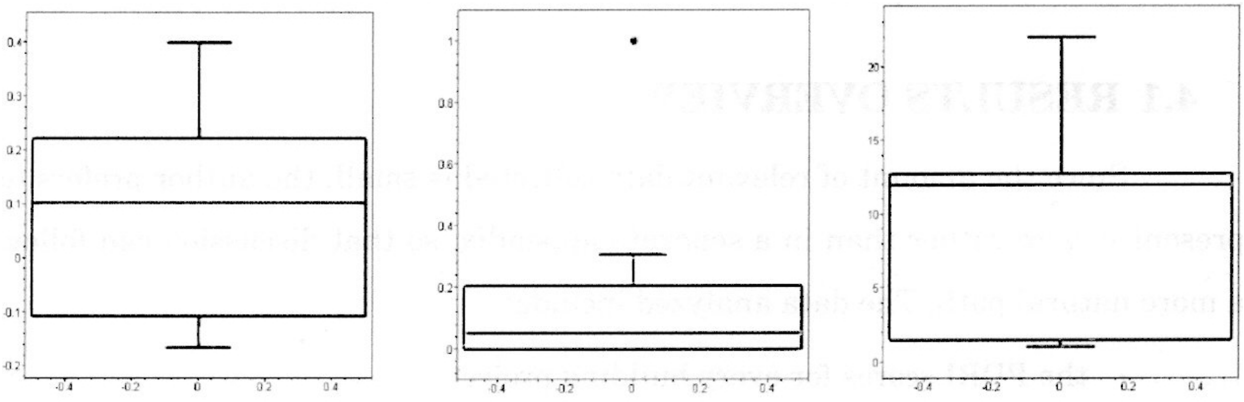
Since the amount of relevant data collected is small, the author prefers to present it here rather than in a separate appendix, so that discussion can follow a more natural path. The data analyzed include:

- the PDRI scores for every building project
- the performance variable related to cost
- the performance variable related to schedule
- the performance variable related to change orders
- the performance variable related to financial performance
- the performance variable related to achievement of original intent
- the performance variable related to owner satisfaction.

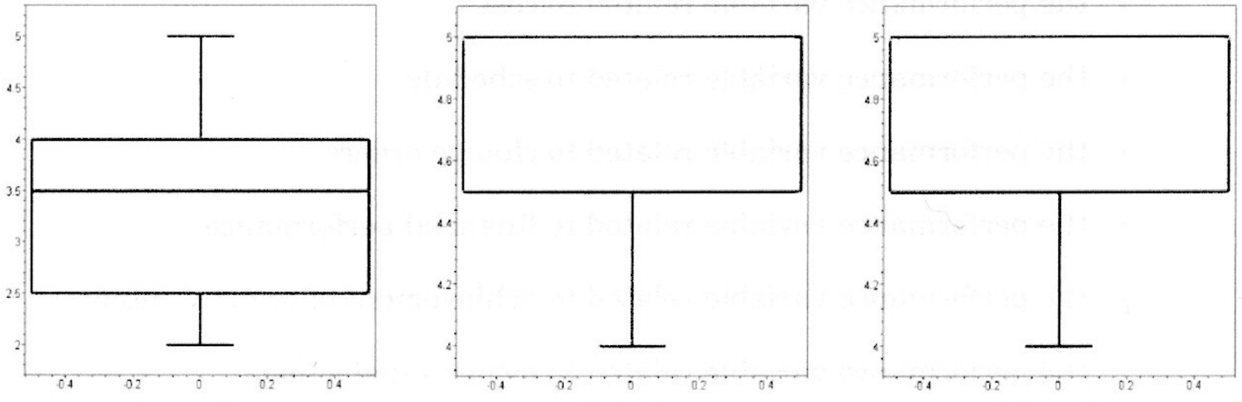
	Cost	Schedule	Change Orders	Financial Performance	Intent	Success	PDRI
70 Pacific Street	-0.17	0	3	5	5	5	115.75
E19 Renovations	-0.05	0	1	3	5	5	163.25
Dreyfus Chemistry Building	0.16	0.1	12	4	5	5	204.25
224 Albany Street Dorm	0.28	0	13	3	4	4	120
Zesiger Center	0.4	1	22	4	5	5	92
Stata Center	0.04	0.31	N/A	2	5	5	182

Table 4.1 Values of the performance variables used and PDRI scores for every project.

4.2 BOX PLOTS



COST SCHEDULE CHANGE ORDERS

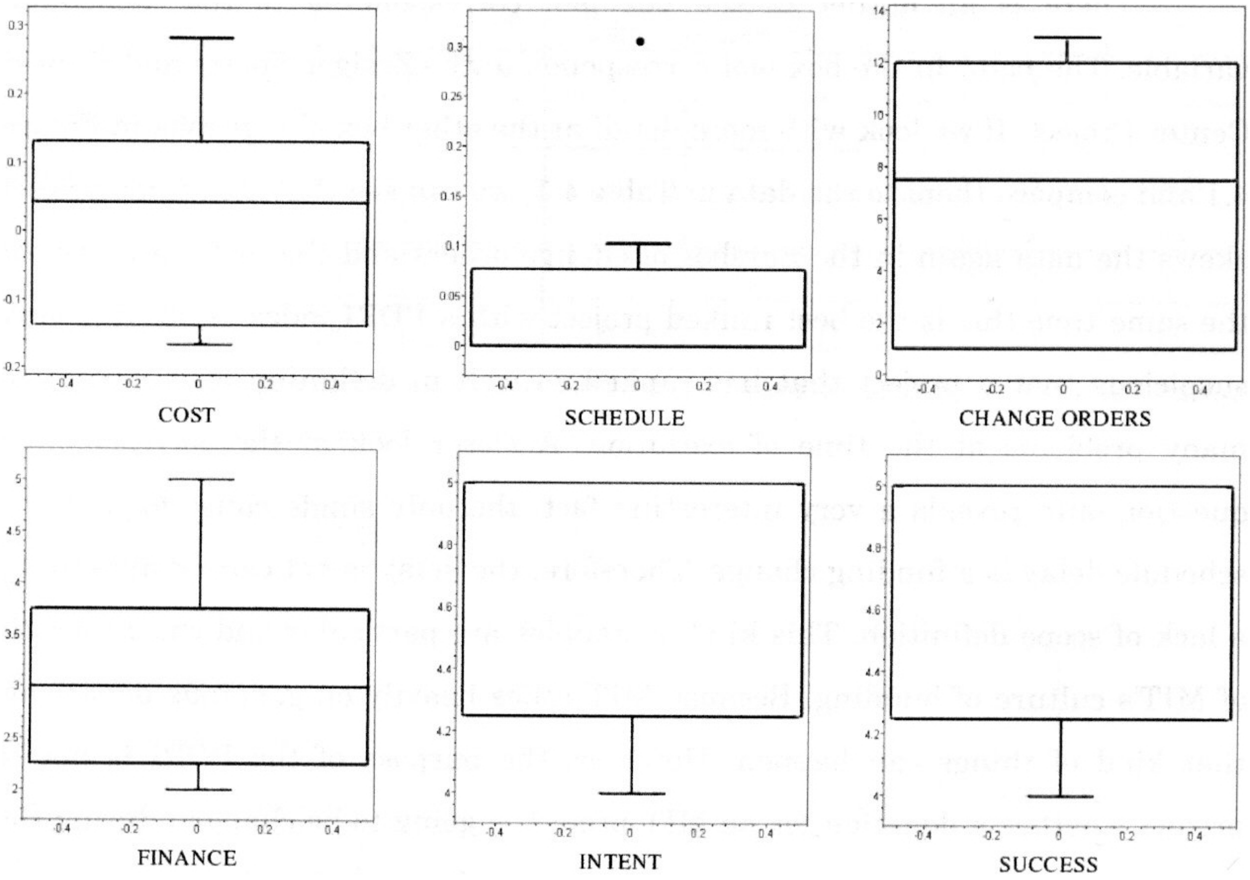


FINANCE INTENT SUCCESS

Figure 4.1 Box plots of the 6 different success variables used.

There is an outlier in the box plot corresponding to the “Schedule” variable. The point in the box plot corresponds to the Zesiger Sports and Fitness Center Project. If we look with more detail at the other box plot graphs in Figure 4.1 and compare them to the data in Table 4.1, we can see that this same project skews the data again in the number of change orders and the cost variables. At the same time this is the best ranked project with a PDRI index of 92. It is very suspicious that a project that has ranked so well in definition level causes so many problems at the time of execution. A closer look at the corresponding questionnaire reveals a very interesting fact: the only single cause for a 100% schedule delay is a funding change. Therefore, the delay is not caused directly by a lack of scope definition. This kind of troubles are particular and characteristic of MIT's culture of building. Because MIT relies heavily on generous donations, that kind of things can happen. However, the purpose of the PDRI is not to predict whether a donation for an MIT project is going to be changed during the life of the project, but rather to identify potential areas of problems that stem from a lack of project definition. Because of all of these reasons, the author decides to remove the Zesiger Sports and Fitness Center from the project data. With the Zesiger Sports and Fitness Center taken out of the dataset, a new set of box plots is needed, see Figure 4.2.

Once more, we find another outlier in schedule performance. In this case the project in question is the Stata Center. Nevertheless, since it does not skew any other parameter and there is no particular reason that justifies removing this project from the dataset, the author prefers to conserve this project and continue with the analysis.



COST SCHEDULE CHANGE ORDERS

FINANCE INTENT SUCCESS

Figure 4.2 Box plots of the 6 different success variables used after removing the Zesiger Sports and Fitness Center project.

4.3 SCATTER PLOTS AND CORRELATION FACTORS

This section provides another type of graphical representation of the data. Now the purpose is to observe how each of the performance variables confronts to the PDRI ratings. To accomplish this the author employs bi-variate scatter plots with each of the pair of data using the PDRI ratings as the independent variable. Also, the author calculates the correlation factor existent to give a numerical value to any possible correlation.

SCATTER PLOTS AND CORRELATION FACTORS

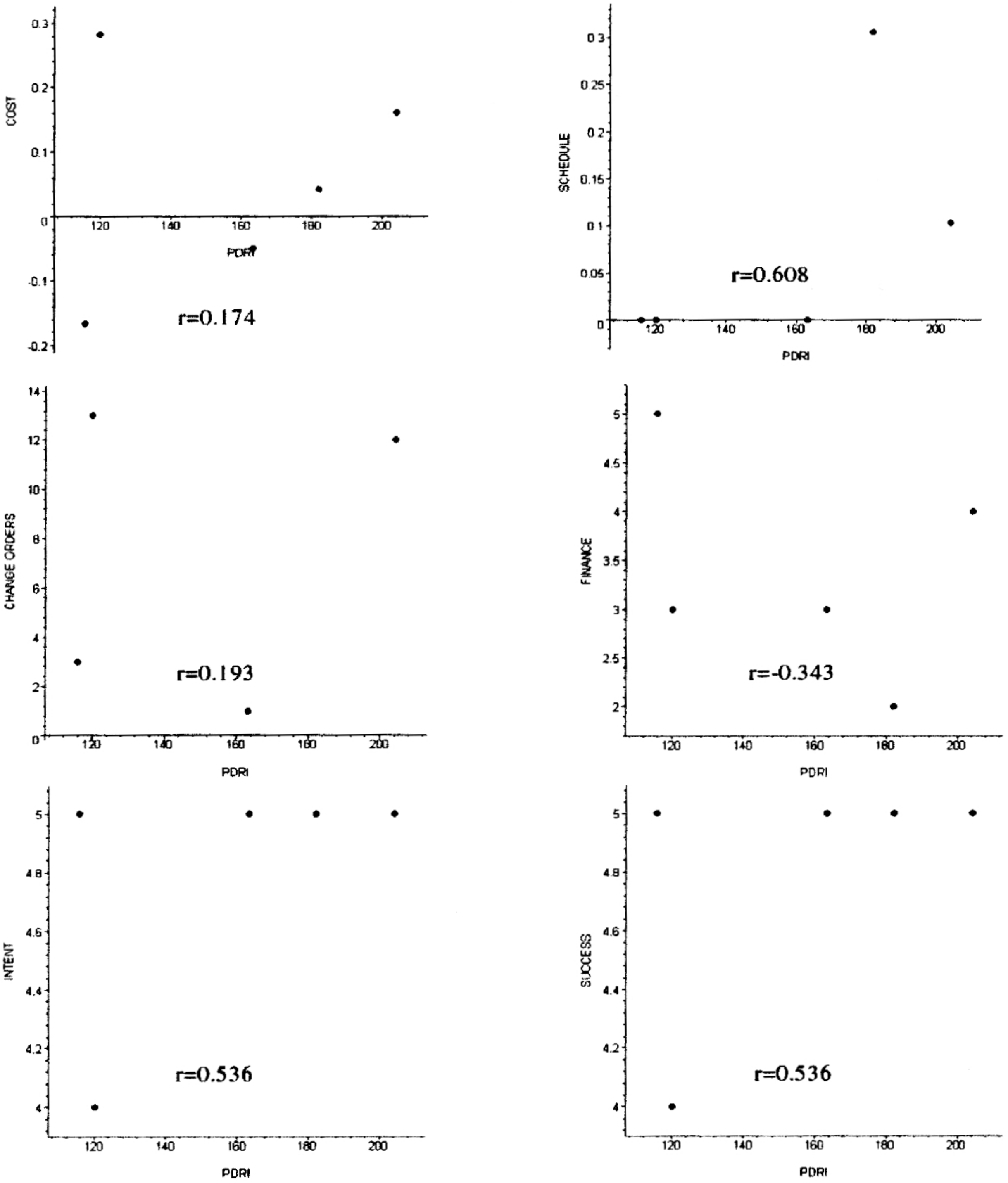


Figure 4.3 Scatter plots showing the correlation between the different performance variables and the PDRI indexes.

The first plot represents the scatter plot of PDRI scores versus the cost performance variable. In this plot we can identify clearly a linear tendency of the 4 bottom points. However the top left point in the graph destroys that line. This point corresponds to the 224 Albany Street project. Taking a closer look to the project questionnaire, the author recalls that the project suffered from a total of 13 change orders for an amount equivalent to 10.6% of the total estimated cost of the project. Additionally, after project authorization there were 3 scope/design changes that increased the cost of the project for a total value representing 8.4% of the planned construction costs. This is an objective indicator of a lack of definition in pre-project planning. Another consideration that the author makes is that a project scoring as low as 120 in the PDRI (being 70 the lowest possible and 1000 the highest possible) one would expect that the project performed better. In addition, out of all the projects sampled this is the single one that does not score 5 in the two subjective questions regarding customer satisfaction. That is, the performance variables measuring original intent matching, and project success. Finally, when computing the linear correlation factor of this variable respect to the PDRI with and without the 224 Albany Street project, the difference in results is dramatic. With the project taken into account r receives a value of just 0.174, while the value of r jumps to 0.978 if the project is removed from the sample. Taking all these factors into account, the author decides to remove the 224 Albany Street Project, for the purpose of finding a correlation between the two named variables.

No clear relation can be drawn from the other scatter plots. In all cases the spacial distribution of the points is either random-looking, or with a tendency to uniformity (in the owner satisfaction related questions), which does not imply correlation of data.

One observation the author makes however, regarding the second plot representing the relationship between PDRI scores and project schedules, is that all the projects scoring below 170 in the PDRI did not present any schedule delays.

4.4 REGRESSION ANALYSIS

This section presents the regression analysis that the author performs to correlate the PDRI ratings with the projects' cost performances. In the previous section has been shown that a strong linear relationship exists between the 2 variables. Therefore it is interesting to write an equation for that relationship and study its characteristics.

The equation of the line approximated using the least squares method is:

$$Cost\ Variation(\%) = -60.3 + 0.36 \cdot PDRI$$

Equation 4.1 Linear regression of the Cost-PDRI correlation.

This equation is represented in Figure 4.4 with the points of the data that make a correlation r = 0.978, and R^2 = 0.957.

Also a more accurate quadratic model can be adjusted by the equation:

$$Cost\ Variation(\%) = 7.9 - 0.54 \cdot PDRI + 0.0029 \cdot (PDRI)^2$$

Equation 4.2 Quadratic regression of the Cost-PDRI correlation.

Where the graphical representation is shown in Figure 4.3.

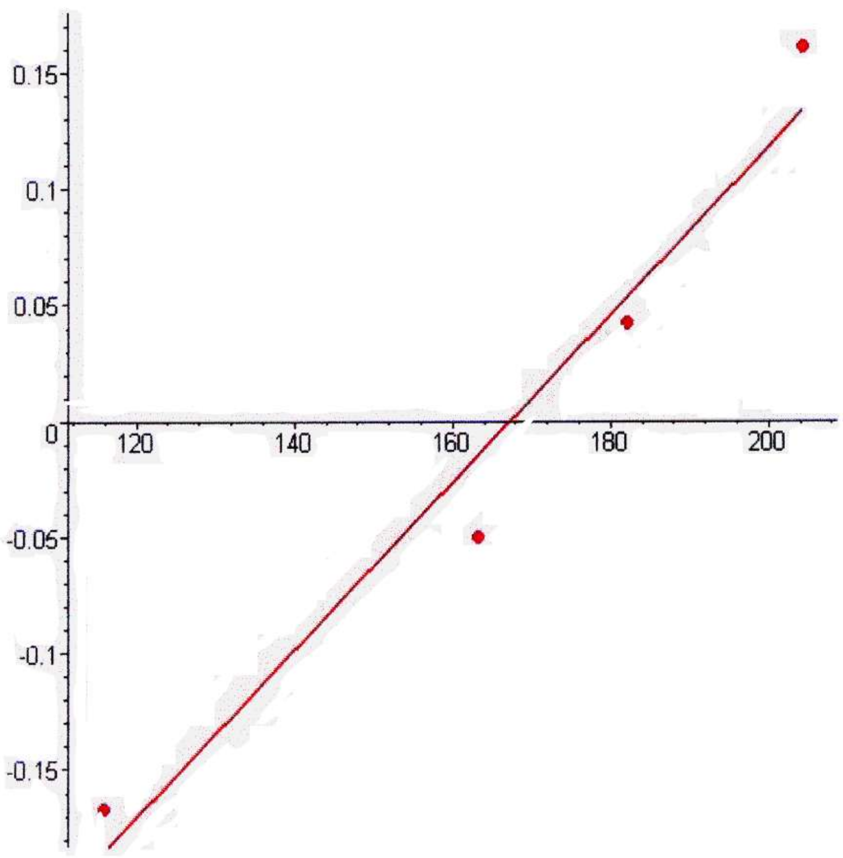


Figure 4.4 Linear regression of the relationship between Cost and PDRI (R^2=0.957).

This quadratic model can be interpreted as representing the physical limit that exists to reducing the cost of the project. It can be observed that the curvature of the equation increases as the costs are reduced more and more. At the other end, the equation can be fairly approximated by a straight line.

One particular interesting point to study in both cases is the 0 cutting point, since that point defines the definition level at which the project will presumably be completed on budget. For the linear model that point is PDRI = 167.5, whereas for the quadratic model that point lies at PDRI = 170.2.

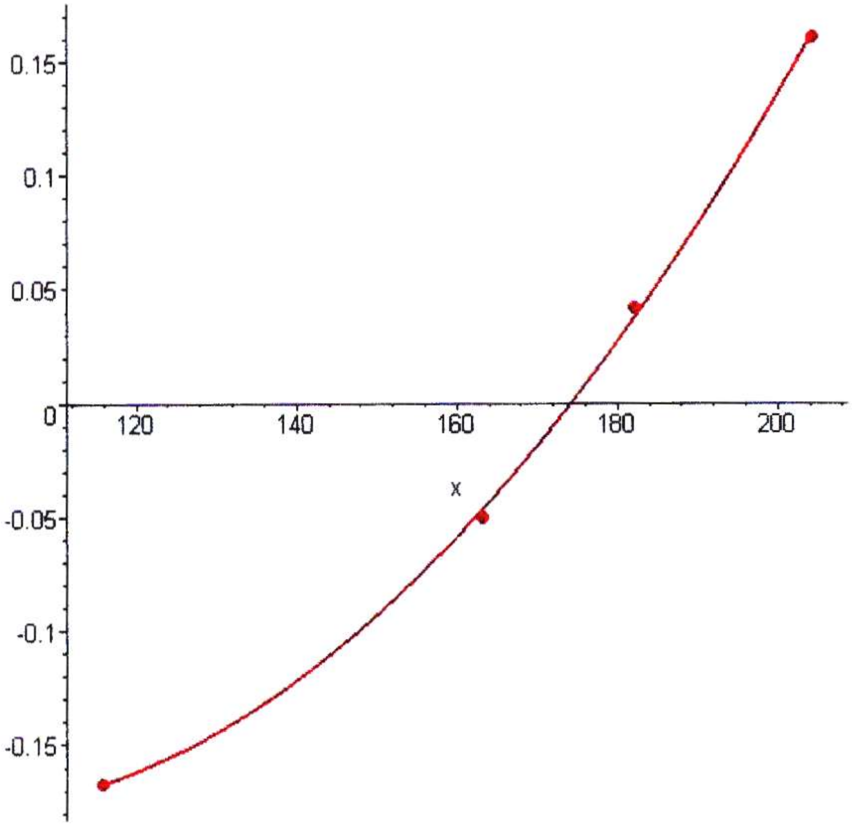


Figure 4.5 Quadratic regression of the relationship between Cost and PDRI.

4.5 CRITICAL ANALYSIS OF RESULTS AND COMPARISON

The results presented in this chapter differ substantially from those presented by previous researchers on the topic (Cho, Furman and Gibson 1999, Cho 2000, Cho and Gibson 2001). The previous research discussed in the first 2 chapters of this thesis proposed a generic model for predicting the performance of a building project based on the definition level during the pre-project planning phase. While the formulation of the model was very serious, the validation part lacked coherence in the assumptions and strictness in the conclusions.

In chapter 2 the author mentions that the criteria used to generate the weights of the different elements in the PDRI score list is essentially economic. The author also recalls that the relationship established by the model between the different levels of element definition and the corresponding weights is forced to be linear by definition. From these 2 basic model characteristics, one would expect in the validation process to find a linear relationship between total project scores and success based on economic data. This can be explained because of the way the total score is computed. It is done by the simple addition of the scores provided by each single element of the list. Given the property of additivity consisting of the fact that linear functions added together result in another linear function, it is possible to infer that the scores that a project is given by the PDRI are linearly related to the necessary contingency to cover the risk of indefinition in the project.

However, this was neither proved nor proposed by the previous researchers who formulated the model in the literature review the author has found. In fact from the statistical data collected by those researchers, they could find correlation levels as high as $R^2 = 0.121$. Erroneously they claimed that such value represented positive proof of existence of a linear relationship between PDRI scores and performance variables based on cost. The author poses the question whether the grouping of the data used by previous researchers into 3 discrete groups might have ruined the statistical value of that data. It would be a pity if such theory turned true.

On the self critic exercise the author must say that in order to accomplish a good linear relationship representation had to discard one observation from the sample whose contribution was doubtful to the goodness of the dataset. However, enough arguments were presented supporting that decision. In addition, the fact that those “bad” points appeared in the sample must be understood as a warning on the use of the PDRI. The evaluation has to be made based on serious principles and with the aim of being impartial at the moment of rating the project. This is very important because the project managers are rating their own job and must make a deep exercise of self criticism every time they face a PDRI scoring sheet.

The other observation to make is that the PDRI does not solve all the problems that may arise during the development of a project. The early rejection of the Simmons Hall project as being a suitable project for the study, or the later rejection of the Zesiger Sports and Fitness Center should suffice as proof.

Out of the models proposed in this chapter, the author prefers the linear model because of the qualitative value it brings to demonstrate the principles of the development of the Project Definition Rating Index. However, the quadratic model also adds an important feature as it limits the possible cost reduction to a credible value. In addition, this quadratic model can be eventually approached by a linear one on the higher spectrum of the PDRI range of values.

5 CONCLUSIONS

The work here presented has made interesting findings related to the managerial tool for building projects named Project Definition Rating Index. The three main objectives have been accomplished satisfactorily.

5.1 REVIEW OF OBJECTIVES

Thanks to the critical analysis made in the previous chapter, it is now easier to understand the working principle of the PDRI. The PDRI scores of the projects relate to the cost performance of the project. This relationship appears to be linear. The reason for this relationship is entirely based on the definition of the tool itself. Firstly because of the criteria used by the researchers to weight all the 64 different elements that compose the PDRI list. And secondly because of the decision of interpolating linearly the weights for the different definition levels of each element. In the research the author presents evidences that this relationship exists, and there doesn't appear to be any other reason to explain it. Previous researchers made the hypothesis that PDRI scores could be related to other variables measuring project success. The author instead claims that linear relationship had never been proved before with such strong correlation factors as in the present thesis. The author also concludes that PDRI scores are not related to any measure of success other than cost variables.

Another accomplishment of the thesis is to enlarge the pool of projects used to validate the PDRI for building projects. Before the present work, and based on the literature, the PDRI had been validated using 33 different projects with a total cost of approximately $900 million. This project contributes with 6 new projects that represent a total cost of more than $500 million. This increases of 18% in the number of projects and 55% in the cost of the projects surveyed.

Finally, the author concludes with a few guidelines for future use in MIT building projects. Based on the results presented, the author estimates that the pre-planning effort of MIT projects should lead to definition levels scoring 170 or lower in the PDRI for building projects as it was defined by Cho (2000). This is considered a good target for 2 reasons. First of all, the two regressions performed in the analysis yield equations that cross the zero variation line in cost at points near the 170 value. The second reason is that all the projects considered and that scored below 170 in the PDRI were completed on schedule.

The author emphasizes that the findings based in the regressions do not have to be valid for every organization. The analysis was performed using exclusively projects developed under the ownership of MIT, and therefore results can only be expected valid for MIT projects. However, the methodology presented should be applicable to any organization willing to use the PDRI to assess the definition level of their projects. This methodology also takes advantage of the little variation in the perturbations that may affect the sample used (i.e. location, market conditions, owner experience, etc.), given that all the projects were developed by the same owner, in a short period of time and in nearby locations.

5.2 RECOMMENDATIONS

The author strongly recommends the use of the PDRI to assess the managing team of a particular project. This recommendation becomes even stronger if the team belongs to an organization developing several projects thus having the opportunity to validate the PDRI using the methodology presented in this thesis. In this sense, it is crucial to maintain the linear characteristics of the tool by not rounding the interpolated values of the weights used. It is also very important not to group data values into discrete groups, thus reducing the richness of the data collected. There are no proofs of these actions being pernicious, but by avoiding them the author has achieved very good results.

Another recommendation the author makes is to be very critical whenever using the PDRI to score a project. Since the people evaluating the project with the PDRI are the members of the managing team, it becomes a self evaluation process, in which honesty is critical to yield good results.

Finally the author wants to express his interest in a similar PDRI tool be developed for infrastructure projects. Industrial projects and building projects already enjoy the existence of this tool, and by creating the Project Definition Rating Index for infrastructure projects, all the different fields of the construction industry could benefit from this useful tool.

6 APPENDIX A

This appendix displays the appropriate weights to be used for the PDRI elements in order to maintain linearity between definition levels and element weights.

The definition of the elements has been conserved equal to the original developed by Cho (2000). The only changes therefore are the weights corresponding to levels 2, 3 and 4 of those elements for which the rounding process would have altered the linearity of the weights' sequence. As has been shown in the dissertation, it is convenient not to round the values of these intermediate definition levels because that permits transferring the linear relationship between definition levels and weights from the element level to the total project level.

Since the definition of the weights for each element is based solely on recommended contingencies for each element, depending on the definition status of that element, then we can infer that the definition level of the whole project will be solely related to the necessary contingency for the whole project. The quantitative difference may not be very large, but qualitatively this is an important point that the author wants to recall the attention to. In the following pages the list of the elements with the calculated weights is displayed.

SECTION I – BASIS OF PROJECT DECISION						
CATEGORY	**Definition Level**					
Element	0	1	2	3	4	5
A BUSINESS STRATEGY						
A1 Building use	0	1	11,75	22,5	33,25	44
A2 Business Justification	0	1	7,5	14	20,5	27
A3 Business Plan	0	2	8	14	20	26
A4 Economic Analysis	0	2	6,75	11,5	16,25	21
A5 Facility Requirements	0	2	9,25	16,5	23,75	31
A6 Future Expansion / Alteration Considerations	0	1	6,25	11,5	16,75	22
A7 Site Selection Considerations	0	1	7,75	14,5	21,25	28
A8 Project Objectives Statement	0	1	4,5	8	11,5	15
B OWNER PHILOSOPHIES						
B1 Reliability Philosophy	0	1	5,25	9,5	13,75	18
B2 Maintenance Philosophy	0	1	4,75	8,5	12,25	16
B3 Operating Philosophy	0	1	4,5	8	11,5	15
B4 Design Philosophy	0	1	5,5	10	14,5	19
C PROJECT REQUIREMENTS						
C1 Value-Analysis Process	0	1	5,5	10	14,5	19
C2 Project Design Criteria	0	1	6,75	12,5	18,25	24
C3 Evaluation of Existing Facilities	0	2	7,5	13	18,5	24
C4 Scope of Work Overview	0	1	5	9	13	17
C5 Project Schedule	0	2	6,5	11	15,5	20
C6 Project Cost Estimate	0	2	8,25	14,5	20,75	27

Table 6.1 Weighted List for section I of the PDRI.

SECTION II - BASIS OF DESIGN						
CATEGORY	**Definition Level**					
Element	0	1	2	3	4	5
D SITE INFORMATION						
Dl Site Layout	0	1	4,25	7,5	10,75	14
D2 Site Surveys	0	1	4,25	7,5	10,75	14
D3 Civil Geotechnical Information	0	2	6,25	10,5	14,75	19
D4 Governing Regulatory Requirements	0	1	4,25	7,5	10,75	14
D5 Environmental Assessment	0	1	4,75	8,5	12,25	16
D6 Utility Sources with Supply Conditions	0	1	4	7	10	13
D7 Site Life Safety Considerations	0	1	2,75	4,5	6,25	8
D8 Special Water and Waste Treatment Requirements	0	1	3,5	6	8,5	11
E BUILDING PROGRAMMING						
El Program Statement	0	1	4,75	8,5	12,25	16
E2 Building Summary Space List	0	1	6	11	16	21
E3 Overall Adjacency Diagrams	0	1	3,25	5,5	7,75	10
E4 Stacking Diagrams	0	1	4	7	10	13
E5 Growth and Phased Development	0	1	4,5	8	11,5	15
E6 Circulation and Open Space Requirements	0	1	4	7	10	13
E7 Functional Relationship Diagrams Room by Room	0	1	3,25	5,5	7,75	10
E8 Loading and Unloading Storage Facilities Requirements	0	1	2,75	4,5	6,25	8
E9 Transportation Requirements	0	1	3	5	7	9
E10 Building Finishes	0	1	4,5	8	11,5	15
E11 Room Data Sheets	0	1	4	7	10	13
E12 Furnishings Equipment & Built-Ins	0	1	4,25	7,5	10,75	14
E13 Window Treatment	0	0	1,25	2,5	3,75	5
F BUILDING PROJECT DESIGN PARAMETERS						
F1 Civil / Site Design	0	1	4,25	7,5	10,75	14
F2 Architectural Design	0	1	6,25	11,5	16,75	22
F3 Structural Design	0	1	5,25	9,5	13,75	18
F4 Mechanical Design	0	2	6,5	11	15,5	20
F5 Electrical Design	0	1	4,5	8	11,5	15
F6 Building Life Safety Requirements	0	1	3,25	5,5	7,75	10
F7 Constructability Analysis	0	1	4,25	7,5	10,75	14
F8 Technological Sophistication	0	1	3	5	7	9
G EQUIPMENT						
G1 Equipment List	0	1	4,5	8	11,5	15
G2 Equipment Location Drawings	0	1	3,25	5,5	7,75	10
G3 Equipment Utility Requirements	0	1	3,5	6	8,5	11

Table 6.2 Weighted List for Section II of the PDRI.

SECTION III – EXECUTION APPROACH						
CATEGORY	**Definition Level**					
Element	0	1	2	3	4	5
H PROCUREMENT STRATEGY						
H1 Identify Long Lead Critical Equip. & Materials	0	1	4,25	7,5	10,75	14
H2 Procurement Procedures and Plans	0	1	3,5	6	8,5	11
J DELIVERABLES						
J1 CADD / Model Requirements	0	0	1	2	3	4
J2 Documentation Deliverables	0	1	2,5	4	5,5	7
K PROJECT CONTROL						
K1 Project Quality	0	1	2,75	4,5	6,25	8
K2 Project Control Cost	0	1	4	7	10	13
K3 Project Schedule Control	0	1	4,25	7,5	10,75	14
K4 Risk Management	0	1	5,25	9,5	13,75	18
K5 Safety Procedures	0	1	3	5	7	9
L PROJECT EXECUTION PLAN						
L1 Project Organization	0	1	3,25	5,5	7,75	10
L2 Owner approval Requirements	0	1	3,5	6	8,5	11
L3 Project Delivery Method	0	1	4,5	8	11,5	15
L4 Design Construction Plan & Approach	0	1	4,5	8	11,5	15
L5 Substantial Completion Requirements	0	1	3	5	7	9

Table 6.3 Weighted List for Section III of the PDRI.

7 APPENDIX B

VALIDATION QUESTIONNAIRE PROJECT DEFINITION RATING INDEX (PDRI) FOR BUILDING PROJECTS

Construction Industry Institute (CII) PDRI for Building Projects Research Team

1 PROJECT BACKGROUND INFORMATION

1.1 Date:____________________

1.2 Point of Contact

1.2.1 Name:____

1.2.2 Title:____

1.2.3 Address:____

____

1.2.4 Tel. No.:_______________________Fax. No.:_____________________________

1.2.5 E-mail:____

2 General Project Information:

2.1 Project Name:____

2.2 Project ID Number (if applicable):____________________________

2.3 In what town or city is the project located?_____________________

In what state or province?______________________________

2.4 What type of facility is this project? (chose one)

[ ] Apartments
[ ] Banks
[ ] Churches
[ ] Dormitories
[ ] Hotels/Motels
[ ] Industrial control buildings
[ ] Institutional buildings
[ ] Light assembly/Manufacturing
[ ] Medical facilities (Airport, Train/Bus Station, etc.)
[ ] Nursing homes

[ ] Offices
[ ] Parking structures
[ ] Public assembly/Performance halls
[ ] Recreational/Athletic facilities
[ ] Research & Laboratory facilities
[ ] Schools
[ ] Stores/Shopping centers
[ ] Transportation terminals
[ ] Warehouses

[ ] Other (please specify)________________________________

2.5 What are the primary uses or functions of this facility? (please check all that apply)

[ ] Food service
[ ] Research
[ ] Multimedia
[ ] Instructional

[ ] Medical
[ ] Institutional
[ ] Residential
[ ] Office

[ ] Retail

[ ] Recreational

[ ] Light manufacturing

[ ] Storage

[ ] Other (please specify)____

2.6 What is the size of the facility (e.g., number of occupants, volume/capacity, net or gross square footage, number of floors, etc.)

____

____

2.7 Did the project considered involve (if renovation cost is greater than 50%, consider it as a renovation)

[ ] New construction

[ ] Renovation

2.8 What was the level of the project complexity?

[ ] High

[ ] Average

[ ] Low

2.9 Was there anything unique about this project? (please check all that apply)

[ ] New process or technology for the organization/location

[ ] First of a kind technology for the industry

[ ] Largest (scale)

[ ] Other (e.g., special development requirements, equipment, location, execution, etc.) Please describe:____

[ ] Not applicable

2.10 What was the delivery method that you used on your project?

[ ] General Contractor
[ ] Multiple Primes
[ ] Turnkey
[ ] Construction Manager
[ ] Design-Build
[ ] Build Operate Transfer
[ ] Other (please specify)______________________________

2.11 What was the type of contract used?

[ ] Lump Sum
[ ] Cost Plus
[ ] Unit Price
[ ] Guaranteed Maximum Price
[ ] Other (please specify)______________________________

3 Schedule Information:

3.1 Please provide the following schedule information:

Item	**Planned** (mm/dd/yy)	**Actual** (mm/dd/yy)
Start Date of Construction Documents Development		
End Date of Construction Documents Development		
Start Date of Construction		
Date of Substantial Completion		

3.2 If there were any schedule extensions or reductions during development of construction documents and construction, please indicate the reason(s) in the appropriate box(es) below by supplying the duration(s) of the change(s) (in months) and whether it was an extension (Ext) or reduction (Red).
(please check all that apply)

Delay	Months	Ext	Red	Delay	Months	Ext	Red
Scope/Design		[ ]	[ ]	Engineering Productivity		[ ]	[ ]
Funding Change		[ ]	[ ]	Master. Shortage/Delivery		[ ]	[ ]
Labor Shortage		[ ]	[ ]	Technology Change		[ ]	[ ]
Regulatory Change		[ ]	[ ]	Design Error		[ ]	[ ]
Contract Dispute		[ ]	[ ]	Differing Site Conditions		[ ]	[ ]
Equipment Availability		[ ]	[ ]	Design Coordination		[ ]	[ ]
Weather		[ ]	[ ]	Unreal/Inaccurate Schedule		[ ]	[ ]
Construction Productivity		[ ]	[ ]	Commissioning Problem		[ ]	[ ]
Strike		[ ]	[ ]	Other (please specify) ________________ ________________		[ ]	[ ]

3.3 Do you have any additional comments regarding any causes or effects of schedule changes (e.g., special causes, freak occurrences, etc.)?

____

____

____

4 Cost Information:

4.1 Please provide the following cost information: (If the person filling out this section does not have the information, please state Don t know, if it was 0, state as 0.)

Item	Estimated Costs at Start of Construction Document Development	Actual Costs After Construction Complete
Total Design Costs[1]		
Construction Costs		
Fit up Equipment Costs[2]		
Soft Costs[3]		
Owner's Contingency		
Other		
Total Project Costs		

1. Total Design Cost is Architect s total fees which include programming, schematic design, construction document development, and design development fees
2. Fit-up Equipment costs include non-core equipment and FFE
3. Soft Costs include interest, due diligence, and other consulting services (not including land)

5 Change Information:

5.1 What were the total number of change orders issued (including during both construction document development and construction)?____________________

5.2 What were the total dollar amounts of all change orders? $_______________

5.3 What was the net duration change in the completion date resulting from change orders?________________________months

5.4 Did the changes increase or decrease the length of the original project duration? [ ] Increased [ ] Decreased

5.5 Were there any individual changes after project authorization that exceeded 1% of the project budget?

[ ] No

[ ] Yes - If "Yes," what were the total cumulative effects and the direction of these changes on:

a) Cost: $___________________[ ] Increase or [ ] Decrease

b) Schedule:________________months. [ ] Increase or [ ] Decrease

c) How many changes comprised 1% of the original contract amount or greater?_

d) What were the reasons for the changes? (Please check all that apply.)

[ ] Scope/Design Change
[ ] Labor Shortage
[ ] Contract Dispute
[ ] Weather
[ ] Strike
[ ] Funding Change
[ ] Regulatory Change
[ ] Equipment Availability
[ ] Constr. Productivity
[ ] Engr. Productivity

[ ] Material Shortage/Delivery
[ ] Design Error
[ ] Design Coordination
[ ] Technology Change
[ ] Differing Site Conditions
[ ] Unrealistic/Inaccurate Sched.
[ ] Other (please specify)____

Do you have any additional comments regarding any causes or effects of change orders?

____

____

____

6 Financial/Investment Information:

6.1 The decision to design and construct a facility relies heavily on specific project financial performance measures such as capital turnover, return on investment, benefit/cost ratio, return on equity, return on assets, etc. For the major financial criteria used on this project to date, how well has the actual financial performance matched the expected financial performance measurement using the scale below?

Using a scale of 1 to 5, with 1 being fallen far short of expectations to 5 being far exceeded expectations at authorization, please circle only one.

1	2	3	4	5
fallen far short		matched closely		far exceeded

6.2 What type of specific project financial measurement was used to authorize the project (e.g., Return on Assets, Return on Equity, Internal Rate of Return, Benefit/Cost Ratio, Payback Period, etc.)?

____

7 Operating Information:

7.1 What percent of design size (e.g., square footage, number of occupants, etc.) was planned or anticipated (at the time the project was ready to begin development of construction documents) and actually obtained after the end of commissioning (e.g., if the facility was planned to be 50,000 gsf, but was built at 40,000 gsf, the percentage would be 80%)?

	Obtained
a) Design Size at Commissioning	__________________%

Design size is defined as "the nominal facility requirements (number of occupants, volume, net square footage, etc.) of the facility which is used during design to determine space, develop facility functions, as well as to size equipment and mechanical and electrical systems."

b) Was the facility scope reduced/increased in any significant manner?
If so, please indicate:

___________Build shell, not interior finish

___________Size

___________Materials of construction

___________Equipment

___________Other (please specify)_______________________________________

7.2.What percent of facility utilization was planned or anticipated and actually obtained 6 months after the end of commissioning?

	Planned	Obtained
Facility Utilization 6 months after commissioning	____________________%	____________________%

Do you have any additional comments regarding facility utilization?

____

____

Utilization is defined as "the percentage of the facility actually being used versus that anticipated at the time the project was conceived or approved for design and construction. " For example, the rental occupancy may have been planned at 75% after six months of operation and actually was only 50%.

7.3 After the first 6 months of use, have operational and maintenance costs for the facility been: (circle only one)

1	2	3	4	5
fallen far short		matched closely		far exceeded

8 Customer Satisfaction:

8.1 Based on the original scope of work for the facility set prior to the beginning of construction document development and construction, rate how the facility matches the original intent: (circle only one)

1	2	3	4	5
very different	-->			closely matches

If the facility is very different from the original intent, please specify what caused the changes____

____

____

8.2 Reflecting on the overall project, rate how successful you feel the project has been using a scale of 1 to 5, with 1 being very unsuccessful to 5 being very successful: (circle only one)

1	2	3	4	5
very unsuccessful	-->			very successful

8.3 Do you have any additional comments regarding customer satisfaction?

____

____

____

9 Project Rating Information: Next, please complete the Project Rating Information form located on the next few pages. Detailed instructions for completing this form are explained below.

INSTRUCTIONS FOR RATING A PROJECT

The Project Definition Rating Index (PDRI) is intended to evaluate the completeness of the scope definition for a project when it is submitted for authorization (prior to detailed design and construction). When rating a project, the team involved in the pre-project planning effort should consider the level of definition of each element in the project definition package **at the time the project was ready to begin development of construction documents and construction**. The project must have been in commercial/business/normal operation for **at least 6 months**.

The PDRI consists of three main sections, each of which is broken down into a series of categories which, in turn, are further broken down into elements. Scoring is performed by evaluating and rating the individual elements. Elements should be rated numerically from 0 to 5 based on its level of definition at the point in time prior to beginning detailed design and construction. Think of this as a zero defects type of evaluation. Elements that were as well defined as possible should receive a perfect rating of "one". Elements that were completely undefined should receive a rating of "five". All other elements should receive a "two", "three", or "four" depending on their levels of definition. Those elements deemed not applicable for the project under consideration should receive a zero. The ratings are defined as follows:

0 - Not Applicable

1 - Complete Definition

2 - Minor Deficiencies

3 - Some Deficiencies

4 - Major Deficiencies

5 - Incomplete or Poor Definition

To rate an element, first read its definition in the Description section of the 64 PDRI Elements document. Some elements contain a list of items to be considered when evaluating their levels of definition. These lists may be used as checklists. Note *that some of these items may not be applicable for your project. Next, refer to the Project Rating Information form and locate the element. Please choose only one definition level (0, 1, 2, 3, 4, or 5) for that element based on your perception of how well it was defined when the project was authorized. Once you have chosen the appropriate definition level for the element please check (√) the corresponding box. Do this for each of the 64 elements in the PDRI. Be sure to rate each element.*

SECTION I – BASIS OF PROJECT DECISION						
CATEGORY	**Definition Level**					
Element	0	1	2	3	4	5
A BUSINESS STRATEGY						
A1 Building use						
A2 Business Justification						
A3 Business Plan						
A4 Economic Analysis						
A5 Facility Requirements						
A6 Future Expansion / Alteration Considerations						
A7 Site Selection Considerations						
A8 Project Objectives Statement						
B OWNER PHILOSOPHIES						
B1 Reliability Philosophy						
B2 Maintenance Philosophy						
B3 Operating Philosophy						
B4 Design Philosophy						
C PROJECT REQUIREMENTS						
C1 Value-Analysis Process						
C2 Project Design Criteria						
C3 Evaluation of Existing Facilities						
C4 Scope of Work Overview						
C5 Project Schedule						
C6 Project Cost Estimate						

SECTION II - BASIS OF DESIGN						
CATEGORY	Definition Level					
Element	0	1	2	3	4	5
D SITE INFORMATION						
Dl Site Layout						
D2 Site Surveys						
D3 Civil Geotechnical Information						
D4 Governing Regulatory Requirements						
D5 Environmental Assessment						
D6 Utility Sources with Supply Conditions						
D7 Site Life Safety Considerations						
D8 Special Water and Waste Treatment Requirements						
E BUILDING PROGRAMMING						
El Program Statement						
E2 Building Summary Space List						
E3 Overall Adjacency Diagrams						
E4 Stacking Diagrams						
E5 Growth and Phased Development						
E6 Circulation and Open Space Requirements						
E7 Functional Relationship Diagrams Room by Room						
E8 Loading and Unloading Storage Facilities Requirements						
E9 Transportation Requirements						
E10 Building Finishes						
E11 Room Data Sheets						
E12 Furnishings Equipment & Built-Ins						
E13 Window Treatment						
F BUILDING PROJECT DESIGN PARAMETERS						
F1 Civil / Site Design						
F2 Architectural Design						
F3 Structural Design						
F4 Mechanical Design						
F5 Electrical Design						
F6 Building Life Safety Requirements						
F7 Constructability Analysis						
F8 Technological Sophistication						
G EQUIPMENT						
G1 Equipment List						
G2 Equipment Location Drawings						
G3 Equipment Utility Requirements						

SECTION III – EXECUTION APPROACH						
CATEGORY	Definition Level					
Element	0	1	2	3	4	5
H PROCUREMENT STRATEGY						
H1 Identify Long Lead Critical Equip. & Materials						
H2 Procurement Procedures and Plans						
J DELIVERABLES						
J1 CADD / Model Requirements						
J2 Documentation Deliverables						
K PROJECT CONTROL						
K1 Project Quality						
K2 Project Control Cost						
K3 Project Schedule Control						
K4 Risk Management						
K5 Safety Procedures						
L PROJECT EXECUTION PLAN						
L1 Project Organization						
L2 Owner approval Requirements						
L3 Project Delivery Method						
L4 Design Construction Plan & Approach						
L5 Substantial Completion Requirements						

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