A METHODOLOGY TO FACILITATE CONTINUOUS IMPROVEMENT IN THE SERVICES PROVIDED BY THE FACILITIES DEPARTMENT AT UPRM

By

Martha Liliana García Díaz

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Approved by:

_____	_____
Viviana Cesaní Vázquez, Ph.D. Member, Graduate Committee	Date
_____	_____
María Irizarry Serrano, Ph.D. Member, Graduate Committee	Date
_____	_____
Pedro Resto Batalla, Ph.D. President, Graduate Committee	Date
_____	_____
José R. Cedeño Maldonado, Ph.D. Graduate Studies Representative	Date
_____	_____
Agustín Rullán Toro, Ph.D. Department Chairperson	Date

Abstract

Business Process Reengineering (BPR) is a methodology used to radically improve processes. Resistance to change is a problem found in the literature which is higher in labor union environments. This research developed a methodology of continuous improvement in the presence of a union, based on BPR concepts and focused on the work measurement systems. The Information Technology (IT) was addressed by implementing a web-based database in the Facilities Department of the University of Puerto Rico, solving data management problems. The methodology included: knowing the original process and data collection activities; defining an improved process with user and customer participation; preparing people with trainings and setting up the database structure; and developing a method to predict the maintenance job duration. Results included the implementation of the web-based work order system. Three examples showed the validity of the method to predict job duration using hypothesis tests and regression models. Benefits were: improved service response, active participation of system users, and an understanding of response times.

Resumen

La Reingeniería de Procesos de Negocios (BPR) es una metodología utilizada para mejorar procesos radicalmente. La resistencia al cambio es un problema comúnmente encontrado en la literatura y es alto en ambientes de unión laboral. Esta investigación desarrolló una metodología de mejoramiento continuo en presencia de una unión, basado en los conceptos de BPR y enfocado en los sistemas de medición del trabajo. La tecnología de informática fue atendida mediante la implementación de una base de datos en el web para el Departamento de Facilidades de la Universidad de Puerto Rico, solucionando problemas en la administración de datos. La metodología incluyó: conocimiento del proceso actual y sus actividades de recolección de datos; definición de un proceso mejora con la participación de usuarios y clientes; capacitación de los usuarios y preparación de la estructura de la base de datos; y desarrollo de un método para predecir la duración de las tareas de mantenimiento. Los resultados incluyen la implementación del sistema de órdenes de trabajo en el web. Tres ejemplos muestran la validez del método para predecir la duración de las tareas con la ayuda de pruebas de hipótesis y modelos de regresión. Algunos beneficios fueron: mejoras en el servicio a los clientes, una participación activa de los usuarios y el entendimiento del tiempo requerido en responder a los clientes.

"Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the World"

Albert Einstein

(1879-1955)

To the memory of my grandfather Roberto Díaz (1900-2002)

This thesis is dedicated to my parents, Leonarda and Edgar, my brother César and my sister Diana, for the fulfillment of our dreams.

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Symbols List

AT: Available Time

BPR: Business Process Reengineering

FD: Facilities Department

IT: Information Technology

NW: Number of Workers

TR: Time Required

UPRM: University of Puerto Rico at Mayagüez Campus

WM: Work Measurement

WO: Work Order

WOS: Work Order System

Appendix List

Introduction

The Facilities Department (FD) of the University of Puerto Rico at Mayagüez Campus (UPRM) is divided into 14 sections. They perform campus maintenance requirements managed by a Work Order System (WOS). The reports generated by the system reveal that each section has a very low efficiency calculated using the ratio of man-hours applied to man-hours available. An initial effort to understand the cause of this poor performance revealed that some finished orders appeared like active orders on the system database, indicating data flow and communication problems (for example, open orders from 1997 were found in the system). There was evidence that other Work Orders (WO) were not executed with the promptness required by the customer.

The main objective of this thesis was focused on developing a methodology to facilitate continuous improvement in the services provided by the Facilities Department at UPRM addressing three main issues:

- *Improving the information of the process and communication flow of the Work Order System (WOS), and assessing its effectiveness, based on reengineering principles*. This research addressed issues such as:
    a) Information requirements (data collection needs)
    b) Data collection ownership and role of each system participant.
    c) Acceleration of data entry and data flow.

d) System control accuracy measurement (reports that provide visibility to work order usage discipline, data collection accuracy, and employee time allocation).

- *Developing an approach to predict work duration of maintenance services while improving data accuracy for a better understanding of employee and sections efficiency.* This included:

a) Establishment of a time standard model for maintenance activities.
b) Identification of relevant work parameters (e.g. distance, # of equipments, area, etc.).
c) Evaluation of people assignment to each work order and their roles within their team.
d) Definition of a relationship between work parameters, people, and work duration.

- *Implementing a solution to the problem taking into account the current union environment*.

a) Familiarizing with union policies.
b) Minimizing the resistance to change.
c) Increasing employee participation into the proposed solution by interviews and surveys.
d) Training personnel on Information Technology issues.

Figure 1 summarizes the three main focus areas that comprise this research work.

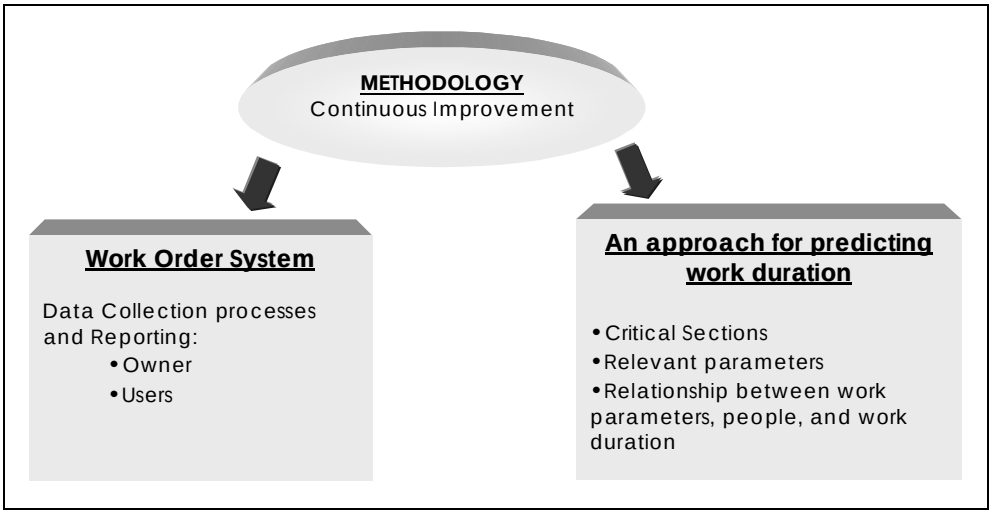

Figure 1. Research Frame

The restrictions of this research were:

1. The time frame of the research.
2. Only critical activities and sections were chosen to perform the time study analysis.

This research was a contribution of the Industrial Engineering Department to improve internal systems, processes and services provided by the Facilities Department of the University of Puerto Rico at Mayagüez Campus (UPRM). It was important to propose a methodology based on BPR principles taking care of the resistance to change (higher in a union environment) originated by transforming a process. Also, it was important to develop a prediction model to estimate service times because changes of processes may include changes in measurement systems. The intellectual contribution of this research focused on three areas:

1. The development of a problem-specific sequence of steps or methodology to improve the work order and measurement system at

UPRM's Facilities Department based on Business Process Reengineering concepts.

2. The design of a model to predict the duration of maintenance services.
3. Implementation of an improved process in a labor union environment in Puerto Rico.

This document is structured into three chapters. Chapter 1 presents concepts and studies regarding BPR, work measurement and improvements made on union environments. Chapter 2 describes the methodology used to implement the proposed solution in the UPRM Facilities Department, including the description of the model to predict maintenance job durations. On Chapter 3 the results achieved are presented. This includes database and web page development details, followed by the validation of the model to predict job duration. Three case studies are presented to demonstrate how good the models are. The document ends with a discussion on conclusions and recommendations stemming from this research.

Chapter 1
Literature Review

The review of the literature was broken down into three areas:

- *Business Process Reengineering* (BPR), which provided the methods relevant to process redesign;
- *Service process characterization and time estimate development* as a base of system performance measurement.
- *Process improvements in a labor union environment* that allowed the researcher to experience the management change in a specific environment.

1.1 Business process reengineering

Business Process Reengineering (BPR) is a philosophy developed in the early 90's. It was popularized because provided a methodology to better fit the post-industrial environment and markets [10]. BPR is known by different names: core process redesign, new industrial reengineering, and working smarter [10]. Other related terms are: business reengineering, business process redesign, business process improvement and process innovation [58].

BPR philosophy has many definitions mainly given by Hammer [24], T. Davenport [14], Chen [10] and Larsen [36] among others. Some researches argued that there is no commonly agreed definition of BPR because of the extended list of meanings, making difficult to evaluate the success or failure

of the philosophy [58]. However, compiling the definitions, most of them have four common points [21]:

- It consists of a radical or at least significant change.
- The unit of analysis is the business process as opposed to departments or functional areas.
- It tries to achieve major goals or dramatic performance improvements.
- Information technology (IT) is a critical enabler of this change.

BPR includes a fundamental analysis of the organization and a redesign of: Organizational structure, job definition, reward structure, business workflows, control processes and, in some cases reevaluation of the organizational culture and philosophy [58]. Thus, the main BPR objective is to study processes and find new ways of organizing tasks and people, using information systems and technology, so that the new processes support the goals and the strategies of the organization. These activities begin by identifying and analyzing business processes, changing them in a radical manner and making them more efficient and effective [10]. A conceptual model of BPR is shown in Figure 2 [23]. BPR is focused in the way of transforming inputs into outputs by understanding the original process and making a new method, changing or eliminating operations in a creative way, without restrictions.

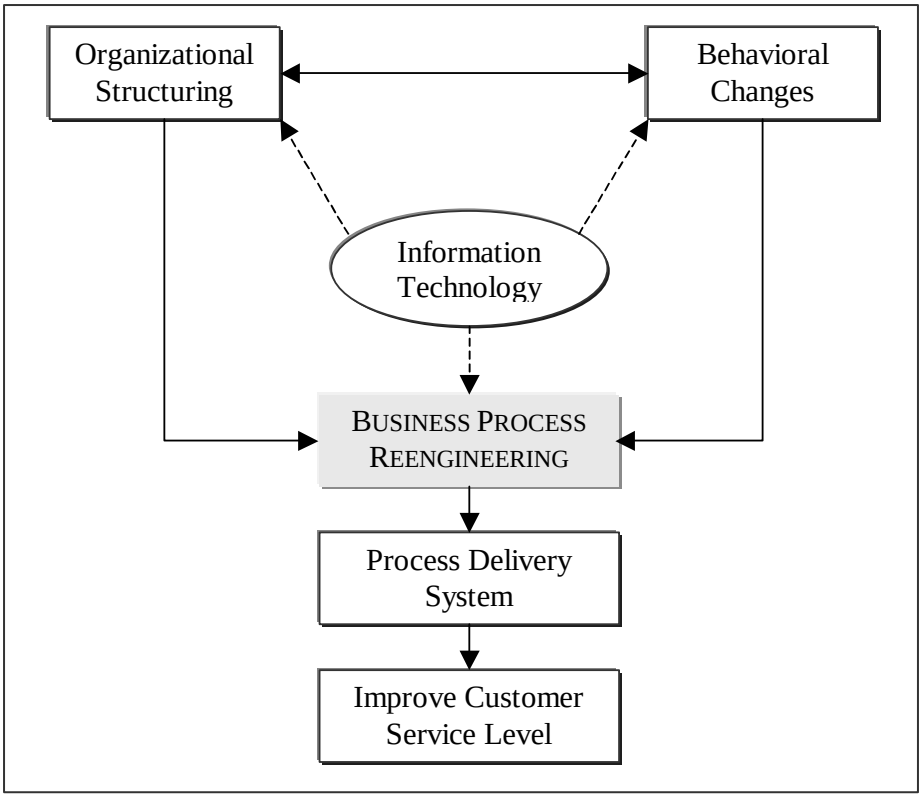

Figure 2. A conceptual model of BPR
Resource: Modeling and Analysis of Business Process Reengineering by A. Gunasekaran et. al.

Business process concept is one of the most important terms in this philosophy. The most cited definitions of a business process are given by Hammer and Champy [24], Davenport [14], Chen [10], Anderson [2] and Barber [1] among others. A Business Process is a collection of activities or tasks that have some inputs and helps to create outputs of value to the customer. These activities should add value and be important to the customers (internal or external). They have to be performed in the best way to the company (refer to Figure 3). Through the definition it is noted that BPR is concerned with customer-orientation. The outputs of business processes should not only achieve the company's objectives but also need to satisfy requirements that are defined by the customer [28].

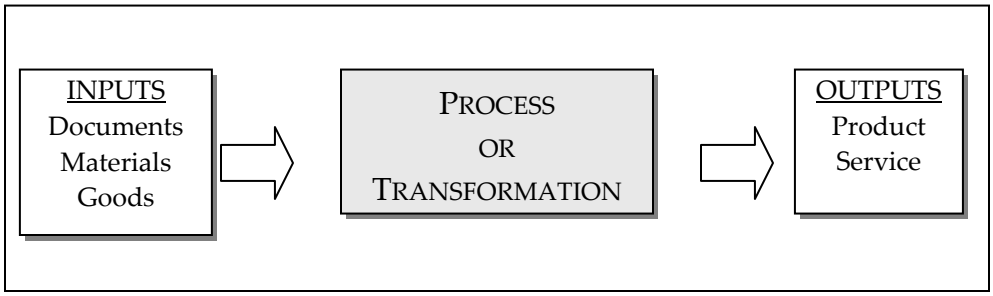

Figure 3. Business Process Description
Resource: Business Process Reengineering and Software Systems Strategy B. Jahnke et. al.

The philosophy studies four key areas: processes, structures and strategies, technology and people, where the first two are the base for the utilization of the technology and make possible the redesign of the human activity system [59]. Other way to study the four-key areas was given by Hammer & Champy [24]. According to them, the main criterion for reengineering success is around the business system diamond. This one identifies the relationship between process, jobs and structures, management and measurement systems and values and beliefs (See Figure 4):

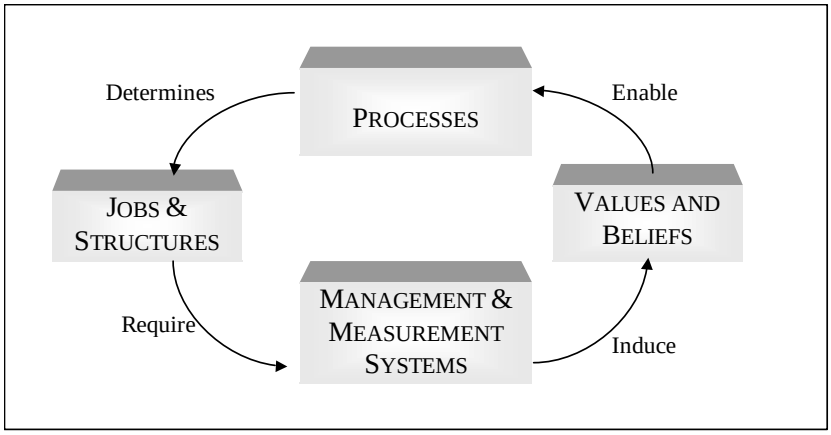

Figure 4. Business System Diamond
Resource: From Reengineering to Process Management: A Longitudinal Study of BPR in a Danish Manufacturing Company by M. Holm-Larsen et. al.

On the other hand, BPR is based on three main disciplines for the analysis (See Figure 5) [50]:

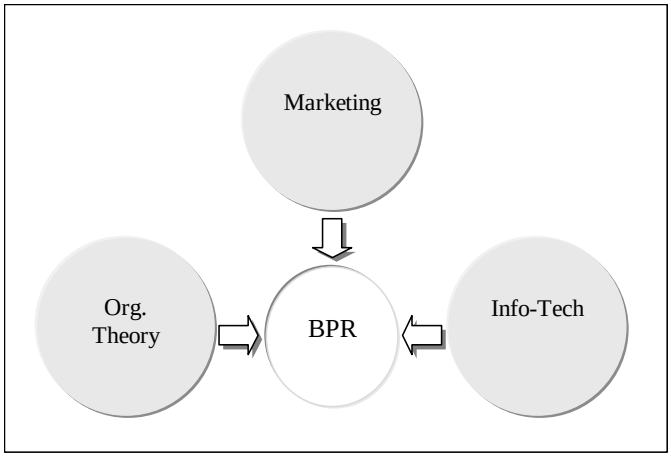

Figure 5. BPR Theoretical Framework
Resource: Towards a Theoretical Framework for Business Process Reengineering by K.AS Simon

- Marketing: Related with the competitive advantage, customer focus, industry value systems and value adding chains. On the BPR theory it is based on the questions: What does customer value mean? and How can be achieved the added value for customers? The customer value related to business processes can be a determinant factor for the organizational change.

- Organizational Theory: It includes important aspects of Human Resources Management like the rearrangement of organizational structures, processes and tasks. Also, it is related with the relocation of people, changes on jobs descriptions, positions and titles. It considers necessary to find new ways of dividing organizations that aim to improve productivity and putting customers into the focus of the organizational activities.

- Informatics: BPR uses IT as an enabler to perform business processes in the best way.

Based on the disciplines just mentioned, it is agreed that BPR have the following steps [30], [41], [44]:

- Preparation: Develop business vision and business objectives (executives and managers).
- Process-Think: Identify process to be designed.
- Creation: Understand and measure existing processes.
- Technical design: Identify IT levers.
- Social design: Study of jobs structures.
- Implementation: Design and implement a prototype of a process having into account new technical and social issues.

The methodology is strongly design-oriented, and is not clear through the implementation process [30]. It was found that the main barrier of this implementation is poor change management [41], [23], [5], [30]. This issue can be minimized with training, education and other motivational facts. [41], [23].

1.2 Work Measurement (WM) in maintenance services

Work Measurement (WM) has an important place in productivity improvement since the early part of the twentieth century. It consists on determining the duration of a job consistently [34]. Frederick Taylor and Frank and Lillian Gilbreth were the founders of modern motion and time analysis. They began to study the body motions used in operations, searching for ways to perform tasks more efficiently [35]. Since then, WM has been widely applied on the direct labor force [69].

1.2.1 Work Measurement (WM) for manufacturing operations

The most commonly used techniques to WM are presented in Figure 6.

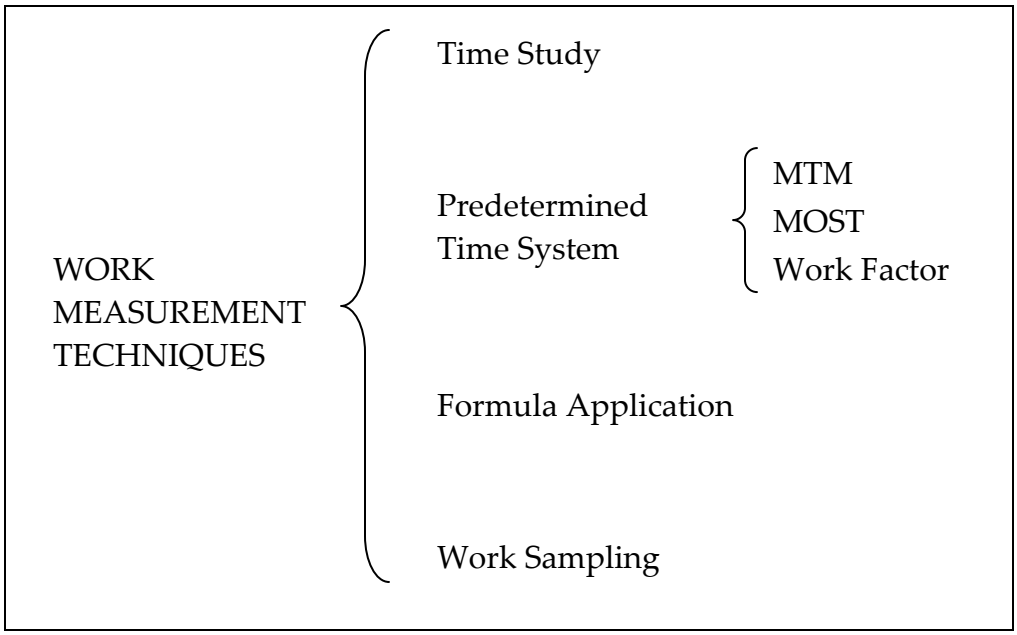

Figure 6. Work Measurement Techniques.

These techniques are applied to standardized jobs. Next they are briefly explained.

- *Time Study (Stop watch study):* A stopwatch is used to estimate the duration of work, and compensates working factors such as deviations from the normal pace, personal needs, fatigue, and delays among others [47], [34].

- *Predetermined Time System (PTS):* It studies fundamental or grouped motions that cannot be precisely evaluated with ordinary stopwatch time study procedures. They are also the result of studying a large sample of diversified operations with a timing device capable of measuring very short

elements. Basically, the PTS are sets of motion-time tables with explanatory rules and instructions values [47], [34]. At the International Labor Organization (ILO) there are more than 200 PTS classified. The origins of PTS was in the 1920`s with contributions by Gilbreth, Segur, Maynard, and others [35]. Three well-known methods are:

1. Methods Time Measurement (MTM): It gives time values for fundamental motions such as: reach, move, turn, grasp, position, disengage, and release [47], [34]. Detailed systems such as MTM-1 are designed for high repetitive task, to less detailed systems as MTM-2. Another system that analyzes the clerical-related tasks such as keypunching, filing, data entry, and typing, is MTM-C [35].

2. Maynard Operation Sequence Technique (MOST): This system is based on MTM, but is much simpler. Analysts can establish standards at least five times faster than with MTM. MOST identifies three basic sequence models: general move, controlled move and tool use, using larger blocks of fundamental motions [47]. There is a classification of MOST methods: Basic MOST (analyzes the very wide range of manual operations most common to industry); Mini MOST (analyzes highly repetitive operations such as electronic assembly; Maxi MOST (used for longer cycle operations) and Clerical MOST (it is an extension of Basic MOST used for analyzing office activities) [11].

3. Work Factor: This technique is based on the outputs of an average experienced operator, and it includes allowances in a table format. This technique provides three system levels: detailed, ready, and brief [34].

- *Formula Application*: The formulas have particular application in no repetitive work, in which it is impractical to establish standards for each job using an individual time study. This method has been successfully used in office operations, maintenance work, painting, grass cutting, etc. and involves the design of an algebraic expression or a system of curves that establishes a time standard in advance of production by substituting known values peculiar to the job for the variable elements [47]. Formula application has some relationship to the approach to be proposed for maintenance services.

- *Work Sampling*: It is a technique used to investigate the proportions of total time devoted to the various activities that constitute a job or work situation. The results of work sampling can be effectively used to estimate time standards for indirect labor such as material handling and office activities. In such case a sample size must be calculated for a predefined level of accuracy [47], [34], [35], [57].

1.2.2 Work Measurement (WM) for indirect labor[1] operations

Most of the techniques used for work measurement are applicable for repetitive operations (except formula application and work sampling). The increasing indirect labor scenarios and their non-repetitive operations create the need for improved work measurement approaches [69]. Some techniques developed for measurement of indirect labor are:

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[1] *Indirect labor*: Labor which does not add value to the product or service but which must be performed to support it [47],[69].

- *Universal Indirect Labor Standards (UILS):* These standards are applicable for indirect and maintenance works in which tasks are numerous and diversified. This technique groups single operations and considers the average duration for the whole group with a dispersion of ±2σ for the group activities [47], [62], [68].
- *System Point Method:* The method was developed by Jack Andin Wu and Nesa L´abe Wu (1991) [69]. Their method measures and controls indirect work methods and procedures, allowing the comparison between different operations by using a point system. This methodology consists of five steps:

    - *Identify key tasks and set the standards*: The key tasks are the main activities of the operation studied. First, they should be classified like repetitive and non-repetitive. Then, they are measured (in terms of time) by using any method applied for direct labor.
    - *Determine the frequencies*: The frequencies refer to the measurement unit: squared-meters, repairs number, etc.
    - *Define the Standard Manning Level (SML):* The SML refers to the right number of workers needed to perform the operation studied including the time standard, frequency, available hours and the modifiers (allowances).
    - *Calculating the Point System*: The point system allows comparing different activities and sets a general perform once for workers, taking as a base 100 points as equal to the standard of the operation.
    - *Performing Statistical Performance Control*: Using Control Charts as an indicator of the group performance by comparing the number of earned points with the expected.

Other articles on time measurement techniques for indirect labor were found for specific situations. Examples are Major Unit Activity Techniques [54], other standards methods for general and indirect jobs [47], work sampling applied to indirect labor [57] and the use of prediction formulas for project duration applied to the construction industry [8], [9].

The applications of WM are mainly to plan the work activities, measure performance, and estimate costs [35], [34]. This thesis was focused in the design of a model to predict time duration helping to measure performance in maintenance services provided by the FD at UPRM. It is known in the literature that the main reasons for implementing a performance measurement system are: monitoring performance, identification of areas that need attention, enhancing motivation and improve communication [66].

On the other hand, BPR requires a balanced set of new measurements, which enables organizations to enhance their knowledge about their new processes and their implementation [66]. This research assessed the application of a technique based on the *Point System Method* to measure the system performance as a part of the BPR diamond system (discussed in the previous section). The main reason for selecting this method was the inclusion of task characterization, which provides an understanding of the activities that comprise the job, which then allows the collection of data on activity duration.

1.3 Process improvement in a labor union environment

The effect that a union may have on a company's ability to adopt changes is ignored in many discussions. Unions can severely limit managerial discretion or in certain situations may actually increase the rate of adoption of change [6]. Through negotiation, management and union representatives agree on a contract or rulebook that must be followed. Union contracts are often very inflexible regarding change of any sort. Some authors agree that unions can severely limit the managerial decision-making through work rules, seniority systems and provisions on outsourcing, among others [25].

There are some potential areas of conflict between management and union employees:

- *Cross-training:* When changes are implemented, it requires that employees learn new tasks, which could violate union contract, demanding to work among the boundaries of a work description.

- *Productivity improvement program:* union workers could perceive increasing productivity demands as an uncompensated increase in value per employee. In fact, union workers could fear "running out of work" and might respond by slowing the work pace to prevent being sent home with no pay.

- *New technologies*: Union workers might be threatened when new technologies are acquired, since it might require a higher skill level not available within the rank in file.

- *Seniority Systems:* These allow unions to control promotions and could eliminate managerial control over the assignment of specific jobs to employees with the desired skill set for the task at hand. The problem becomes worse in the presence of older employees.

These potential conflicts can be overcome with strong communication and assertive education programs that typically require union employees to go beyond their work description [27]. Communication channels should facilitate the flow of ideas between management and union. New initiatives require workers to be an integral part during implementation. The education process must serve a dual purpose: fact transfer (why, how and what of an operation) and behavioral change to transform the adversarial relationship between management and union workers [25].

The union perceived that change is good "…when operators really can see that management is seriously involved" [27]. Examples where the union environment has had a positive effect are presented by Bertain [6]. Some innovation initiatives are even beneficial to unions while other initiatives are in direct conflict with the union environment [25].

Organizations should not forget how members would benefit when implementing programs like Just-In-Time (JIT), Total Quality Management (TQM) and Business Process Reengineering (BPR). Such programs pursue:

improved quality, improved equipment uptime, decreased setup times, improved employee motivation and commitment, among others. Unfortunately, in many instances change leaders forget the negative effect of such changes in union members [27].

The BPR framework, considered by Hammer [24] assumes that "old company and union policies run against a serious desire for change". However, some studies imply that with a strong change management, unions facilitate the implementation of new processes. An example is the study from Handfield et al. [25]. They compared unionized and non-unionized firms and concluded that the type of relationship that management has with its union may have a major effect on the success or failure of strategic initiatives, especially the adoption of innovation which improves manufacturing competitiveness. The findings suggest that companies with a union environment may compete in a different manner to non-union firms, which are expected to be more successful when deploying reengineering-driven initiatives. The results confirm the need for a broader set of variables addressing the effect of management-labor relationships on performance. The research suggests that unionized firms can gain a competitive advantage regardless of industry by either capitalizing on their efficiency or by working to change relationships with the union to allow more flexible work practices.

Understanding the priorities of today's unions is an imperative. In past years, union negotiations were focused on wages and better working conditions. Nowadays, union members are looking for job security, better quality of work life and a closer partnership with firms. In this era of downsizing, slow economy growth and global competition, keeping the job

has become more important. Union leaders have learned that partnering with management is critical for improved competitiveness, which assures jobs. For this reason union employees are accepting working conditions they never would have considered before [7].

As mentioned earlier, change management is one on the weaknesses of the BPR methodology and is more evident in a union environment. The first step is to identify sources of potential resistance and develop a plan to reduce them [15]. It is considered that the strength of resistance depends on past experiences of change inside the organization [66]. An effective management plan associated to change must include the following activities [15]:

- Define key change management roles.
- Build and maintain effective project sponsorship.
- Build commitment through effective communication.
- Acknowledge and manage resistance.
- Build synergy through teamwork.

This research intends to minimize the impact of the existing union environment through a change management plan. This requires securing management and stakeholder support, monitoring the dynamics of political forces, and nurturing new values and beliefs (fourth element of the BPR diamond) [66].To evaluate resistance to change a conceptualization model was used and applied in the research [19]. It consists on thirteen sentences divided in four groups (refer to Appendix B):

- Supporters of change: Well disposed attitudes that reveal personal conformity to the change (questions 5 to 7);

- Indifferent or passive resistors to change: they are approving behaviors to promoting and facilitating the change in other people (questions 1 to 4);
- Confused about the change: Critical behaviors expressing personal dissatisfaction with the change (questions 8 and 9);
- Active resistors to change : They are attitudes aiming to sustain other people actions in disagreement with the change (questions 10 to 12).

The first and second groups of behaviors are considered as a pro change attitudes. The third and fourth are considered an anti change conduct.

1.4 Concluding remarks

This thesis provides three areas of contribution to the field of knowledge of Industrial Engineering:

1. *The development of a problem-specific sequence of steps or methodology to improve the work order and measurement system at UPRM's Facilities Department based on BPR concepts*. The methodology requires significant interaction with the Facilities Department population throughout the project. This included a change management plan that helped to internalize the proposed changes.

2. *A Work measurement methodology for maintenance services.* Work measurement studies typically relate to manufacturing activities, which have cyclic tasks and are highly repetitive. This research focuses on time studies for maintenance service tasks, which are mostly non-cyclic and non-repetitive. The purpose is to improve not only the service processes, but also

the measurement system. This is considered as a tool to evaluate process performance; the intent is to identify and control specific problem areas.

3. Implementation of Process Improvements in a Labor Union Environment in Puerto Rico. It is necessary to gain experience from the implementation of disciplines like TQM, BPR and others in a union environment. The methodology included a change management plan considering legal and cultural issues of local labor unions.

Chapter 2
Methodology

The methodology was based on BPR principles. Figure 7 presents the methodology flowchart. It consisted on a sequence of systematic steps to make a radical redesign of a service process making emphasis in the implementation process and management of the resistance to change and taking into account the union environment in the working place.

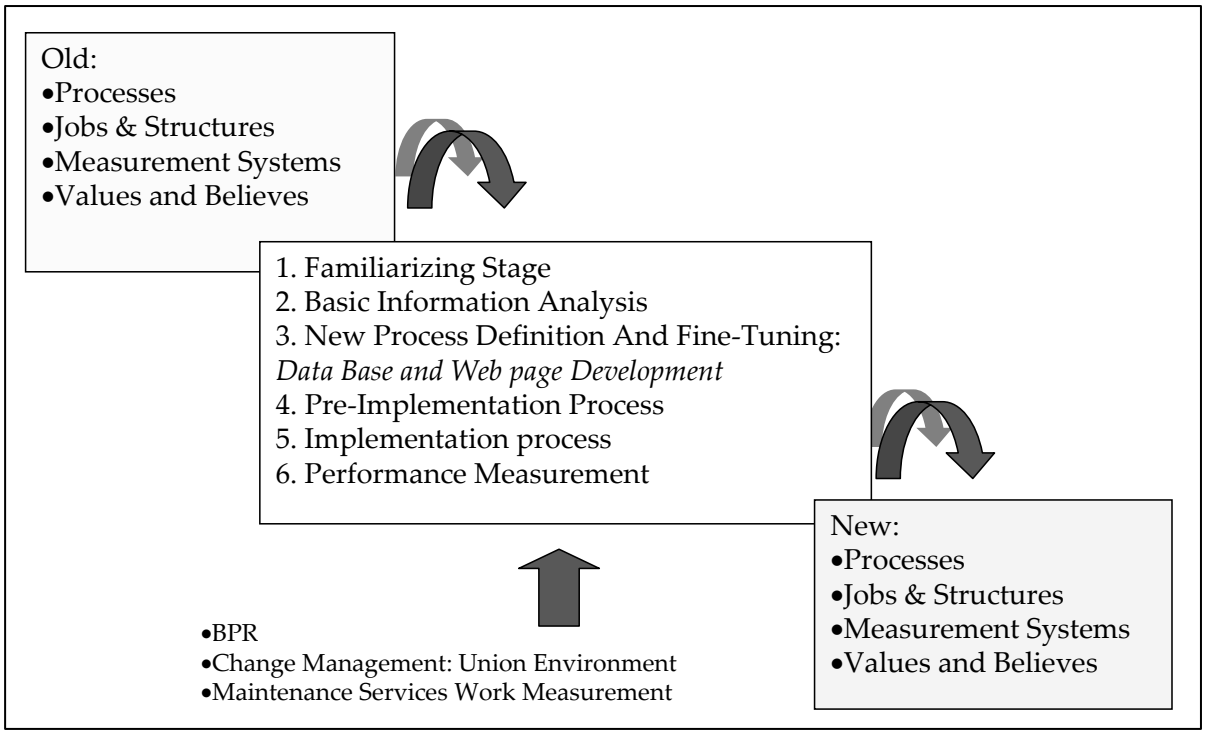


Figure 7. Research Methodology.

2.1 Familiarizing stage

This step consisted of defining needed roles and becoming acquainted with the areas included in the study. Involvement from management started at the very beginning, by helping to define:

- Description of the problem.
- Variables of the study that could not be controlled: market, general policies, budget, initial investment, time frame, government regulations, etc.
- Areas and people involved in the study and their roles:
  - Users and process owners (who will use the new system);
  - Customers (who is impacted by the new system);
  - Suppliers;
  - Internal and external teams;
  - Steering committee: mostly managers who make important decisions about the project; and
  - BPR lead (who has the responsibility for managing the change process throughout the implementation).
- Criteria or goals definition. Examples are: cost minimization, quality improvement, and customer service improvement.

The BPR lead acted like a "bridge" between management and employees being the sponsor for change. Also, the BPR lead met with union members helping to anticipate and to prepare people for the new system and assessing the readiness of the department for change.

The BPR lead conducted interviews, surveys and meetings with the people involved, obtaining information about original status of: business

processes, jobs and structures, measurement systems and values and beliefs (refer to system diamond of Figure 4 on page 8).

Interviews, performed by the BPR leader (author), helped to complement the initial information collected, increasing the cooperation of people in the research and allowing immediate clarifications. Prior to the interview, the BPR leader prepared some structured questions regarding the jobs performed by FD sections and details previously collected concerning the original process. During the one-on-one interviews, which typically lasted one hour, questions were open-ended.

On the other hand, surveys were used to evaluate the subjective opinions of the stakeholders and assess the existing resistance to change. The main objective was to capture opinions and attitudes regarding the original process. The data collection method provided a clear insight into opportunities. Written surveys where given to users and customers during the introduction meetings and they had to return them in the term of five days.

2.2 Basic information analysis

This step involved the unification of the information collected in the previous step. Useful tools for this activity included flow process charts (including operations, cycle times and data collected), process maps (when characterizing the activities across functions), inter-relationship diagrams (to identify the contributions to key business metrics) and cause-and-effect diagrams (to identify the contributors to process success or failure).

Statistical analysis of surveys and interviews findings gave credibility to the conclusions reached. Some of the results were presented to the working team in order to develop a shared process vision and consensus in the goals.

2.3 New process definition and fine-tuning

This stage defined the solution to be implemented. This solution included:

- New operations, designs, policies, flow diagrams and forms taking into account the goals defined in the first stage;
- New roles and responsibilities (who, when and what activities are to be performed);
- Maintenance operations and key tasks and activities for the envisioned system;
- Relevant performance measures for key tasks and activities;
- Needed changes to working environment (e.g. hardware, software, etc); and
- Information technology features (e.g. new databases and network architectures).

The improvements were focused on the criteria (goals) defined by the managers in the first stage. The alternatives were presented to the managers and the employees who addressed the selection of the best alternative and guided the fine-tuning developing corrective actions throughout versions of the database. Regarding resistance to change it was important to establish that the change nature and its own characteristics were based on the

introduction of new technology. The benefits of the changes to each group of users were explained. This generated the commitment at all levels of the organization, improved communication channels and motivated the employees to use the new system. It was also important the selection between the active or passive role of the customer in the proposed service process.

2.4 Pre-implementation process

This stage prepared the population for the implementation process. The objective was to minimize the change resistance (e.g., using new information technology systems) and to have a transition between the old system and the new system. The most important part of the pre-implementation was to introduce the users to the new system. This allowed them to focus on their goals and tasks instead of the underlying technology and the interaction required. It was also important to consider the impact on union employees and to discuss with them possible concerns about the new working environment.

The pre-implementation included:

- Participatory and coordinated fine-tuning of the system with users.
- Development of documentation and guidelines (e.g., procedures and user manuals);
- Strong training with the features about new IT hardware and software;
- Usability features and fine-tuning: interaction with each group of users requesting feedback on IT hardware and software functionality; and
- Customer training and participation when they interact with the system.

2.5 Implementation process

The main objective was to follow up on the adoption of the new processes and systems. The active involvement of the steering committee and the BPR lead were crucial for a successful implementation. A collaborative atmosphere through teamwork was another key ingredient for successful implementation.

The BPR lead took special care of the following:

- Physical changes in the work environment;
- Successes and failures of users with the new system;
- Discipline in the use of procedures and user manuals;
- Additional training needs in response to user difficulties; and
- Building a good environment through motivation and commitment.

After the implementation an empirical evaluation was made to verify the impact of changes in the FD.

2.6 Job duration estimation and measurement system

This research included the definition of a strategy for predicting the duration of tasks performed for each section of the FD. It was assumed that the nature of the task must be understood to plan the number of resources that must be assigned such that the service is completed on time. The methodology used to estimate job duration is presented in Figure 8.

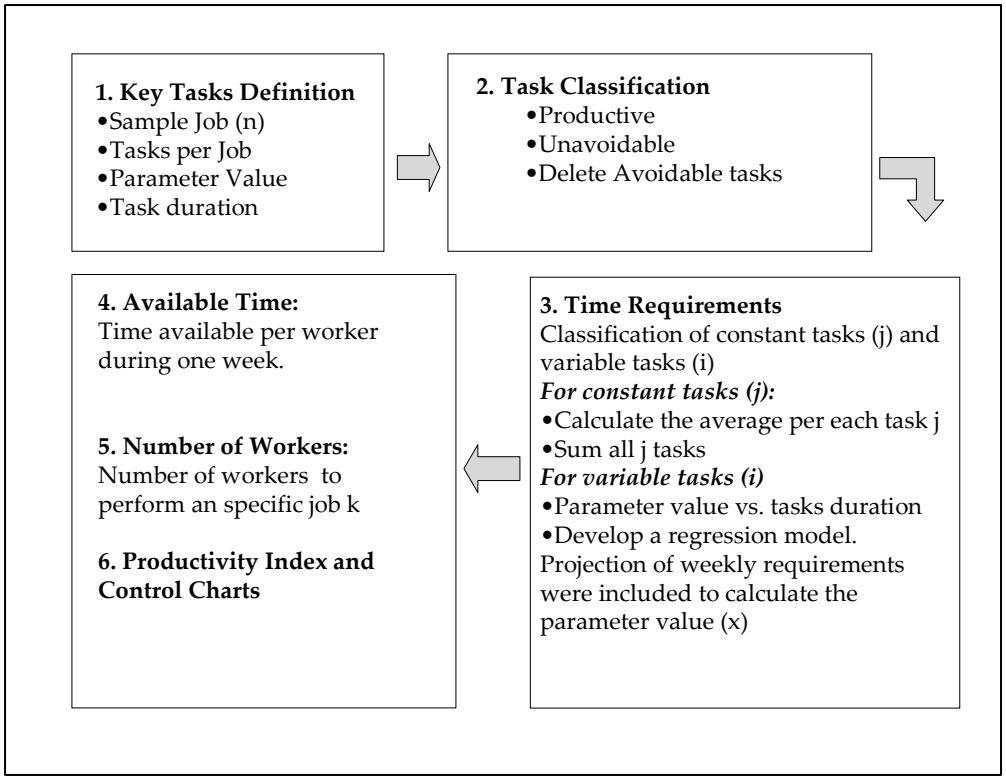


Figure 8. Job Duration Estimation Methodology

2.6.1 Key task definition

The research was focused on key jobs from selected sections to propose a model for time estimation. A section was defined like a job shop that executes common maintenance operations or jobs (e.g. plumbing, electricity, refrigeration, and others).

The following actions were envisioned:

- Design of forms to gather information (used by employees and supervisors);
- Definition of the parameter value related with activity duration; that is, the units of measurement for each job (for example, total area for painting, units installed or replaced, among others); and

- Collection of data on time spent and task parameters by the employees involved.

2.6.2 Task classification

In defining the time estimation model, the first step was to classify the activities reported by task contribution: *productive tasks:* those related with the direct maintenance or administrative tasks; *unavoidable tasks:* those that involve employees but did not have a direct contribution to the maintenance job (e.g. set-up time, transportation and breaks); and *avoidable tasks:* unexpected situations in which time is wasted (e.g. waiting for materials).

2.6.3 Time Required (TR) calculation

The Time Required (TR) was referred to the time needed to complete a work order, considering the tasks involved and the magnitude of the task parameter(s). It was based on the data obtained from 2.6.1 and 2.6.2 and the weekly load of work orders.

The time requirement consisted of:

- Constant part (C_j): Tasks whose duration are not depend on the task parameters; and
- Variable part (V_i): Tasks whose duration depend on the task parameters.

The productive, avoidable and unavoidable tasks were subdivided into constant (C_j) or variable (V_i). Constant tasks were estimated using weighted

averages while variable tasks were modeled using linear regression equations. The estimation of the Time Required (TR) was obtained from equation 2.6.1:

$$TR_k = \left[\sum_{j=1}^{m} C_{(j)k} + \sum_{i=1}^{n} V[x]_{(i)k} \right] * W[x] \qquad \textit{(Equation 2.6.1)}$$

Where:

i: a specific variable task.

j: a specific constant task.

k: a specific maintenance job.

$C_{j(k)}$: time to perform constant task j on job k.

$V_{i(k)}$: time to perform variable task j on job k.

x: number of units .

m: total number of constant tasks of job k.

n: total number of variable tasks of job k.

W[x]: number of Work Orders projected for a planning period for performing of x units (parameter value).

As it is known the regression model considers a dependent variable, y_i (in this case $V_{i(k)}[x]$) , as function of one independent variable, x , subject to a random 'disturbance' or 'error', u_i . The error or residual associated with each pair of data values is $\hat{u}_i = y_i - \hat{y}_i$, where y_i is the observed value and $\hat{y}_i$ is the fitted value.

The residual term $\hat{u}_i$ is assumed to:

- Have a mean value of zero;
- Have a constant variance; and
- Be independent across the observations.

To validate these assumptions, it was important to make the residuals analysis verifying the model adequacy.

2.6.4 Available Time (AT) calculation

The available time, calculated using equation 2.6.2, refers to the hours available per worker to perform specific maintenance jobs and can be calculated for the desired time period (i.e. week, month or year) per employee.

$$AT = [(S - B) * D] * P \qquad \textit{(Equation 2.6.2)}$$

Where:

S: Hours per shift

B: Time of breaks

D: Working days during the planned period (week, month, year)

P: Percentage of the shift that workers were assigned to maintenance jobs.

The variable P is used because there are sections that have people assigned part of the shift to respond to work orders (WO) and the other part of the time to projects. However, some sections had some people working on WO for the entire shift.

2.6.5 Number of Workers (NW) required

The Number of Workers (NW) needed to perform maintenance job was calculated by using TR and AT obtained in the previous steps. This calculation is shown in Equation 3:

$$NW_k = \frac{TR_k}{AT} \qquad \textit{(Equation 2.6 3)}$$

Where:

NW_k: Number of workers to perform job k

TR_k: Time required performing job k per planned period.

AT: Available time per worker per planned period.

2.6.6 Productivity index calculation

The variability of the maintenance tasks performed between FD sections created a challenge in establishing meaningful comparisons. Such comparisons were possible when jobs were broken down into tasks with constant and variable components, with meaningful (task) parameters. A productivity index could be used to measure performance by job type. The target value for any job was 100. The calculation is performed using Equation 4.

$$P_k = \frac{TR_k[x]}{TM_k[x]} * 100 \quad Points \qquad \textit{(Equation 2.6.4)}$$

Where:

P_k: Points obtained for job k.

$TR_k[x]$: Time estimated to perform job k to install x units (parameter value).

TM_k [x]: Time observed to perform job k to install x units (parameter value).

2.6.7 Control charting of the productivity index.

Control charts are a tool used to monitor a variable through time. This research proposes the use of individual control chart because the sample size is 1) to monitor the variability of the productivity index. When the process is considered in control, the fluctuations will be around a common mean (the in-control mean). Thus, a horizontal centerline is plotted on the chart representing the in-control mean. In addition, the control limits represents horizontal lines drawn on either side of the centerline. When the variable measured is in control, most of the points lie within three-sigma control limits. Then, the process is judged out of control when a point plots outside the control limits; productivity results outside of control limits are assumed to have an assignable cause (refer to Figure 9).

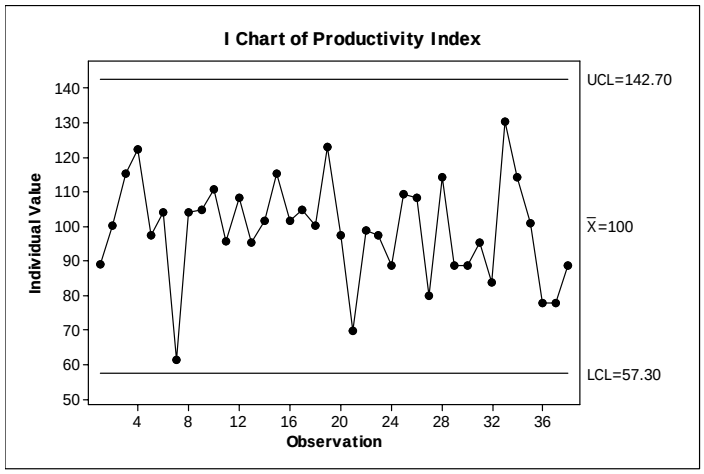


Figure 9. Example of individuals control charts

For the variable charts, the mean was set to 100 and the control limits were calculated with the formulas [43]:

$$UCL = 100 + \frac{k\sigma}{\sqrt{n}} \text{ and } LCL = 100 - \frac{k\sigma}{\sqrt{n}}. \qquad \textit{(Equation 2.6 5)}$$

In the estimation of the standard deviation for individual charts, artificial groups are created by using moving averages with the formula [43] :

$$MRBAR = \frac{1}{n-1}\sum_{i=1}^{n-1}\left|x_{i+1} - x_i\right|. \qquad \textit{(Equation 2.6 6)}$$

The estimate of the standard deviation is obtained with the expression [43]:

$$\hat{\sigma} = \frac{MRBAR}{1.128}. \qquad \textit{(Equation 2.6 7)}$$

2.7 Research Gantt chart

The time frame of the research was approximately one year and 4 months. The activities that demanded most of the time were the *familiarization with FD* and the *pre-implementation process,* which required significant interaction and direct contact with people in FD. During the familiarization with FD the researcher became acquainted with the current system and started defining the elements of the new system. The pre-implementation process involved the definition and development of the database which houses all the data provided by customers and FD users. The Gantt chart is shown on Appendix E.

Chapter 3
Results and Discussion

This section presents a detailed description of the activities developed in the design and implementation of radical changes to the original work order system. It required a strong interaction with FD director, supervisors, union employees and FD customers throughout Campus, and a significant effort for system development regarding software and hardware. Another important result to be presented is the discussion of three jobs for which the tasks and jobs durations were estimated.

3.1 Familiarizing stage

The BPR lead involved the FD personnel in defining the problem. Meetings were conducted throughout FD to describe the project at hand.

3.1.1 Becoming acquainted with the facilities department

The Facilities Department is a department of the UPRM dedicated to maintenance and installation services throughout the entire Mayagüez Campus. FD is lead by a general director; all maintenance activities are the responsibility of a maintenance manager. These two managers periodically verify the work order and projects performance. On the other hand, FD is divided into fourteen sections which provide multiple services to Campus. Each section has a supervisor and a group of technicians assigned to perform different jobs like maintenance services and the execution of projects that

involves installations and construction of new facilities. FD also have five secretaries, one person dedicated to coordinate the campus activities and one system and data administrator who prepares reports on the work order and project activity. Figure 10 shows FD's organization chart.

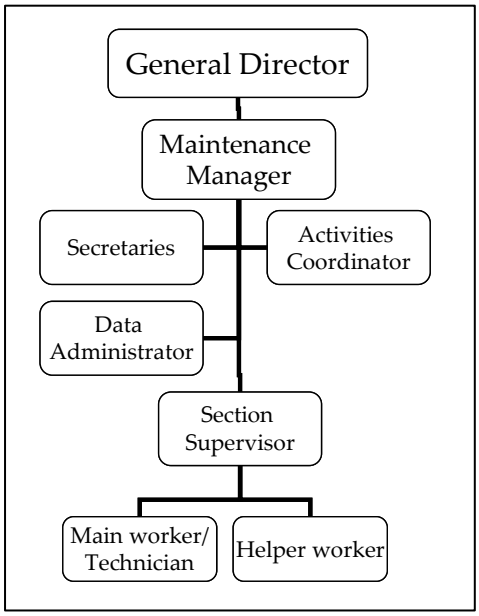


Figure 10. Organization Chart of the Facilities Department

Regarding the work schedule it begins at 7:00 am and ends at 3:30 pm. They have two breaks of 15 minutes each and a lunch period at noon. There are three sections with personnel on two shifts: cleaning, plumbing and electricity. The second shift personnel typically respond to emergencies or urgent orders. They work from 3:30 p.m. to 11:30 p.m.

3.1.2 Meeting with the FD director and the maintenance manager

In the first meeting the FD Director and the Maintenance manager emphasized the need for an improved work order system (WOS). The main problems mentioned were:

- Difficulties measuring the work performed by each FD section. There was no evidence on the documentation of tasks executed per each job.
- Work orders were not returned on a timely manner. For example, there were orders opened from 1998 which never closed;
- In many instances the information was incomplete; and
- Erroneous information was reported: hours of work reported were significantly low and the work accounted for by section was minimal. Efficiency reports from the database comparing worked hours versus available hours were extremely low and for sure did not reflected reality (see in Appendix A);

From the meeting the following key tasks were defined:

- Reorganize the WOS;
- Define data collection properly;
- Redefine information requirements to improve data quality;
- Provide reporting requirements to give a clear picture of each section contribution;
- Characterize the jobs executed by each section of the department and estimate tasks duration based on their own characteristics and people assigned; and

- Maintain active communication with managers and union workers throughout the project.

3.1.3 Meeting with union leaders

The second step in this process was to present the ideas to the union leaders. They were in charge of communicating the purpose of the study to all the employees. The union members were worried about the privatization of the maintenance services, because of work being done by subcontracting the service to other companies. They were also concerned with the fact that some UPRM buildings have their own maintenance teams (e.g. Chemistry, Electrical & Computer Engineering and the Research and Development Center). They also mentioned in the meeting that the study has to contribute to the quality of the work environment and it is not accepted downsizing.

3.1.4 Individual interviews with supervisors.

After the interaction with the Union Leaders, the project was presented to the supervisors of the different sections. Individual meetings were scheduled in order to familiarize ourselves with the work order process and to identify the various jobs performed within each section. In the interview, some general questions were made related to the following topics:

- Work Order (WO) process description
- Tasks and activities performed
- Main problems of the system

The description given by each supervisor was analyzed and then unified to define the current or original process. The general process description is shown in Figure 11. The process begins when the customer make a requirement for maintenance by phone or letter. Then the secretaries or the activities coordinator generate a WO and then they publish the orders on the bulletin board. Typically, supervisors pick-up the orders next morning and assign them to the section personnel. After the work order is completed, the technician reports the cost of materials used and the hours worked. Finally, the data administrator closes the order and generates the reports. A detailed process description is given the Section *3.2*.

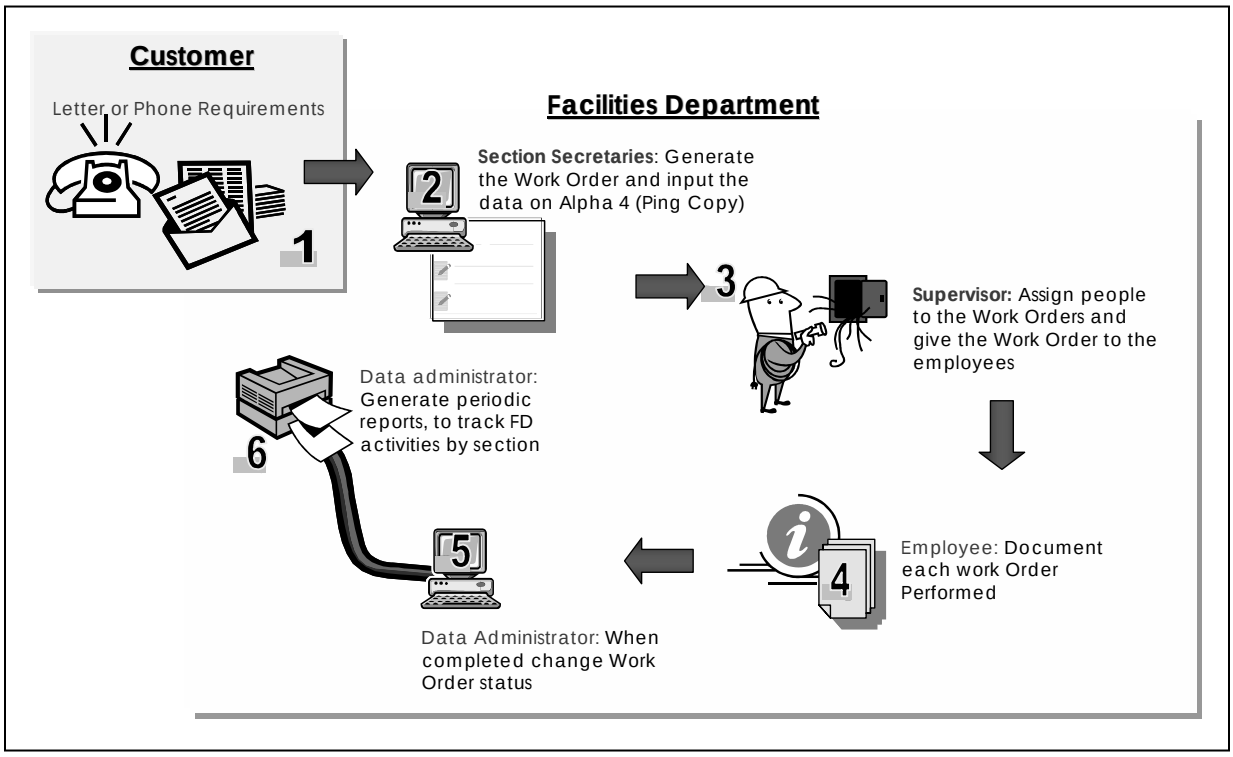


Figure 11. General Work Order Process

Work Order requests are not limited to the UPRM Campus. Work orders can be received from: Darlington Building, Alzamora Farm, Art workshop, Union Offices, La Montaña Farm (Aguadilla), CORA (Colegio Regional de

Aguadilla), Laboratories at Lajas, Toro Negro, Juana Díaz, Isabela, Maguelles (Marine Sciences) and Cornelia (Fishing Laboratory) among others.

A brief description of the jobs performed by FD sections is presented in Table 1.

Table 1. Jobs Performed by Sections at FD

SECTION	MAIN JOBS
Electricity	Maintenance of electrical flow into the UPRM regarding: Outside and inside illumination. Power Lines 110, 208, 240,277, 480, 4160 Volts. Preparation of the illumination of annual scheduled activities. Materials list evaluation for specific jobs.
Supplies Storage	Distribution of materials to sections. Monitor material stock. Follow up on materials with low or no inventory. No work orders are necessary.
Plumbing and Painting	Plugged or broken drains and all the work related with sinks. Painting inside and outside structures and equipments. Roof repairs (includes cleaning).
Special Services	Preparation of RUM activities (seats, tables, scaffold). Elaboration of general signs (traffic, offices, buildings, etc). Change of equipment (inside and outside UPRM).
Construction	Repair of construction structures like : Offices, Floors, Fences and Scaffolds. Construction of Kiosks.
Carpentry	Doors maintenance and all their mechanisms (wood and metal). Office Furniture maintenance.
Welding	Gates, elevators and metal ramps maintenance. Machinery maintenance (Roads and Grounds). Water Piping repairs.
Transportation	Students and employees transportation to different places of the island. There is no utilization of Work Orders in this section.
Vehicles repairing	Repairing and maintenance of UPRM vehicles. There is no use of the work orders in this section. No work orders are necessary.
Refrigeration.	Maintenance and repairing of air conditioners and tubes. Removal / replacement of air conditioners.
Cleaning	Cleaning of the general facilities of the UPRM. Polish of floors and washing the windows and walls.
Ground and Fields.	Plans and flowers for special events. Cut grass out of the scheduled cycle. Cut of dried branches from trees and plants.

Table 1. Jobs performed by sections at FD (continued)

SECTION	MAIN JOBS
Electronics	Maintenance and repair of electronic equipment. Control access installation.
Keys and locks	Make key orders manufacture and follow up pending orders. Maintenance and repairing of locks. Quote and make purchasing orders of locks.

Finally, some problems reported by the supervisors were:

- The administrative processes were too long and sometimes require many signatures (bureaucracy).
- The information of the work orders taken by the assistants was sometimes mistaken or incomplete.
- Some sections needed more personnel.
- There were no preventive activities, only corrective.
- Employees' training was needed.
- There is not clearly defined what kind of student activities and professor requests regarding student's projects should be performed by the FD.

3.2 Basic information analysis

The engineering tools used to study the information collected were flow charts and statistical analyses of surveys made to employees, supervisors, customers and secretaries.

3.2.1 Original process description: process flow diagram

The original WO form used to collect the information is shown in Figure 12. It included three copies. The white copy was filled up in the central office; the yellow copy was filed in the supervisor's office; and the pink copy which was destroyed once the white copy (original) returned to the data administrator.

Figure 13 shows that the process began with a contact from the customer by phone or letter. At this stage it was important to define if the request was a maintenance activity. If the request was for fixing some existing equipment or facility then it was considered as maintenance. When the work request involved the purchase to install or replace the equipments, it was considered as a project. Work orders were only used for maintenance/repairing jobs.

In the original system, work orders were entered into a database called ALPHA 4. A work order was added to the database with the help of the pink copy. In case of emergencies, work orders were given directly to the supervisor. Routine orders were published in the bulletin board of the central office.

The next step was to visit the work place, and identify the materials needs. If the cost of materials was less than 100 dollars, then they proceed to buy them with Petty Cash. If the materials costs were less than 300 dollars but more than 100 dollars, then they proceeded to make a Purchase Order. If the order costs were more than 300 dollars, it was considered as a project and the order was closed in the ALPHA 4 database.

Universidad de Puerto Rico
Recinto Universitario de Mayagüez
Departamento de Edificios y Terrenos

Orden De Trabajo

FECHA			NÚMERO
MES	DÍA	AÑO	20951

DECANATO	EDIFICIO	SOLICITA	
LOCALIZACIÓN		HORA	TELÉFONO
TALLER	DESCRIPCIÓN DEL TRABAJO		
PRIORIDAD			
RECIBIDA POR			

LLENAR A LA MAYOR BREVEDAD Y DEVOLVER

EMPLEADOS		FECHA COMENZÓ		
DIESTROS	HORAS	MES	DÍA	AÑO
AYUDANTE	HORAS	FECHA TERMINÓ		

TAREA ▶

ASIGNADA A — REALIZADA POR

FIRMA DEL SUPERVISOR — ACEPTADA POR

MATERIALES

Hoja Blanca - Oficina — Hoja Amarilla - Taller — Hoja Rosa - Oficina

Figure 12. Original Work Ordes Form

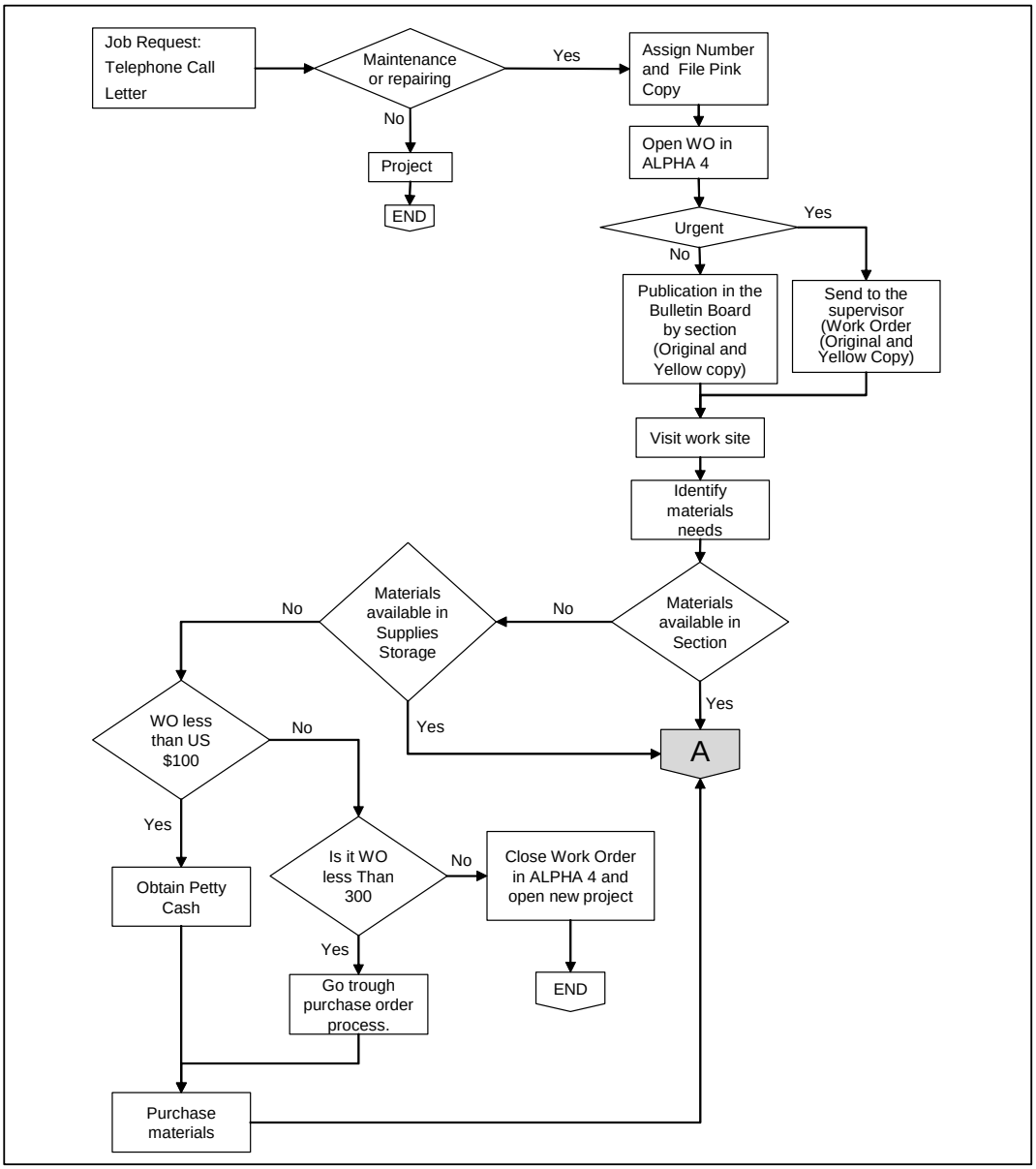


Figure 13. Original Process Flowchart

When the request was performed as maintenance, upon completion it was the customer's responsibility to accept the completed job. If he/she rejected the job, the supervisor defined the pending tasks such that customer expectations were met (see Figure 13).

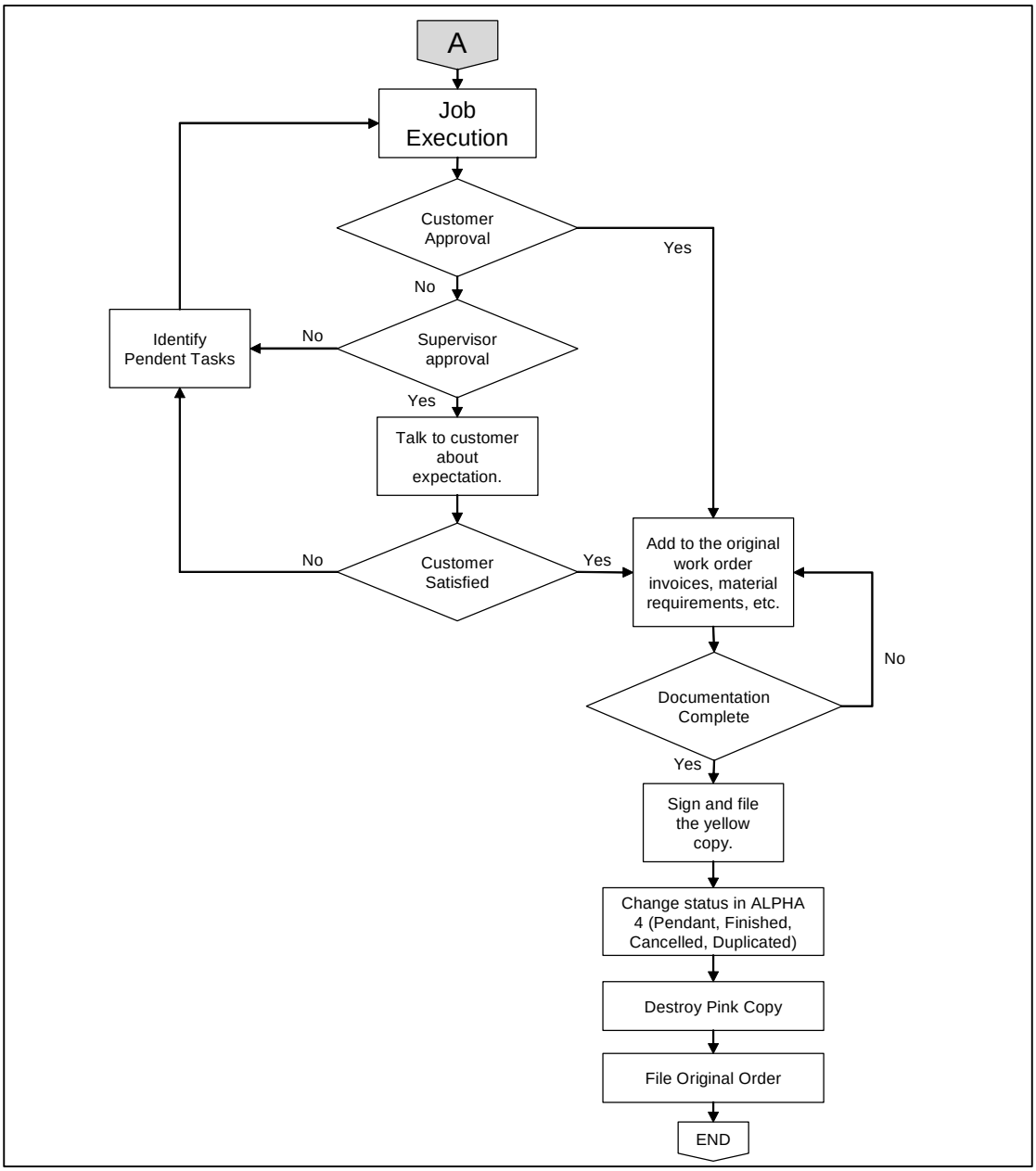


Figure 13. Original Process Flowchart (continued)

After the customer approval, the supervisor signed the order to approve it too. He filed the yellow copy and gave the white copy (original) to the data administrator. He was in charge of change the new order status in the system and then to close the order. Finally the pink copy was destroyed and the original was filed in the central office.

3.2.2 Original system description (ALPHA 4)

The system used originally was named ALPHA 4. It was made on dBase IV (1998 version) and was divided in two menus: one for the data entry and the other to update existing data. It had a general menu at the bottom of the screen (enter, change, browse, find, index, options, and change of screen). A view of such windows is presented in Figure 14.

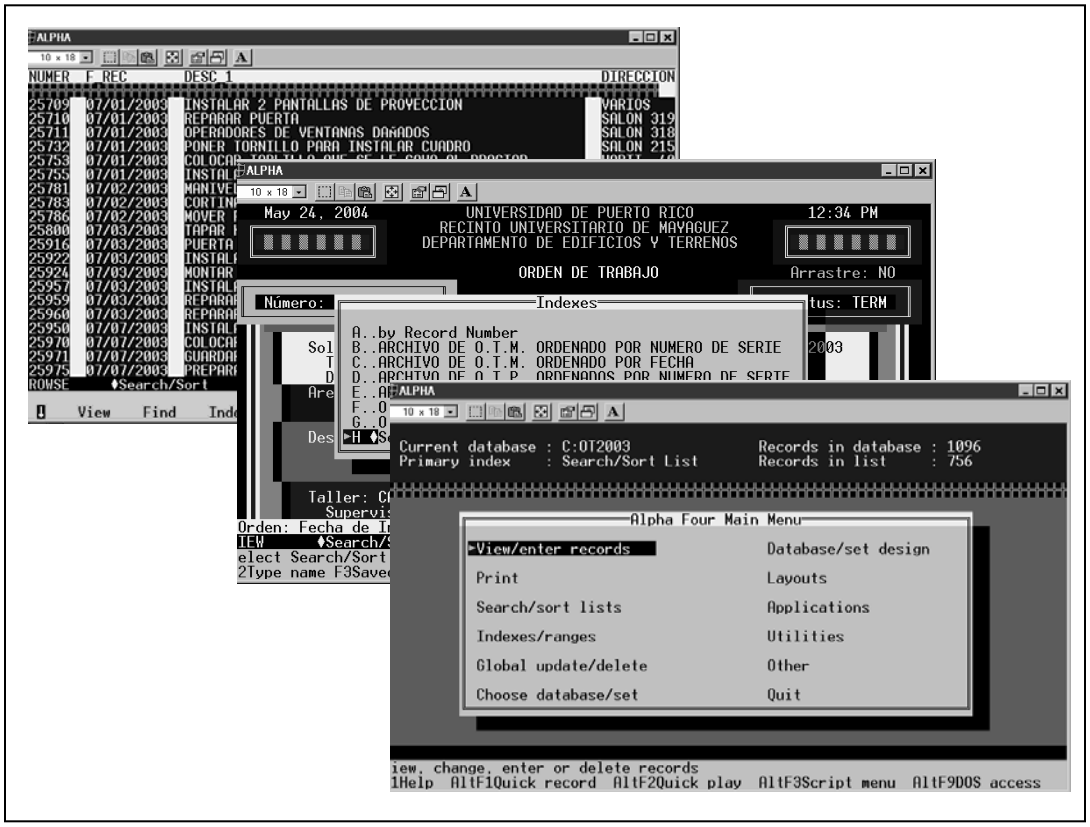


Figure 14. ALPHA 4 Windows

The database had only one table and the data was managed by multiple queries. There was no entity-relation diagram. It had an extended list of buildings and places. In addition, it had the name of the employees, but these names could not be assigned or attached to the work orders.

The system had two types of reports:

- *Global Report*: It presented a listing of closed versus pending work orders per section.
- *Dragging WO Report*: It presented a listing of work orders that were opened the previous fiscal year and that should be closed on the current fiscal year.

The database resided only in one computer and the mouse was not functional; the system was managed only through special (control key plus letter) commands.

In general terms, the system did not allow an efficient handling of the data. There were fields that were not used; some writing styles were not understood by the data administrator and the fields are filled up by an "x" or question mark. Some problems found with the original database were:

- It did not enable the users to complete the tasks quickly;
- It was difficult to learn because the different commands have to be memorized;
- The processes for data entry, printing and making queries on the database were not aligned with original practices; and
- Its only user is the data administrator.

3.2.3 Surveys analysis

Surveys served to capture user opinions and to gather feedback from employees. They also helped to motivate and increase employee participation in the new processes, minimizing their resistance to change. Four key players were targeted through surveys: secretaries, supervisors, managers and customers.

The first survey applied was the Change Management Survey (refer to Appendix B). The survey was given to 20 employees, including secretaries, supervisors and the maintenance manager. Regarding "supporters of change" questions, only 25 percent of responses encouraged the change actively while the other 75 percent were against an initial change. Questions related to "indifference and passive resistors" revealed through written comments that they if they understand the benefits for change, then they could promote it. Seventy (70) percent of the people agreed to promote the change if the advantages are demonstrated. Questions related to "confused about change" attitude, revealed that only 30 percent of respondents made critical remarks about change to their peers and supervisors. The other 70 percent agreed that they were not influencing other people against change. Finally, for questions to identify "active resistors", only 20 percent of respondents claimed that they would take action to influence their superiors and union leaders against change. The other 80 percent disagreed. It was concluded that in general most of the people had an indifferent or passive attitude to the change.

The second survey applied was the BPR Survey (see Appendix C) with a focus on the original system used (Alpha 4). The survey was distributed to the same people who responded the Change Management questionnaire plus

the general director. Concerning the efficiency of the system, only 23 percent of the people answered that the system was good; 46 percent thought it was acceptable; and 31 percent thought it was bad. Reports on the other hand, had slightly better reviews: 8 percent thought that reports were excellent, 38 percent felt these were good, 46 percent felt these were acceptable, and 8 percent felt these are bad. Figure 15 presents these results using a pie chart format.

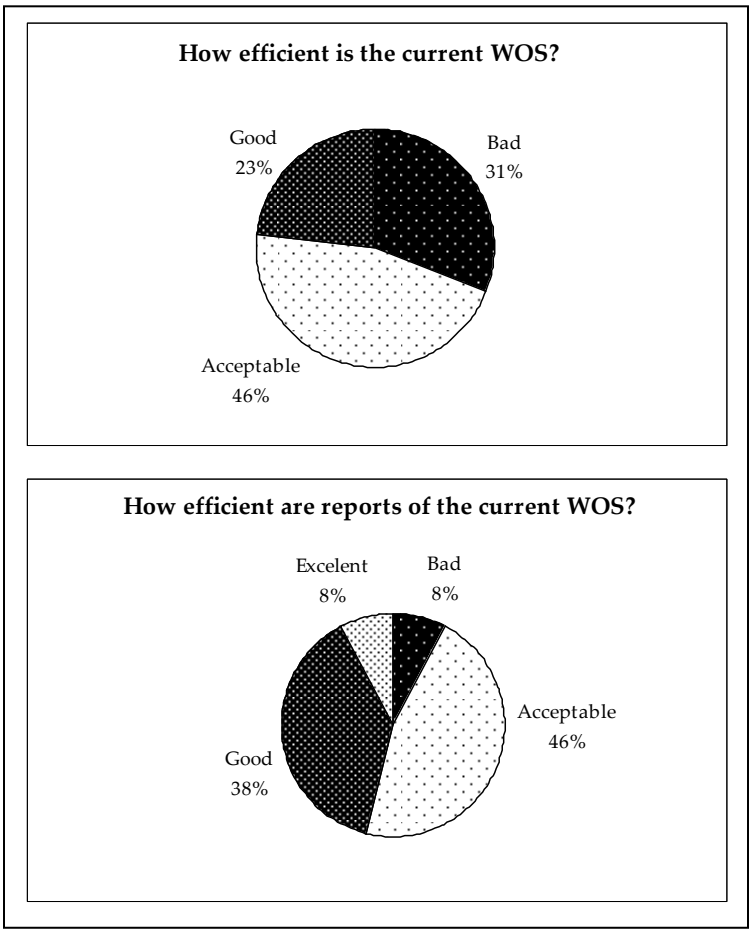


Figure 15. Analysis for questions 1 and 2

Concerning database understanding (see Figure 16), 21 percent were positive on database accessibility, 44 percent felt uncomfortable with accessibility, and 35 percent had no opinion. The survey also showed that

only 7 percent were confident with their data collection know-how, 50 percent were not confident with their data collection know-how, and 43 percent had no opinion.

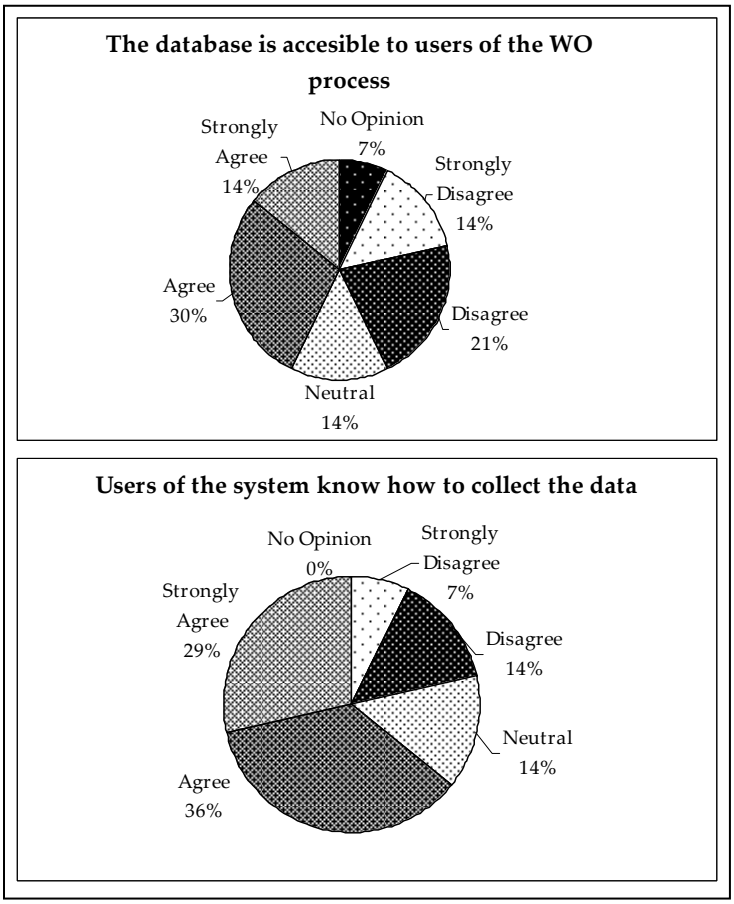


Figure 16. General Opinion about the Work Order database

In the question regarding possible improvements to the original work order form, most people said that the form had to be more detailed. Other opinions included to:

- Provide additional space to collect more specific information (special cases and tasks)
- Use a computerized form
- Roles definition regarding the collection of information.

Within the management team (managers, supervisors and secretaries) 43 percent were union members (see Figure 17). They considered that services privatization and downsizing were actions that go against union policy.

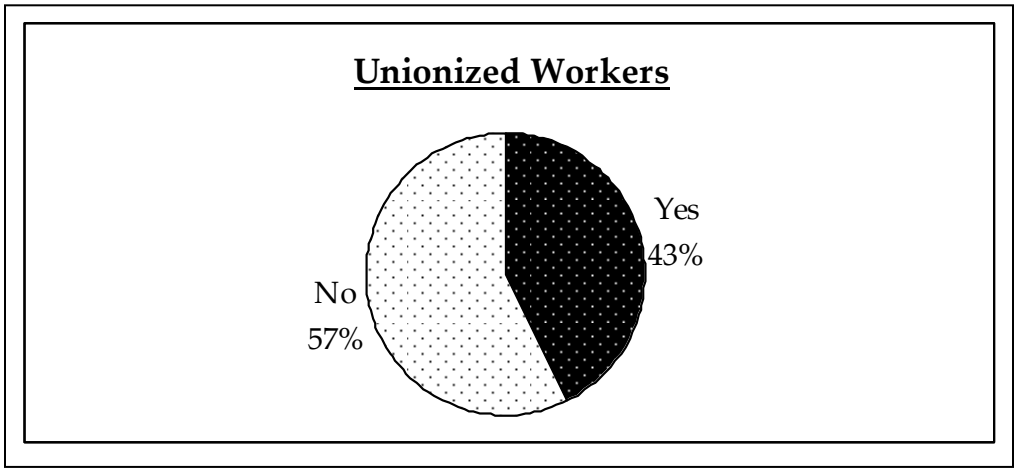


Figure 17. Unionized Workers

The third survey used was the Customer Service Survey (see Appendix D). It helped to identify customer priorities and identified situations in which the FD services had not met customer expectations. Concerning the original system, 95 percent of customers were satisfied with the phone services provided by secretaries. In general terms, customers were satisfied with the service given: 77 percent agreed that service was good and 14 percent disagreed (see Figure 18).

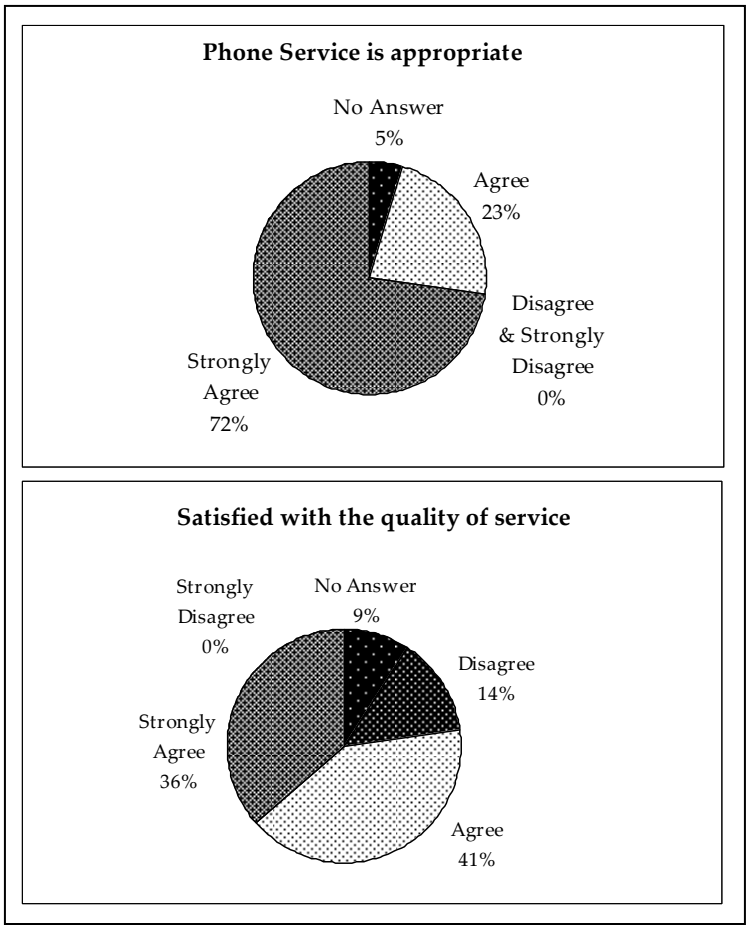


Figure 18. Phone and quality Services

Regarding response time to customer queries, 63 percent of respondents though that the response time was good, 32 percent though that response time was not acceptable, and 5 percent had no opinion. Regarding the on-time completion of work orders, 67 percent were satisfied, 28 percent were unsatisfied, and 5 percent had no opinion (see Figure 19).

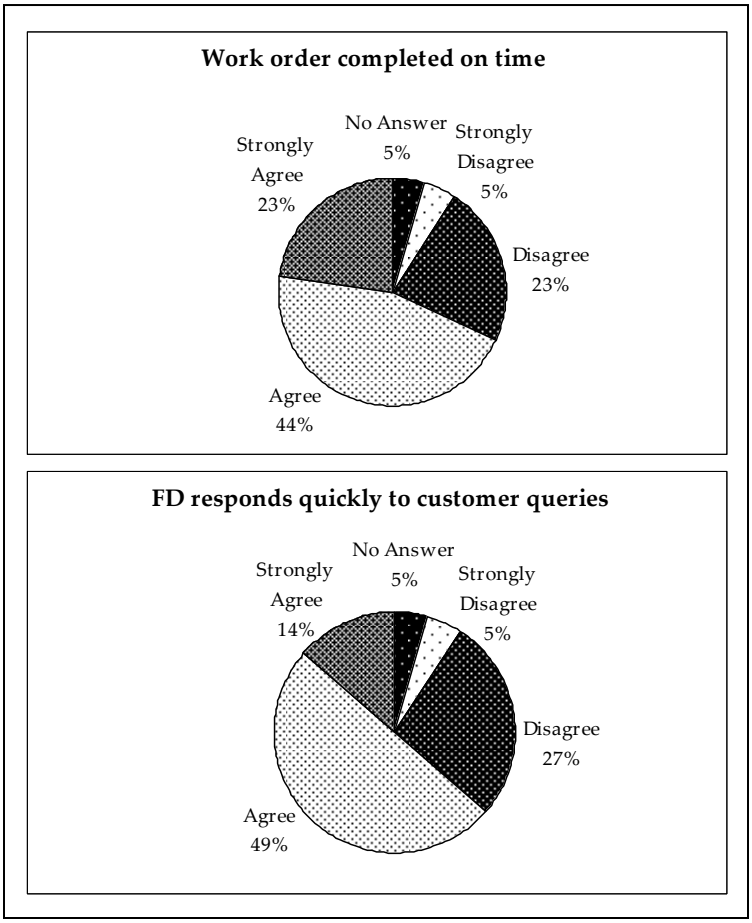


Figure 19. Response and execution times

The last question demonstrated that 59 percent of customers were satisfied with the service given, 36 percent were not, and 5 percent provided no answer (See Figure 20)

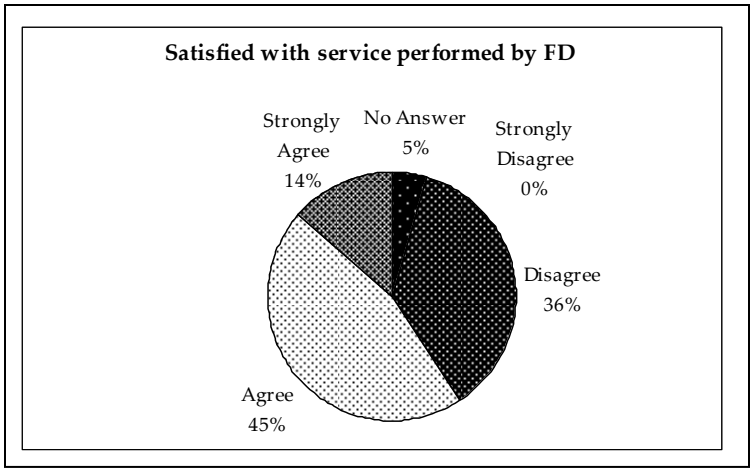


Figure 20. Customer Satisfaction for services given by FD

Following are some additional comments collected during the interview process:

- Some employees in FD were not appreciative of feedback for which they were perceived as having a bad attitude;
- The WO had to improve their time of performing;
- There was a problem in defining the correct materials requirements;
- It was difficult to follow up on the status of a work order since the customer did not have a reference number.

3.3 New process definition and fine-tuning

After understanding the original process and identifying its weaknesses aided by the information from the surveys made, an improved new process was defined. Thus, the evaluation of different alternatives was made taking as a base the restrictions of the study and criteria established on the familiarizing stage. The proposed solution was the new system design where the customer and supervisors had more participation in the data collection;

there was a redistribution of tasks among the users of the system; and the there was shared information to improve communication.

The software development effort included two phases: the design of a database developed in Access 2002 and the development of a Web page designed on Front Page 2002.

3.3.1 Proposed process flow diagrams and description

The process begins with the Customer Requirement. He/she makes the request by web, phone or letter (only for activities). When the requirement is made by web, a new record is created in the system, and the customer inputs the information to the Work Order System (WOS). This is only valid for maintenance or routine orders. Whenever an emergency occurs (cases where facilities or people are in danger) the request should be made by phone.

Secretaries should verify incoming requests assigned to their sections. If there is no section specified by the customer, the data administrator should assign it. When the requirement is made by phone, the secretaries input the information to the system. If the order refers to the organization of an activity, then the request should be a letter and the activities coordinator has to input the information to the system.

Each customer has a unique customer number assigned by the system. On the other hand, the system provides the number of request, date and hour automatically. When information is verified by the secretary in charge, then an order is created. One customer request could have more than one work

order. For example, activities organization generally requires the coordination with sections like refrigeration, ground and fields, special services and cleaning. The system automatically provides a single work order number and includes the all information about the customer request.

After the work order is created, the requirement status changes to "checked". Immediately, the information is sent to the supervisor(s) electronically. They have to assign personnel to the order, print it, and give instructions for the job. Generally, the job includes visiting the place and identifying the needs for materials, like in the original process (see Figure 21).

The job execution does not change. It is the same as in the original process. After the customer approval and supervisor revision, the employees have to report the activities executed during the job with date and time. The tasks have to include productive activities, avoidable and unavoidable delays. The lead person for the work order (assigned by supervisor) has to sign the order. Then, the customer and the supervisor have to sign when the documentation of the order is completed. The data administrator has to input the information to the WOS database (refer to Figure 21).

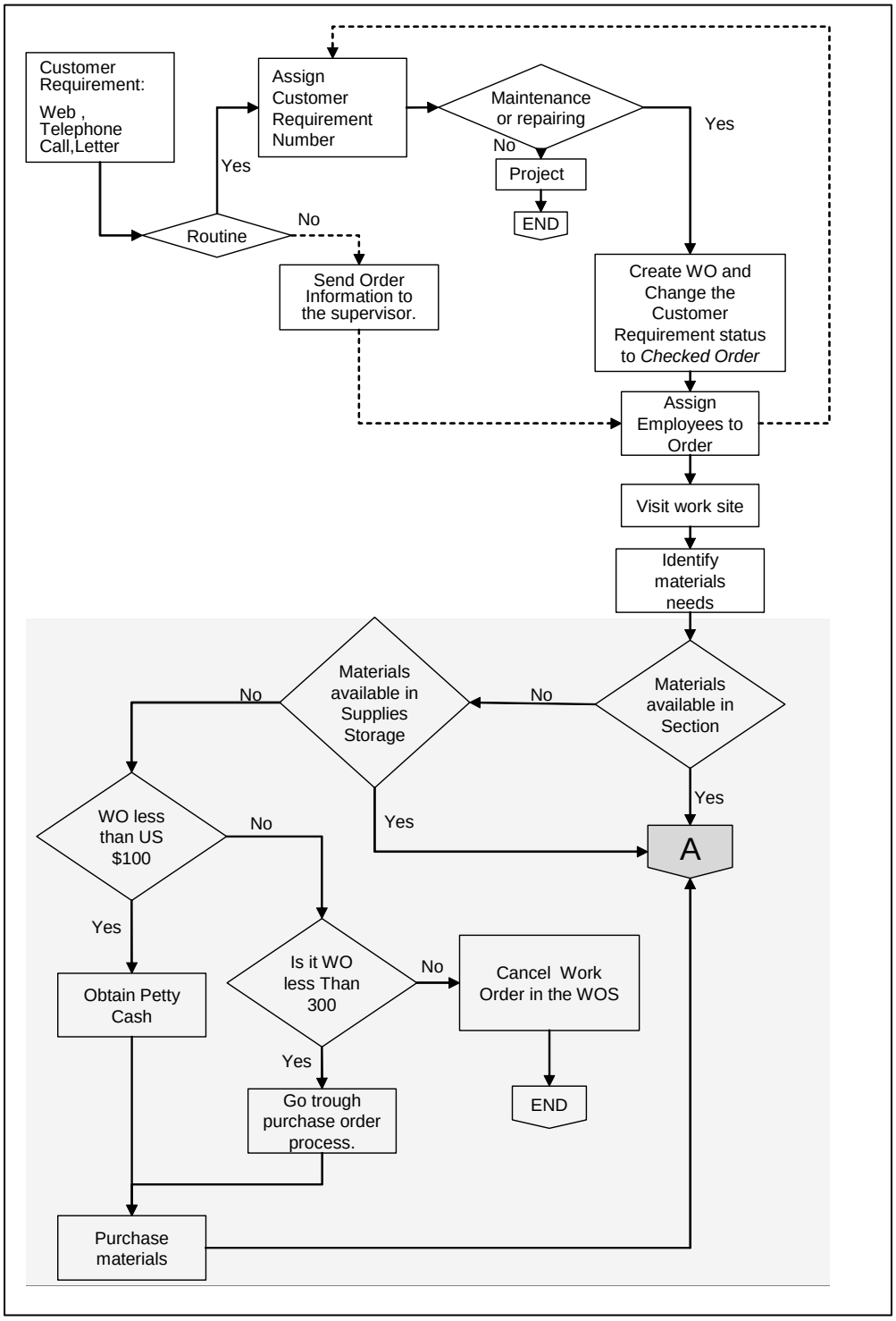


Figure 21. Proposed Process Flow Chart

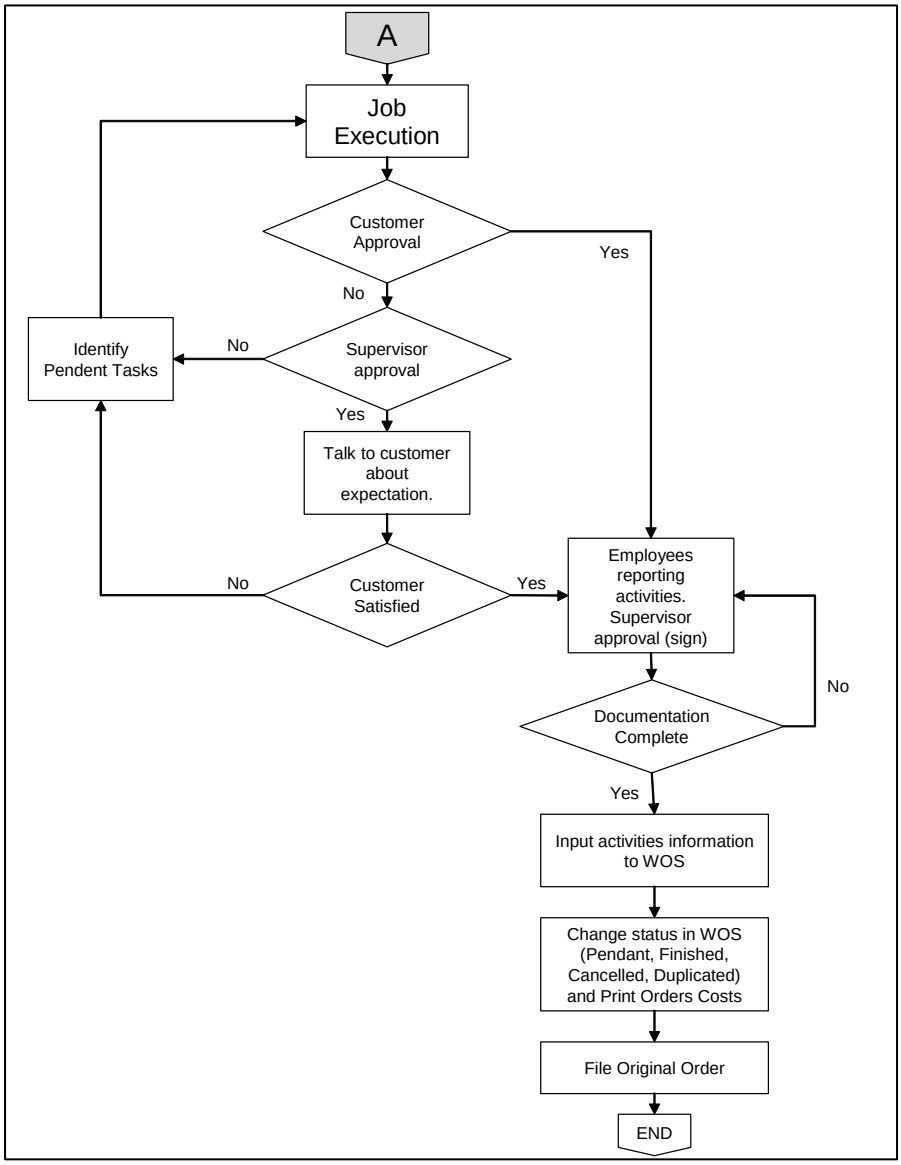


Figure 21. Proposed Process Flow Chart (continued)

3.3.2 Work Order (WO) database

As mentioned earlier, the Work Order Database was designed initially, to solve the communication problems. It was designed in Access 2002. The language used was Spanish (main language on the island) and its name is WOS (for Work Order System). The database design was initiated with a data

flowchart, followed by the definition of the Entity-Relation diagram. The database structure is composed by 10 tables related in the way shown in the Figure 22). The tables have the following information:

- *Customer information*: name and last name, dean, department and phone number.
- *Customer requirement*: requirement number, customer number, building, classroom (or area) and nature of job (description).
- *Work order*: requirement number, work order number, section, order status, employees assigned, quantity and comments.
- *Employees information:* social security number (input in system only by the secretaries), name and type of worker (main or helper worker).
- *Activities:* contains the activities performed by each worker in each order.

WOS users are well defined with responsibilities defined:

- *Secretaries and activity coordinator*: They have to check requests from customers and change request status;
- *Supervisors*: They have to assign personnel to work orders, print the order and collect the completed work orders;

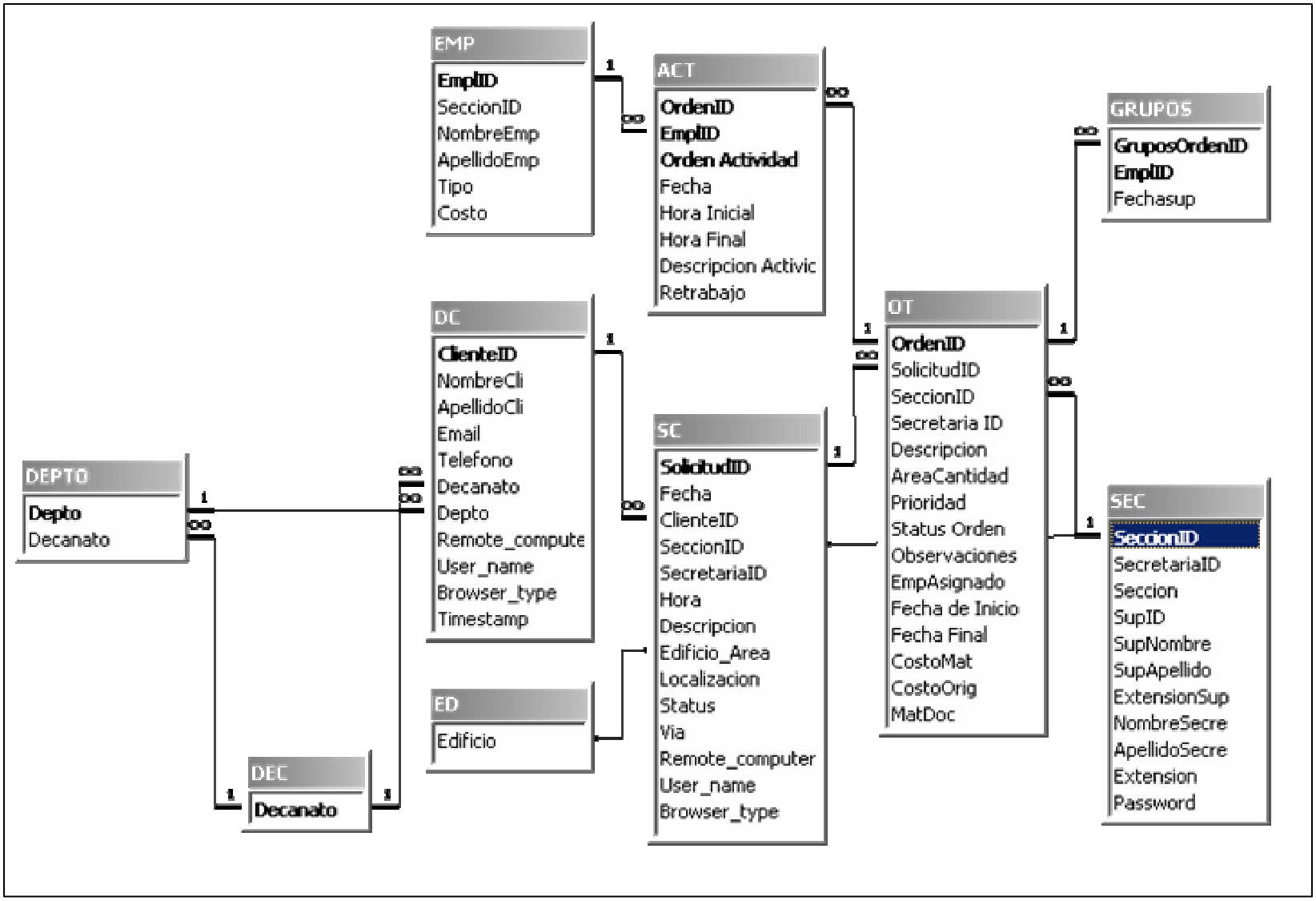


Figure 22. Entity Relation Diagram for Work Order System (WOS) Database.

- *Data Administrator*: He/she has to close the work orders, print the final order and print the periodic reports. Also, is responsible for maintain the security of the orders.

The database is composed by a Main Form that introduces the user to the system. This has a link to the Main Menu, which contains links to seven forms. The first one contains the Customer Requests, with the customer information, details about the job, and details about the order (section and status). The idea is that each Customer Request divides into one or more work orders. When the secretaries or the activities coordinator changes the order status to checked, it allows the supervisors to see it.

After the technicians become in charge of the order, they check the quantities and start entering data into the work order form (see Figure 23).

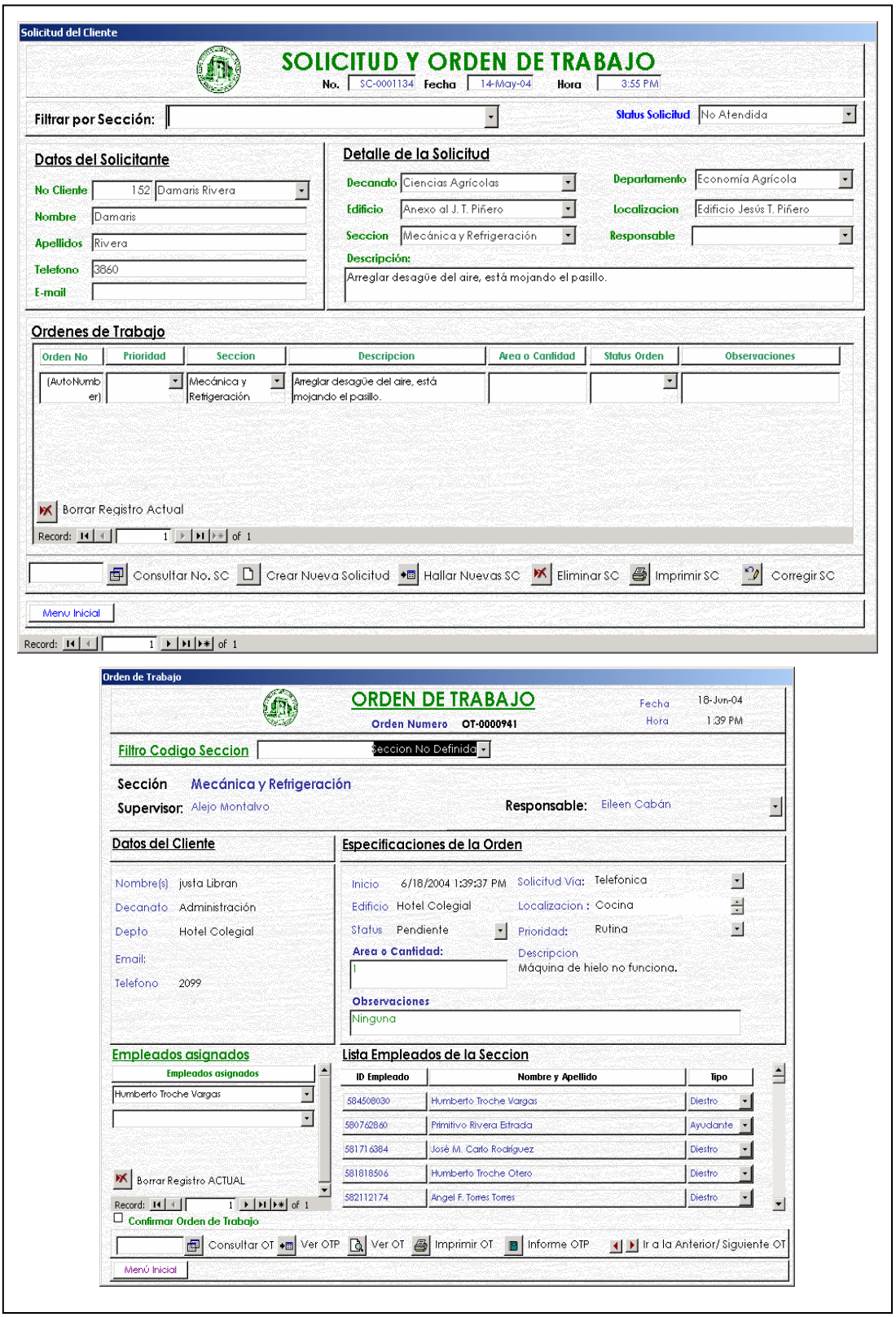
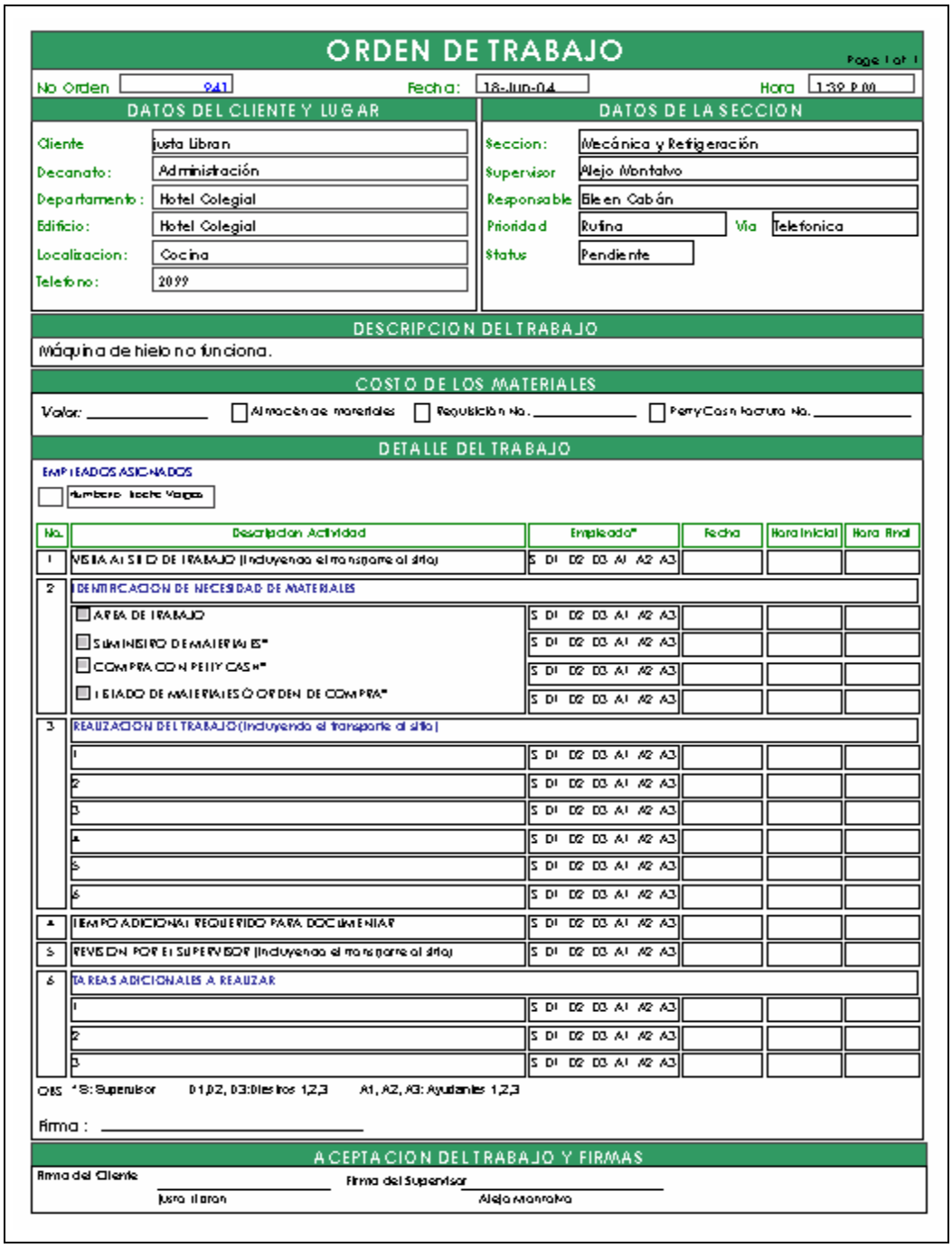


Figure 23. WOS Windows

The proposed system includes a new Work Order form design (See Figure 24). The contents of the work order form was defined after various meetings with supervisors. They gave to the BPR leader their opinions about the proposed design and the best way to present the results. At first, the resistance to change was high because the new form required more details and implied additional data entry work. Since the information is more detailed regarding the time utilization, employee and section results have improved resolution (to be discussed in detail in Section 3.6).

Once the order is completed by the technicians, they obtain the needed approvals. The order is then given to the data administrator for data entry and closing. The data administrator prints the required reports. The reports are designed in the same way as in the other system. The advantage in the new system is that user has to input only the date range for which the report is desired. The system makes any required calculation automatically.

During fine-tuning, one group of users made recommendations to improve the design. At first various windows were available; the general opinion was that having multiple windows open complicated the process of inputting data. Thus, only one window is now used to enter data, show the customer request, and the resulting work order(s). In addition, the supervisor's interaction with the system was minimized to keep them in the office as little as possible. The proposed changes were adopted after two meetings with each group.



ORDEN DE TRABAJO

Page 1 of 1

No Orden 941 Fecha: 18-Jun-04 Hora 1:39 P.M.

DATOS DEL CLIENTE Y LUGAR

Cliente: Justa Libran
Decanato: Administración
Departamento: Hotel Colegial
Edificio: Hotel Colegial
Localizacion: Cocina
Telefono: 2099

DATOS DE LA SECCION

Seccion: Mecánica y Refrigeración
Supervisor: Alejo Montalvo
Responsable: Eileen Cabán
Prioridad: Rutina Via: Telefonica
Status: Pendiente

DESCRIPCION DEL TRABAJO

Máquina de hielo no funciona.

COSTO DE LOS MATERIALES

Valor: _____ ☐ Almacén de materiales ☐ Requisición No. _____ ☐ Petty Cash factura No. _____

DETALLE DEL TRABAJO

EMPLEADOS ASIGNADOS

☐ Numero Noche Vargas

No.	Descripcion Actividad	Empleado*	Fecha	Hora Inicial	Hora Final
1	VISITA AL SITIO DE TRABAJO (Incluyendo el transporte al sitio)	S D1 D2 D3 A1 A2 A3			
2	IDENTIFICACION DE NECESIDAD DE MATERIALES				
	☐ AREA DE TRABAJO	S D1 D2 D3 A1 A2 A3			
	☐ SUMINISTRO DE MATERIALES*	S D1 D2 D3 A1 A2 A3			
	☐ COMPRA CON PETTY CASH*	S D1 D2 D3 A1 A2 A3			
	☐ LISTADO DE MATERIALES Ó ORDEN DE COMPRA*	S D1 D2 D3 A1 A2 A3			
3	REALIZACION DEL TRABAJO (Incluyendo el transporte al sitio)				
	1	S D1 D2 D3 A1 A2 A3			
	2	S D1 D2 D3 A1 A2 A3			
	3	S D1 D2 D3 A1 A2 A3			
	4	S D1 D2 D3 A1 A2 A3			
	5	S D1 D2 D3 A1 A2 A3			
	6	S D1 D2 D3 A1 A2 A3			
4	TIEMPO ADICIONAL REQUERIDO PARA DOCUMENTAR	S D1 D2 D3 A1 A2 A3			
5	REVISION POR EL SUPERVISOR (Incluyendo el transporte al sitio)	S D1 D2 D3 A1 A2 A3			
6	TAREAS ADICIONALES A REALIZAR				
	1	S D1 D2 D3 A1 A2 A3			
	2	S D1 D2 D3 A1 A2 A3			
	3	S D1 D2 D3 A1 A2 A3			

OBS *S: Supervisor D1,D2, D3: Obreros 1,2,3 A1, A2, A3: Ayudantes 1,2,3

Firma: _____

ACEPTACION DEL TRABAJO Y FIRMAS

Firma del Cliente _____ Firma del Supervisor _____
Justa Libran Alejo Montalvo

Figure 24. Work Order Form with new features.

The data administrator showed a high resistance to change. This was possibly due to the fact that he has been the only person knowledgeable in the current/original system. He was interviewed, and one of his worries was that the original system was designed by him and that his participation on

the design of the new system was reduced. However, the managers and the BPR leader explained him the advantages for his job an his attitude regarding the system changed positively.

3.3.3 Web description

The process begins with the customer request. In the original process they made the requests only by phone or letter. It was important to increase the participation of the customer in the process by allowing them to know their order status and by providing the capability to input comments about orders. The web can improve the communication between FD and the customer. The web application consists of (refer to Figure 25) :

- *Introduction Page:* Contains information about FD like vision, mission and objectives.
- *Customer Registration:* In this page, the customer that visits for the first time the web has to register to make a requirement.
- *Customer Requirement:* The customer input the information about the maintenance job.
- *Customer Search:* The system provides the advantage that customer looks for the number assigned if he/she forgot it.
- *Request Search:* The customer can check the status of an specific requirement.
- *Questions and Comments;* Improving the customer service they can make some comments and questions that are received in the system. This section has a tutorial (video) to see how to complete a work request.

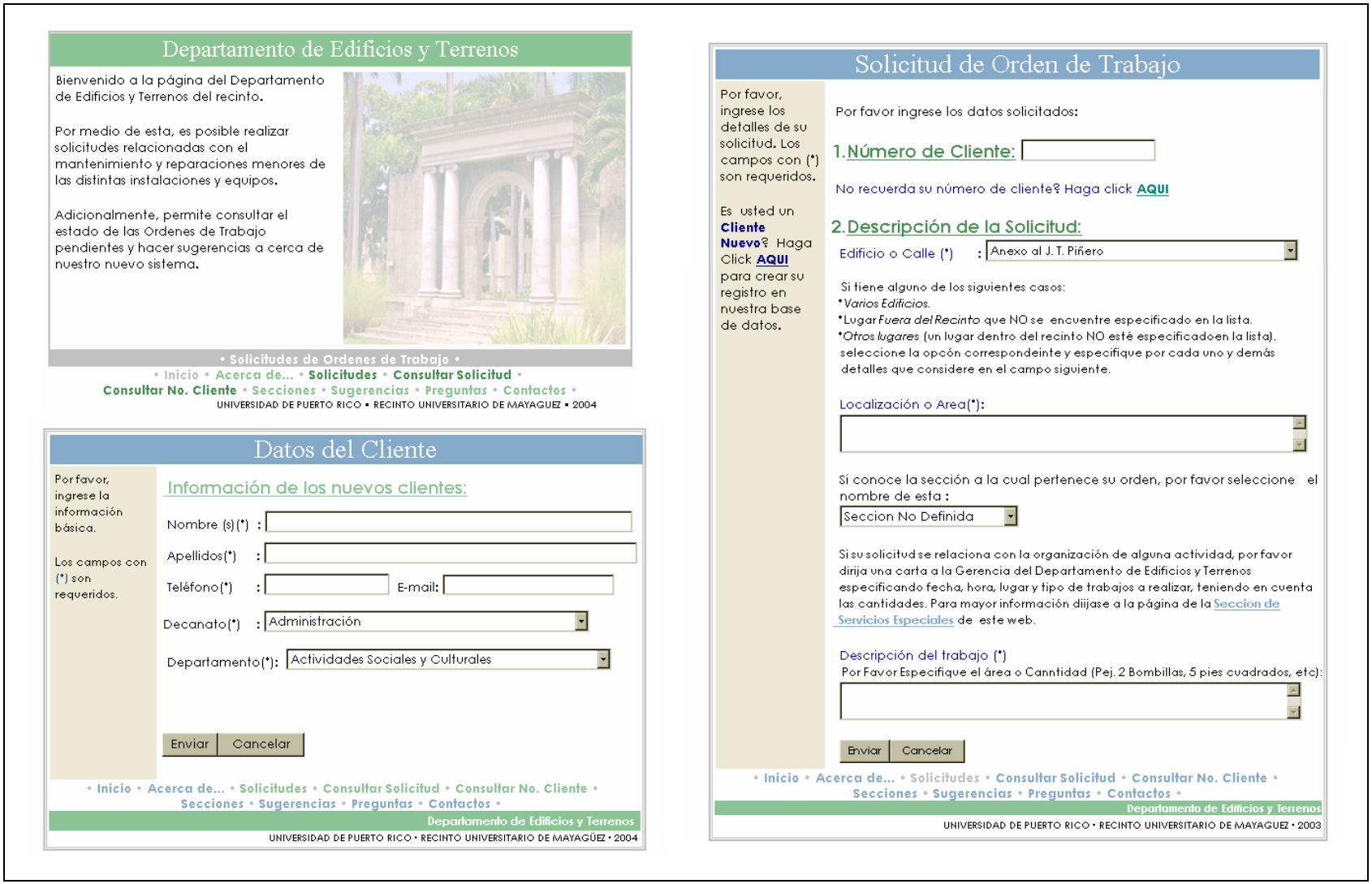


Figure 25. Web forms to Customer Registration and Requirements.

The process to make a request begins with the customer registration. When a customer visits for the first time he/she has to register inputting information like first name, last name, phone, college and department. The e-mail address is optional because not all the persons that use the new system have an account. Once the information is entered, the WOS provides a customer number. In the future, if the customer number is forgotten, the number is obtained after the customer enters its first and last name.

To enter a work request, customers have to go to the link Customer Requirement. Here, they write the customer number, the building and location where the work must be performed, description of the job, and the FD section that should perform the job. When the Requirement is sent, the system reports a request number that the customer can use in future queries.

After one workday the request is converted into a work order, to which a number is assigned. By using the request number, the system displays the order number, supervisor, status and comments about it.

Some warnings should be considered:

- The system cannot be used in an emergency situation.
- The system cannot be used for activities coordination; this requires a letter addressed to the FD Director.

As in the database design, customer opinions about system functionality were important. Using this feedback, an information section was designed containing a brief description of each section and its supervisor. Basic

information is also provided on what constitutes a work order versus a project. Finally some "frequently asked questions" were added to help users resolve basic doubts.

Some advantages of the new system are:

- Allows that customer to interact directly with the system by the web;
- Saves secretary time in data entry;
- Allows the customer to check on order status when desired;
- The supervisor can check the pending orders daily and there is no time wasted going to the bulletin board;
- The employees collect data on their work activities on a daily basis;
- There is only one physical file (hard copy) with the orders;
- Improves the interaction between stakeholders and the system;
- There is data standardization;
- It allows a redistribution of the tasks and the improvement of data and report quality;
- Allows establishing due dates to comply with customer needs;
- Each supervisor can print his own statistics and reports;
- Secretaries are in charge of the general reports for their sections;
- There is no paper based activities; and
- The system calculates automatically the time spend per task, saving time and preventing human error in calculations.

3.4 Pre-implementation process

The pre-implementation process integrated the change management with the project activities and it was useful for tracking the progress and

addressed the implementation process. It began with training modules designed to each group of users. To introduce supervisors to PC's, an initial training on Windows 2000 was provided. Secretaries were the first to receive training on WOS. A small group including the FD Director and the data administrator received a short training on Access 2002.

After the initial training, various work request and work order scenarios were simulated. This involved the creation of both customer request and WO, input of tasks and time duration and finally change the status of the WO. In the meeting the comments and questions helped in making some final fine-tuning. Then, a demo version was installed in the computers of the users. The idea was to allow key FD users to have more interaction with the system so that they could familiarize better with their own roles in the process. Through these activities some errors where detected and some mistaken information (like buildings, sections, names) were corrected.

The customers also had training to use the system. After the initial meeting a personalized training was provided (approximately 30 employees distributed throughout the UPRM Campus). In this case, a demo version of the web page was installed into the computers. This was helpful because the design of the form was better seen in Microsoft Internet Explorer, than in other navigation programs, like Netscape and others. Another issue was the installation of the correct Java applets, which allows seeing the web page without any report errors. A brochure was designed for the customers to help them understand the new process and thus minimize resistance to change.

Once the people were ready to use the system, the other step was to check the computers and the server. The program was installed in the server of the Finance Department (Terrats building). For this, the computers had to be prepared and an account (user and password) for each user was created. The needs for computers were evident. The system requires that computers use Windows 2000 or Windows XP. But most of the computers in FD used Windows 98 and in some cases earlier versions. Also, some sections had no computers. On the other hand, the system was tested on-line to check its behavior when a user inputs an order, to verify the creation of the order in the WOS database.

To minimize the resistance to change, it was necessary to make a meeting with the union members and some employee representatives to explain the new WOS form and to emphasize that the sole motivation for this system was to improve service quality and employee productivity. This should protect current employees from external pressures such as privatization.

Users manual and brochures were developed to help users in using WOS correctly. Users can look for information about the new process and can consult the document to address some questions and problems they might have.

3.5 Work Order (WO) system implementation process

The implementation of WOS was initiated with the assignment of usernames and passwords of each group of users. Individual training and a

brochure with the steps to be followed was distributed. The system was installed on 16 computers, testing the right access to the file and checking the errors that users observed.

During system installation, a computer center was prepared for the supervisors. It consists on one computer placed strategically, where the supervisors can practice on-line with orders.

The BPR leader was checking the data input on a daily basis, correcting and completing the missing information. Constant communication with secretaries was important, to correct any incomplete or mistaken information regarding buildings, employees, sections, etc. Secretaries also communicated to the BPR leader any errors captured by customers on Campus.

Employee participation was important, because they have to write down the tasks and the duration information for each job. In April 2004, high resistance to change was detected by union employees. A meeting was called by union representatives because they felt threaten regarding their jobs. Two general concerns were: the possible use of data against union employees and if the study was used for privatization purposes. After a reaffirmation of the research purposes, union members understood that the project has advantages for them and that it was not a means for downsizing.

During the implementation the data administrator showed a high resistance to change. He felt that the change of his functions was to diminish the labor quality of his job. During the initial training he was skeptical to the adoption of the new system, but with advanced training he is now more

positive. Lately he has been proposing new alternatives and improvements for better system performance.

Some technical problems of communication, including computer viruses, were corrected online. Daily backups are needed to minimize risks and large data losses. The Administration Dean (Prof. Wilma Santiago) sent a memorandum communicating to the UPRM Campus offices that WOS was available online. An e-mail account was created to solve problems and questions. Also, a telephone support line was established.

3.6 Job duration estimation examples

As explained in Section 2.6, a methodology for job duration estimation for the FD Sections has been proposed. Three examples are discussed later, dealing with electricity, refrigeration and plumbing. The sections and jobs selected were those maintenance tasks with the higher demand since the web-based system was inaugurated. The data for the job duration estimation was obtained from the WOs printed out by the supervisor of the FD section and completed by the personnel assigned to the work orders during the past two months (the WO form is presented in Figure 24 on page 64). The first month of data was used to estimate the regression model, while the second month of data was used to validate of the method.

3.6.1 Changing fused lamps/bulbs in the electricity section

An analysis of customer requirements indicates that a frequent maintenance job involves changing fused lamps and bulbs. In the first month

of the study 38 work orders were related to changing fused lamps from a total of 199 total orders.

3.6.1.1 Key task definition

From the review of work orders, six tasks were identified. The number before the description of each task is the *i* subscript of the formula (refer to equation 1):

0: *Initial visit to maintenance place*: Personnel from the Section make an initial visit to verify the magnitude of the work to be performed (e.g. one versus various lamps).
1: *Lamps or bulbs pick-up at the Supplies Storage:* Consists of picking-up the correct type and quantity.
2: *Transportation and set-up at the workplace:* It consists of traveling to the place, carrying tools and materials and putting them in place to perform the required work.
3: Replacing the fused lamp(s) or bulb(s).
4: *Verification and revision by customer*: After completing the work, technicians look for the customer to sign the work order (formal approval).
5: *Documentation*: Consists of recording the tasks performed in the work order form; this includes obtaining the approval signature from the supervisor.
6: *Change of another lamp in a hall*: This was an unexpected task requested by the customer, which had not been defined in the work order.

The orders and times collected are found in Table 2. The columns provide the order number, the number of units per order (parameter value), the task description, the job duration, and the total duration of the work order. The parameter value (units) refers to the number of bulbs or lamps changed. The job duration is measured in minutes and results from the sum of all the tasks reported by employees.

Table 2. Work Orders related to fused lamps change

Order No	Parameter Value (units)	Task No	Task Duration (min)	Work Order Duration
OT-0000004	1	1	10	45
		2	20	
		3	5	
		4	10	
OT-0000005	1	1	15	40
		2	15	
		3	5	
		4	5	
OT-0000011	5	1	5	45
		2	15	
		3	20	
		4	5	
OT-0000012	2	1	5	35
		2	15	
		3	10	
		4	5	
OT-0000018	4	1	15	50
		2	10	
		3	15	
		4	5	
		5	5	
OT-0000031	5	1	20	50
		2	10	
		3	15	
		4	5	
OT-0000037	2	0	20	70
		1	15	
		2	10	
		3	15	
		4	5	
		5	5	
OT-0000186	5	1	15	50
		2	15	
		3	15	
		4	5	
OT-0000199	8	1	10	60
		2	15	
		3	30	
		4	5	

Order No	Parameter Value (units)	Task No	Task Duration (min)	Work Order Duration
OT-0000201	6	1	5	50
		2	15	
		3	25	
		4	5	
OT-0000204	9	1	15	70
		2	15	
		3	35	
		4	5	
OT-0000205	4	1	10	45
		2	10	
		3	15	
		4	5	
		5	5	
OT-0000207	8	1	10	66
		2	15	
		3	30	
		4	6	
		5	5	
OT-0000243	3	1	10	45
		2	20	
		3	10	
		4	5	
OT-0000263	5	1	5	45
		2	15	
		3	15	
		4	10	
OT-0000264	3	1	15	45
		2	10	
		3	10	
		4	10	
OT-0000271	8	1	15	60
		2	10	
		3	25	
		4	10	
OT-0000278	1	1	15	40
		2	15	
		3	5	
		4	5	
OT-0000283	6	1	5	45
		2	15	
		3	15	
		4	10	

Table 2. Work Orders related to fused lamps change (cont)

Order No	Parameter Value (units)	Task No	Task Duration (min)	Work Order Duration
OT-0000294	4	1	10	50
		2	20	
		3	15	
		4	5	
OT-0000306	4	1	15	70
		2	25	
		3	15	
		4	10	
		5	5	
OT-0000392	6	1	10	56
		2	15	
		3	20	
		4	6	
		6	5	
OT-0000409	2	1	10	44
		2	20	
		3	5	
		4	9	
OT-0000443	4	1	15	55
		2	20	
		3	10	
		4	10	
OT-0000450	10	1	10	65
		2	10	
		3	35	
		4	10	
OT-0000462	4	1	15	45
		2	10	
		3	15	
		4	5	
OT-0000517	5	1	20	65
		2	15	
		3	20	
		4	10	
OT-0000568	8	1	10	55
		2	10	
		3	25	
		4	10	

Order No	Parameter Value (units)	Task No	Task Duration (min)	Work Order Duration
OT-0000569	4	1	15	55
		2	15	
		3	15	
		4	10	
OT-0000598	4	1	15	55
		2	15	
		3	15	
		4	10	
OT-0000611	2	1	10	45
		2	20	
		3	5	
		4	10	
OT-0000618	8	1	15	75
		2	25	
		3	30	
		4	5	
OT-0000632	3	1	10	35
		2	10	
		3	10	
		4	5	
OT-0000634	3	1	10	40
		2	10	
		3	15	
		4	5	
OT-0000699	6	0	15	55
		1	15	
		2	10	
		3	15	
		4	10	
OT-0000701	2	1	15	55
		2	15	
		3	5	
		4	10	
OT-0000714	2	1	20	55
		2	10	
		3	5	
		4	10	
OT-0000729	4	1	5	55
		2	15	
		3	15	
		4	10	

3.6.1.2 Task classification

Tasks are classified into productive, avoidable and unavoidable (see Table 3). For the job, the only avoidable (A) task is the initial visit, because it was motivated by lack of understanding on the work to be performed.

Typically the personnel assigned have information on the type of lamp in use before visiting the place. The unavoidable tasks (UA) include activities 1, 2, 4, 5 and 6. The only productive task (P) reported is changing all fused lamps. In addition, changing the fused lamps is the only variable (V) task which depends on the number of units; all other tasks are considered constant

Table 3. Tasks classification

Task Number (i)	Task description	Classification by	Constant or Variable
0	Initial visit to maintenance place	A	Delete
1	Bulbs identification (materials)	UA	C
2	Arriving to place and prepare	UA	C
3	Change the fuse lamp by a new one	P	V
4	Bulb verification and revision by customer	UA	C
5	Documentation	UA	C
6	Cleaning of the protectors of lamps	UA	C

3.6.1.3 Time Requirement (TR) calculation

The time required is calculated taking into account the previous classification. The avoidable delays must be deleted. On the other hand the time of the constant tasks, where *i* takes values of 1, 2, 4, 5 and 6 are used to calculate a weighted average (See Table 4).

The standard deviation and coefficient of variation of each task indicates that the dispersion of the data is low. Furthermore, to calculate the constant part (C) the weighted averages obtained are added. Finally, the value of C is 34.89 minutes, considered as the set up time for the job.

Table 4. Constant task duration by order

Order No	1	2	4	5	6
OT-0000004	10	20	10		
OT-0000005	15	15	5		
OT-0000011	5	15	5		
OT-0000012	5	15	5		
OT-0000018	15	10	5	5	
OT-0000031	20	10	5		
OT-0000037	15	10	5	5	
OT-0000186	15	15	5		
OT-0000199	10	15	5		
OT-0000201	5	15	5		
OT-0000204	15	15	5		
OT-0000205	10	10	5	5	
OT-0000207	10	15	6	5	
OT-0000243	10	20	5		
OT-0000263	5	15	10		
OT-0000264	15	10	10		
OT-0000271	15	10	10		
OT-0000278	15	15	5		
OT-0000283	5	15	10		
OT-0000294	10	20	5		
OT-0000306	15	25	10	5	
OT-0000392	10	15	6		5
OT-0000409	10	20	9		
OT-0000443	15	20	10		
OT-0000450	10	10	10		
OT-0000462	15	10	5		
OT-0000517	20	15	10		
OT-0000568	10	10	10		
OT-0000569	15	15	10		
OT-0000598	15	15	10		
OT-0000611	10	20	10		
OT-0000618	15	25	5		
OT-0000632	10	10	5		
OT-0000634	10	10	5		
OT-0000699	15	10	10		
OT-0000701	15	15	10		
OT-0000714	20	10	10		
OT-0000729	5	15	10		
Weighted Average	***12.11***	***14.61***	***7.39***	***0.66***	***0.13***
Stndard deviation	***4.29***	***4.25***	***2.47***	***0.00***	***N/A***
Coefficient of Variation	***0.35***	***0.29***	***0.33***	***0.00***	***N/A***
Constant	***34.89***				

Regarding variable tasks, only one is performed. Table 5 presents all 38 parameter values (i.e., independent variable) and job duration (response)

combinations. The equation that best describes the data trend (with R^2=0.8919) is:

$$y = 2.7203 + 2.3885x + 0.0954x^2 \qquad \textit{(Equation 3.6.1)}$$

This equation was obtained by evaluating different regression models in Excel 2002 and Minitab 14 software. After evaluating various options the model with a higher coefficient of determination (R^2) was selected. Figure 26 presents how this model fits the 38 data points.

Table 5. Variable tasks duration and parameter value per order

Order No	Task Durarion	Parameter Value	Order No	Task Durarion	Parameter Value
OT-0000004	5.00	1.00	OT-0000294	15.00	4.00
OT-0000005	5.00	1.00	OT-0000306	15.00	4.00
OT-0000011	20.00	5.00	OT-0000392	20.00	6.00
OT-0000012	10.00	2.00	OT-0000409	5.00	2.00
OT-0000018	15.00	4.00	OT-0000443	10.00	4.00
OT-0000031	15.00	5.00	OT-0000450	35.00	10.00
OT-0000037	15.00	2.00	OT-0000462	15.00	4.00
OT-0000186	15.00	5.00	OT-0000517	20.00	5.00
OT-0000199	30.00	8.00	OT-0000568	25.00	8.00
OT-0000201	25.00	6.00	OT-0000569	15.00	4.00
OT-0000204	35.00	9.00	OT-0000598	15.00	4.00
OT-0000205	15.00	4.00	OT-0000611	5.00	2.00
OT-0000207	30.00	8.00	OT-0000618	30.00	8.00
OT-0000243	10.00	3.00	OT-0000632	10.00	3.00
OT-0000263	15.00	5.00	OT-0000634	15.00	3.00
OT-0000264	10.00	3.00	OT-0000699	15.00	6.00
OT-0000271	25.00	8.00	OT-0000701	5.00	2.00
OT-0000278	5.00	1.00	OT-0000714	5.00	2.00
OT-0000283	15.00	6.00	OT-0000729	15.00	4.00

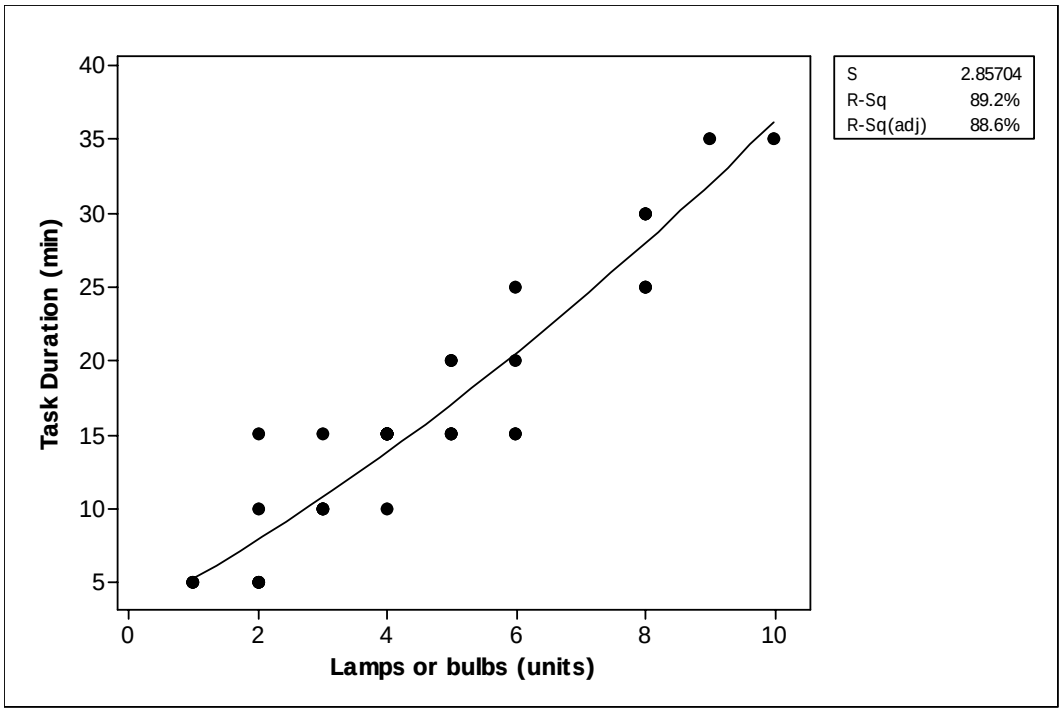


Figure 26. Plot of regression model for the variable task replacing bulb or lamp

The residual analysis for the task duration is shown in Figure 27. The normal probability and histogram plots do not reveal anything particularly troublesome. The histogram shows the mode above zero but the second tallest bar is on the negative side (close to -3). The plot on residuals versus the fitted values does not indicate variance changes and there is no relationship between the order of data and the residuals.

The constant part of this equation indicates an additional set up time not considered in the initial classification of tasks. Then, the time requirement function is:

$$TR_1(x) = (34.89 + 2.7203) + 2.3885x + 0.0954x^2 . \qquad \textit{(Equation 3.6.2)}$$

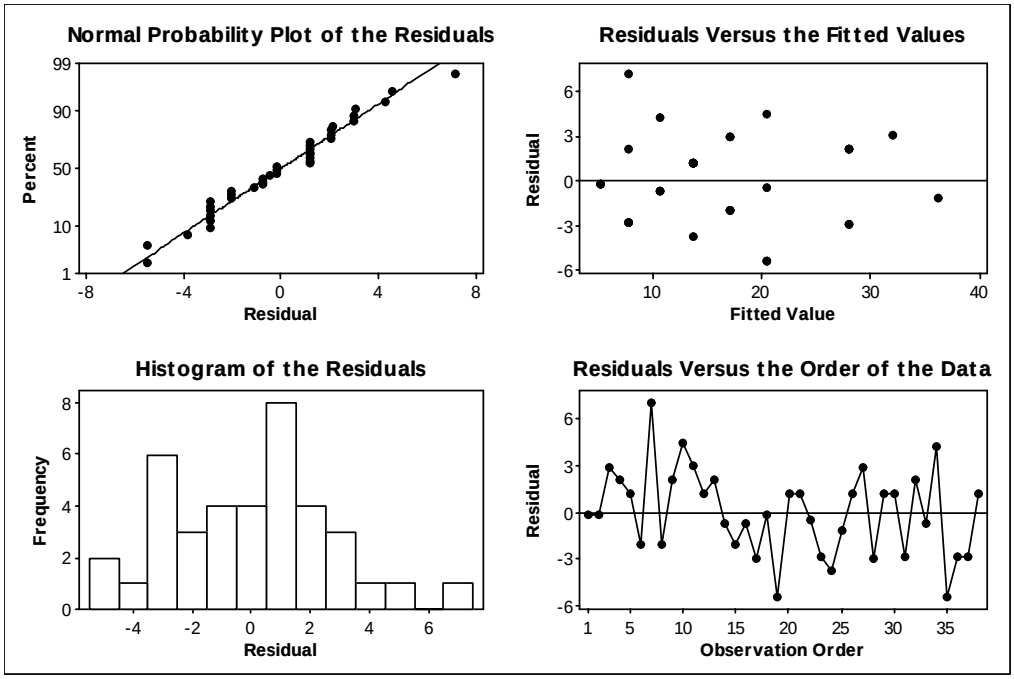


Figure 27. Residual Plots for task duration

Figure 28 shows the comparison between the actual work order duration and the time estimated by the model for the 38 work orders of the first month. Given R^2 (89.2 percent) and the analysis of residuals, we can conclude that the model is adequate.

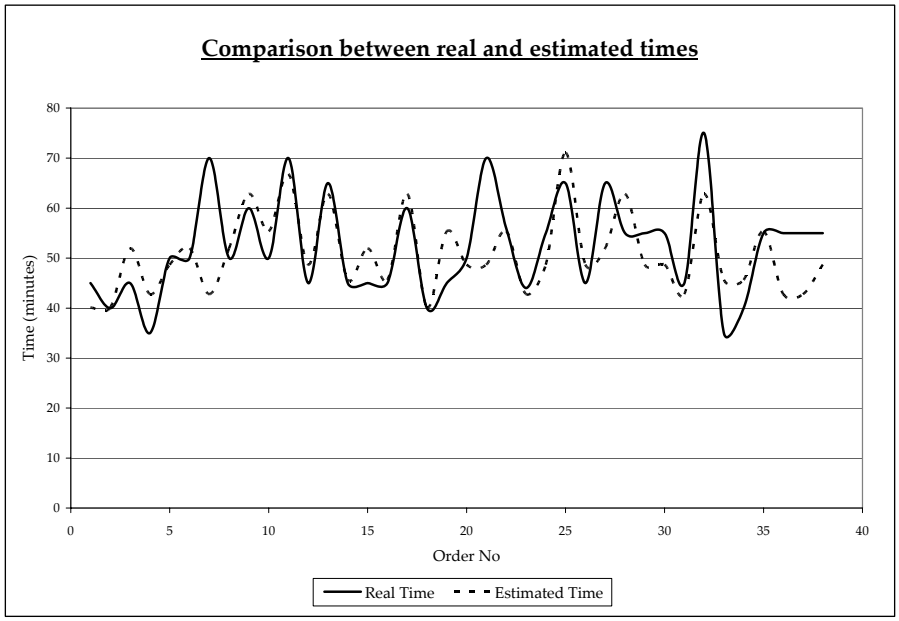


Figure 28. Comparison between actual times and model estimates

The time requirements are calculated for a one week period. Thus, it is necessary to obtain the forecast of Work Orders in a week, taking into account the number of bulbs and lamps to be changed. The work orders estimated for a week are shown in Table 6. For example, the weekly forecast for changes of 1 lamp/bulb is 2 orders; for changes of 2 lamps/bulbs are 2.875 orders; and so on. The time required to perform a job was obtained by replacing in equation 6 the number of units (x variable) and multiplying the result by the weekly forecast.

Table 6. Weekly Projection of Work Orders

Number of Units	**Forcast of Weekly Orders**
1	2
2	2.875
3	0.875
4	3.625
5	1.125
6	1.375
7	0.5
8	1
9	0.25
10	0.5

Table 7 shows the calculation made to obtain the time requirements. The last column shows the time required including the weekly orders and varying x from 1 to 10 units. The estimated Time Requirement for the job is 698.77 minutes per week. It is obtained from the sum of the last column of the table.

Table 7. Time requirements Calculation per bulbs (units)

Number of Units	C	V	Weekly Orders Projection	Time Req
1	34.89	5.20	2	80.20
2	34.89	7.88	2.875	122.97
3	34.89	10.74	0.875	39.93
4	34.89	13.80	3.625	176.52
5	34.89	17.05	1.125	58.44
6	34.89	20.49	1.375	76.15
7	34.89	24.11	0.5	29.50
8	34.89	27.93	1	62.83
9	34.89	31.94	0.25	16.71
10	34.89	36.15	0.5	35.52
			Sum	**698.77**

3.6.1.4 Available Time (AT) calculation

The data needed to calculate the available time is:

- Shift duration (S): it refers to the scheduled work time; eight hours or 480 minutes per day
- Breaks (B): it refers to the rest periods paid by the FD; 30 minutes per day
- Number of days in a week (D): the FD department works from Monday to Friday; five days in the week.
- Percent of day dedicated to Work Orders (P): it refers to the portion of time that the workers are dedicated to perform WO. In this case is 100%.

$$AT = [(S - B) * D] * P$$ *(Equation 3.6.3)*

$$AT = [(480 - 30) * 5] * 1$$

$$AT = 2250 \, {}^{\min}\!/_{\text{worker} - \text{week}}$$

3.6.1.5 Regression model validation

To validate the results a paired t-test was used. The reason for selecting this test is that it allows a direct comparison between actual and model prediction per work order. A sample of 79 new work orders was used. The statistical test compared the actual times and the estimates provided by Equation 3.6.2. The null and alternate hypotheses are:

H_o: There is no significant difference between the two samples. (μ_D=0)

H_a: There is a significant difference between two samples ($\mu_D \neq 0$)

The results of the statistical test are shown in

Figure 29. The confidence interval (CI) indicates that there is no significant difference between the two samples because it includes zero. The p-value (0.444) is greater than the alpha value (0.05). Thus, there was not enough evidence to reject the null hypothesis (Ho) and it was concluded that the model is appropriate.

Paired T-Test and CI: Time estimated, Real Time

```
Paired T for Time estimated - Real Time

                 N       Mean     StDev   SE Mean
Time estimated  79    54.1694   27.0332    3.0415
Real Time       79    54.7468   23.0926    2.5981
Difference      79  -0.577468  6.664187  0.749780


95% CI for mean difference: (-2.070165, 0.915228)
T-Test of mean difference = 0 (vs not = 0): T-Value = -0.77  P-Value = 0.444
```

Figure 29. Two sample t-test for changing lamps job.

3.6.1.6 Number of Workers (NW) required

The number of workers required (NW) is calculated from 2.6.3 presented in page 32. It results from the ratio of Time Required (TR) (which was 698.77 minutes per week) to Time Available (AT) (which was 2250 minutes per worker per week). For the job analyzed, the number of workers was:

$$NW_1 = \frac{TR_1}{AT} = \frac{698.77 \text{ min/week}}{2250 \text{ min/worker} - \text{week}} = 0.311 \text{ workers} \qquad \textit{(Equation 3.6 4)}$$

The result indicated that one worker can be assigned to perform the job.

3.6.1.7 Control chart for productivity index

In this example, the individuals control chart limits were calculated with the first 38 Orders. LCL (lower control limit) and UCL (upper control limit) are 57.30 and 142.70, respectively. The points in the chart include the original 38 plus the more recent 79 for a total of 117 points.

The graph shows that during the two-month period, productivity estimates are in control. The sequence of data points was evaluated for lack of randomness and outliers but nothing abnormal was detected. The data for the first month, which was used for control limit calculation, shows more variability. Since personnel collecting the data were learning about the new system during these initial weeks, it is advised that the control limits be recalculated again in the near future.

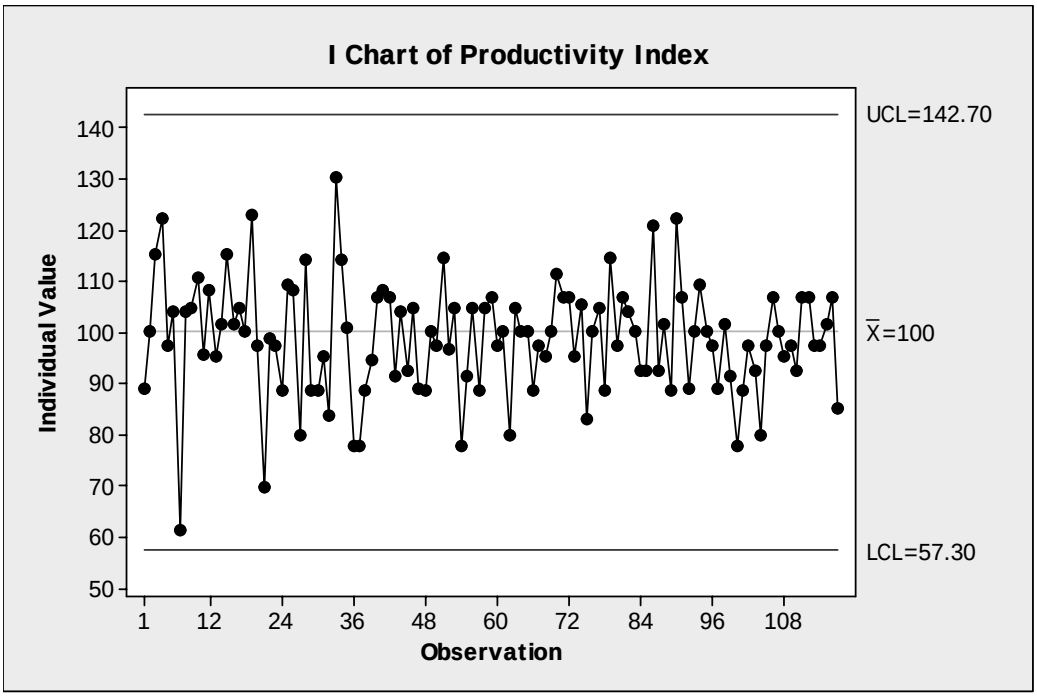


Figure 30. Control Chart for change lamps

3.6.2 Air Conditioner water dripping in the refrigeration section

3.6.2.1 Key Task Definition

A sample of 24 work orders showed that there are only three basic tasks. Similar to the previous example, the numbers before the task descriptions corresponds to the *i* subscript of the formula. The tasks included were:

1: *Arrive to the Working Place*: is the time of transportation to the place.

2: *Diagnosis of the problem:* it refers to the time to examine the problem and verify why the air conditioning is dripping.

3: *Cleaning and verification*. In general, the activities showed that the dripping is solved by the cleaning the tray, overflow pipe or filter.

The time of the work orders for the first month of the study is shown in this case, the parameter value is the number of air conditioners repaired in a single work order. Table 8 shows the work order number, the tasks executed, and the actual time.

Table 8. A/C water dripping work orders

Order No	Task No	Task Duration (min)	Work Order Duration	Parameter Value (units)
OT-0000168	1	10	90	1
	2	5		
	3	75		
OT-0000215	1	15	60	1
	3	45		
OT-0000345	1	5	60	1
	3	55		
OT-0000433	1	10	130	2
	2	10		
	3	110		
OT-0000452	1	15	90	1
	2	10		
	3	65		
OT-0000551	1	15	150	2
	2	5		
	3	130		
OT-0000555	1	10	100	1
	2	10		
	3	80		
OT-0000600	1	5	170	3
	2	15		
	3	150		
OT-0000612	1	15	90	1
	2	10		
	3	65		
OT-0000735	1	10	185	3
	2	20		
	3	155		
OT-0000804	1	15	85	1
	2	5		
	3	65		
OT-0000805	1	10	90	1
	3	80		
OT-0000806	1	15	80	1
	2	10		
	3	55		
OT-0000842	1	5	145	2
	3	140		
OT-0000851	1	10	75	1
	2	5		
	3	60		
OT-0000852	1	10	80	1
	2	5		
	3	65		
OT-0000862	1	10	135	2
	2	20		
	3	105		

Table 8. A/C water dripping work orders (continued)

OT-0000867	1	10	80	1
	2	10		
	3	60		
OT-0000978	1	15	70	1
	2	5		
	3	50		
OT-0000989	1	5	75	1
	2	10		
	3	60		
OT-0001003	1	10	80	1
	2	10		
	3	60		
OT-0001004	1	10	75	1
	2	10		
	3	55		
OT-0001020	1	10	80	1
	2	5		
	3	65		
OT-0001102	1	5	85	1
	2	10		
	3	70		

3.6.2.2 Task classification

The classification of tasks for this case is included in Table 9. As shown in the table, there are no avoidable tasks. The productive tasks are two: diagnosis of the problem and cleaning and verification. The unavoidable (UA) task consisted on arriving to the maintenance place.

Table 9. Tasks for A/C water dripping

Task No (i)	Task Description	Classification By type of task	Constant or variable
1	Arrive to the Working Place	UA	C
2	Diagnosis of the problem	P	V
3	Cleaning (tray, overflow pipe, filter)	P	V

3.6.2.3 Time Requirement (TR) calculation

Taking into account the previous classification, only one task is constant. Tasks 2 and 3 are variable and must be estimated using the formula.

Table 10 shows the time estimation for task 1 (constant task); the value of C is 11. On the other hand, the coefficient of variation is 29 percent, indicating that the dispersion was low.

Table 10. Time estimation for constant tasks

Order No	**1**
OT-0000168	10
OT-0000215	15
OT-0000345	5
OT-0000433	10
OT-0000452	15
OT-0000551	5
OT-0000555	10
OT-0000600	5
OT-0000612	15
OT-0000735	10
OT-0000804	15
OT-0000805	10
OT-0000806	15
OT-0000842	5
OT-0000851	10
OT-0000852	10
OT-0000862	10
OT-0000867	10
OT-0000978	15
OT-0000989	5
OT-0001003	10
OT-0001004	10
OT-0001020	10
OT-0001102	5
Weighted average	***10.23***
Standard deviation	***2.89***
Coeffiecient of variation	***0.29***
Constant (C)	***10.23***

A regression model was fitted to each variable task (diagnosis and cleaning). The results of these analyses are shown in Figure 31. The constant part of this equation indicates an additional set up time not considered in the initial classification of tasks. The second task is presented in 20 orders while the third one is presented in all orders. Moreover, to obtain the variable times (V) the two regressions formula are reduced to one expression. Thus V is equal to:

$$V = -52.22 + 137.63x - 21.24x^2 \qquad \textit{(Equation 3.6.5)}$$

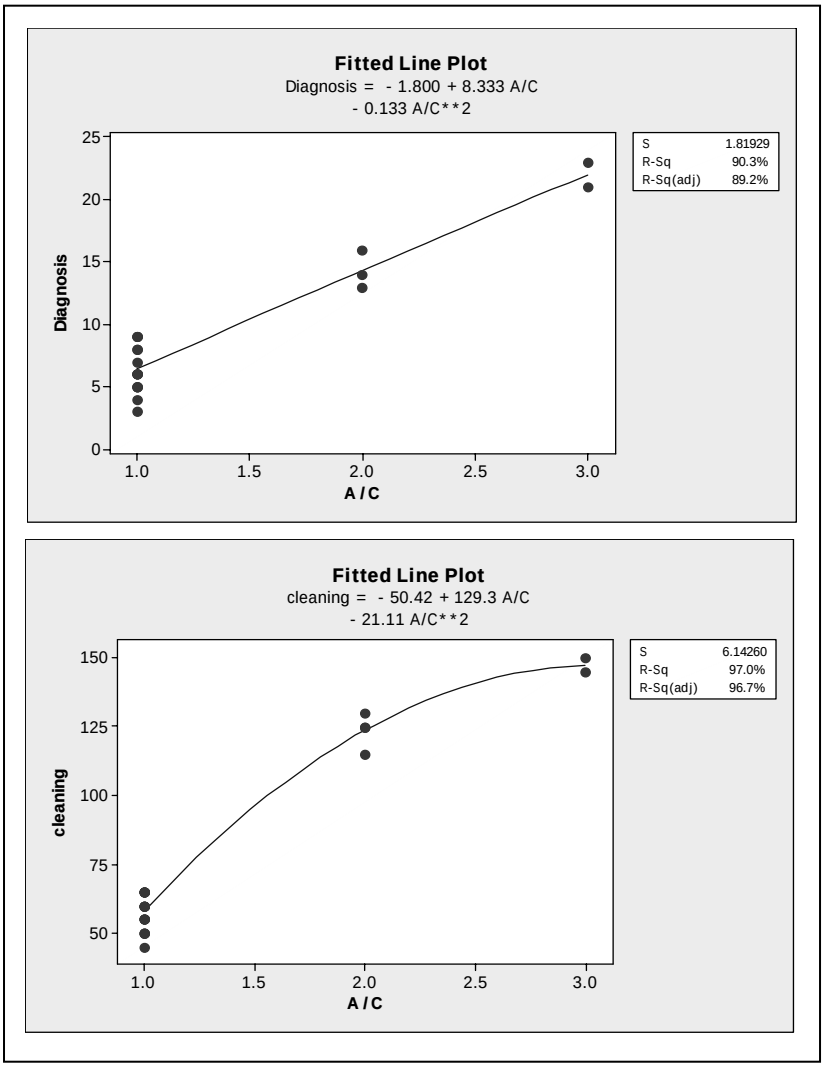


Figure 31. Variable tasks equations for the A/C water dripping work orders.

Finally, the equation for the time required to perform an order related with the A/C water dripping is:

$$TR_2(x) = (10.23 - 52.22) + 137.63x - 21.24x^2 \qquad \textit{(Equation 3.6.6)}$$

Figures 32 and 33 show the residual analysis for both tasks. It is important to mention that the number of data points for the first month were not enough (only ten) for this estimation. Thus, 14 data points of the second month were included into this group for a total of 24 work orders. For the diagnosis and cleaning tasks, the graph in normal probability scale looks marginally normal. The deviation from the normality assumption for residues is related to the fact that the independent variable (number of AC's repaired) only has three values (1, 2 and 3). Out of the 24 work orders, 18 involve just one AC, while 4 involve two and two involve three. The 18 durations for one AC range from 55 to 90 minutes. In situations in which the independent variable has very few values it might be desirable to identify alternative factors to explain duration.

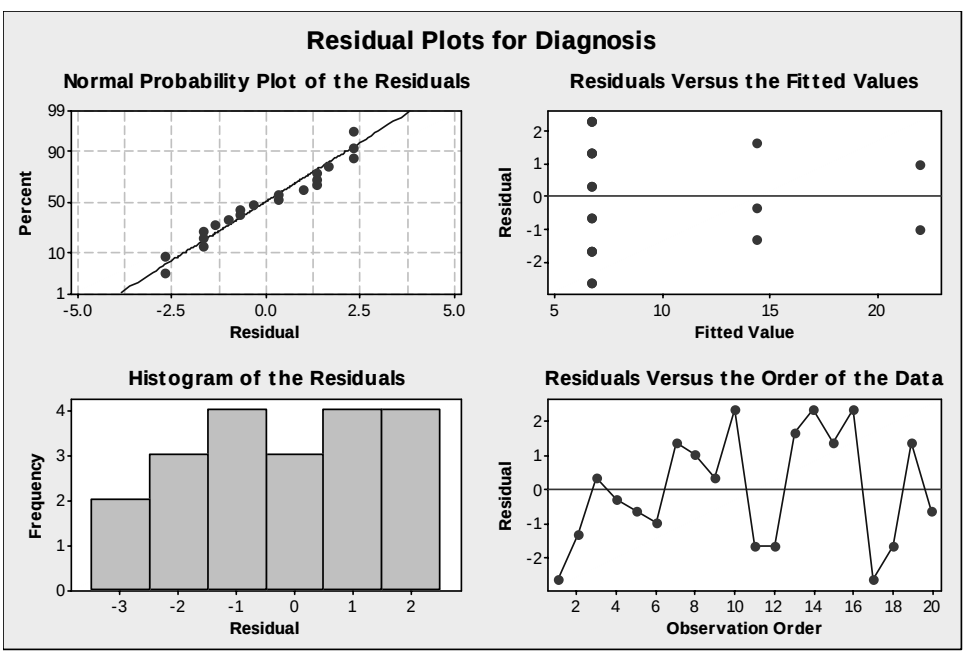


Figure 32. Residuals Plot for Diagnostic task

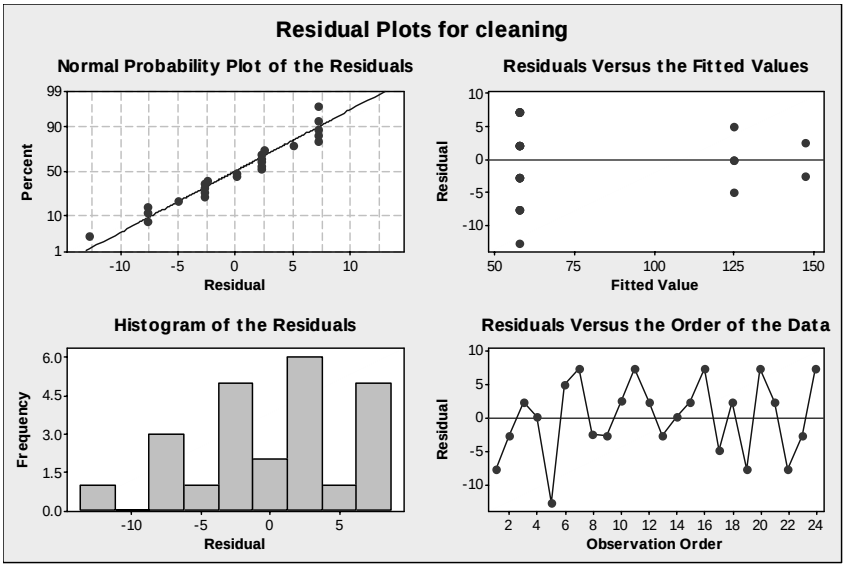


Figure 33. Residual plot for Cleaning task.

The comparison between actual and estimated times is shown in Figure 34. It can be observed that the two methods are similar, except by some observations that are considered as outliers.

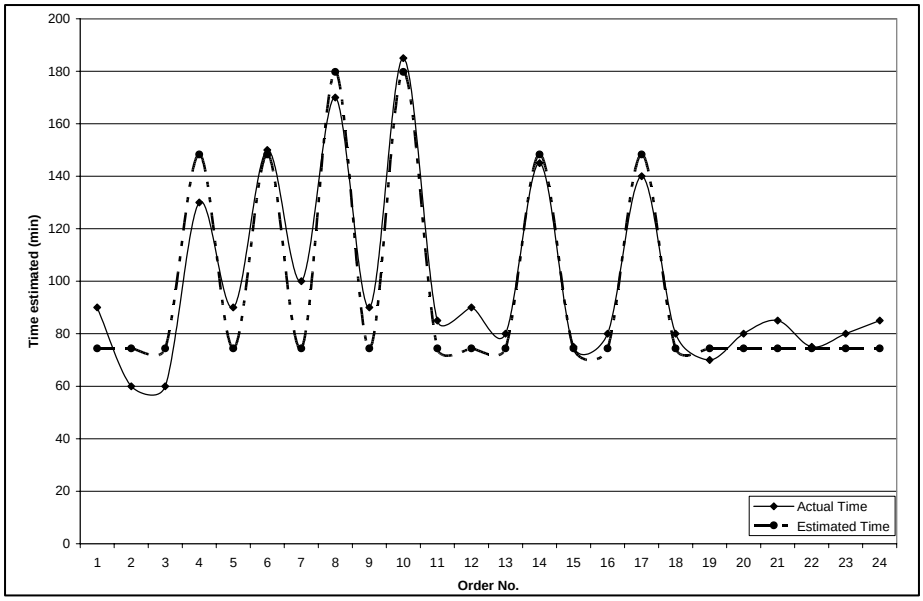


Figure 34. Comparison between observed times and fitted times.

To calculate the time requirement, it is necessary to know the weekly requirements. The data projections to perform the job are shown in

Table 11. To estimate the time requirement for the job, the calculations are made by the formula give in Equation 8. The results are shown in Table 14. Finally, the TR for the job is 516.20 minutes per week.

Table 11. Weekly projections for the A/C water dripping

Number of Units	Weekly Orders Projection
1	3.67
2	0.83
3	0.67

Table 12. Time Requirement calculation for job

Number of Units	C	V	Weekly Orders Forecast	Time Req
1	10.23	64.17	3.67	272.79
2	10.23	138.08	0.83	123.59
3	10.23	169.51	0.67	119.82
			Σ	**516.20**

3.6.2.4 Available Time (AT) calculation

As in previous analyzed task, the value of variables to calculate AT was:

- Shift duration: 480 minutes (S)
- Breaks: 30 minutes per day (B)
- Number of days in a week: 5 (D)
- Percent of day dedicated to Work Orders: 72.56%, estimated from historical data.

$$AT = [(S - B) * D] * P \qquad \textit{(Equation 3.6.7)}$$

$$AT = [(480 - 30) * 5] * 0.7256$$

$$AT = 1632 \, {}^{\min}\!/_{\text{worker} - \text{week}}$$

The available time per worker of this section is 1632.60 minutes per week.

3.6.2.5 Regression model validation

To validate the proposed method a paired-t test was performed using a sample of 14 work orders. As in the previous example, the statistical test compared the observed versus estimated times using Equation 3.6.4. The hypotheses are:

H_o: There is no significant difference between the two samples. (μ_D=0)

H_a: There is a significant difference between two samples ($\mu_D \neq 0$)

where μ_D represents the paired differences mean.

The results are shown in Figure 35. The p-value is 0.336 and the Confidence Interval includes zero. Thus, there was not enough evidence to reject null hypothesis (Ho) and therefore it can be concluded that the proposed model is valid.

Paired T-Test and CI: Observed, Real

```
Paired T for Observed - Real

             N     Mean    StDev  SE Mean
Observed    14  105.286   44.050   11.773
Real        14  103.571   44.351   11.853
Difference  14  1.71500  6.41732  1.71510


95% CI for mean difference: (-1.99025, 5.42025)
T-Test of mean difference = 0 (vs not = 0): T-Value = 1.00  P-Value = 0.336
```

Figure 35. Paired t-test test to compare methods.

3.6.2.6 Number of workers required

The number of workers calculated by the formula (see equation 2.6.3 on page 32), where TR is 576.20 minutes/week and AT is 1632.60 minutes per week per worker. Thus, NW results in:

$$NW_2 = \frac{TR_2}{AT} = \frac{576.20 \text{ min/week}}{1632.60 \text{ min/worker} - \text{week}} = 0.31 \qquad \textit{(Equation 3.6.8)}$$

The previous result indicates that one worker is needed, spending 31 percent of the time on this job.

3.6.2.7 Control chart for productivity index

For this job a sample of 38 orders was taken. The control chart is shown in Figure 36. Control limits were calculated using the formulas specified in Chapter 2.

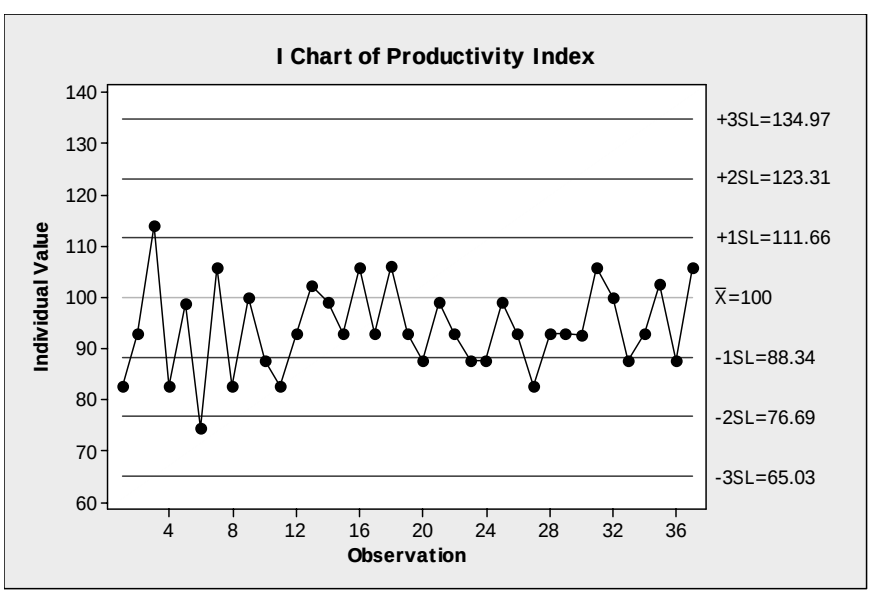


Figure 36. Control Chart for A/C water dripping work orders.

The LCL (Lower Control Limit) and the UCL (Upper Control Limit) are 65.03 and 134.97, respectively. The chart shows that there was no significant variation and the data points stay fairly close to the mean.

3.6.3 Clogged toilets and sinks

The third example constitutes one special case. The number of the parameter value (number of units) is always one toilet or sink.

3.6.3.1 Key task definition

The analysis is based on 33 work orders corresponding to the data collected for the first month. The tasks defined by the employees were:

1: *Arrive to the place:* time taken to travel to the maintenance place
2: *Disassemble toilet or sink:* consists removing the toilet or sink
3: *Unclog the sanitary line*: the main activity of clearing the pipes
4: *Assemble toilet or sink*: consists of putting the toilet or sink back in place
5: *Verify right functioning*: Verify the maintenance made.

The orders collected are presented in Table 15 which includes the tasks and the respective duration for each order.

Table 13. Work Orders for clogged toilets or sinks

Work Order	Task No	Task duration	Duration(min)
OT-0000003	1	25	210
	2	30	
	3	90	
	4	35	
	5	30	
OT-0000129	1	25	215
	2	30	
	3	95	
	4	35	
	5	30	
OT-0000130	1	20	165
	2	25	
	3	75	
	4	25	
	5	20	
OT-0000139	1	20	180
	2	25	
	3	80	
	4	30	
	5	25	
OT-0000148	1	15	155
	2	25	
	3	70	
	4	25	
	5	20	
OT-0000149	1	20	175
	2	25	
	3	75	
	4	30	
	5	25	
OT-0000150	1	25	205
	2	30	
	3	95	
	4	30	
	5	25	
OT-0000171	1	25	235
	2	35	
	3	100	
	4	40	
	5	35	
OT-0000193	1	35	270
	2	40	
	3	130	
	4	35	
	5	30	
OT-0000194	1	20	185
	2	25	
	3	80	
	4	30	
	5	30	
OT-0000195	1	30	235
	2	35	
	3	100	
	4	35	
	5	35	
OT-0000284	1	15	140
	2	20	
	3	60	
	4	25	
	5	20	
OT-0000312	1	35	300
	2	45	
	3	130	
	4	50	
	5	40	
OT-0000319	1	20	150
	2	25	
	3	65	
	4	20	
	5	20	
OT-0000321	1	30	210
	2	25	
	3	75	
	4	40	
	5	40	
OT-0000391	1	30	235
	2	35	
	3	100	
	4	40	
	5	30	

Work Order	Task No	Task duration	Duration(min)
OT-0000410	1	20	195
	2	25	
	3	85	
	4	35	
	5	30	
OT-0000435	1	20	180
	2	25	
	3	75	
	4	35	
	5	25	
OT-0000444	1	30	200
	2	30	
	3	75	
	4	35	
	5	30	
OT-0000465	1	20	225
	2	35	
	3	100	
	4	40	
	5	30	
OT-0000474	1	20	175
	2	25	
	3	75	
	4	25	
	5	30	
OT-0000475	1	20	155
	2	25	
	3	65	
	4	25	
	5	20	
OT-0000510	1	35	295
	2	40	
	3	130	
	4	50	
	5	40	
OT-0000535	1	30	250
	2	35	
	3	105	
	4	45	
	5	35	
OT-0000544	1	15	125
	2	20	
	3	50	
	4	20	
	5	20	
OT-0000573	1	20	175
	2	25	
	3	75	
	4	30	
	5	25	
OT-0000609	1	25	195
	2	30	
	3	80	
	4	30	
	5	30	
OT-0000610	1	20	145
	2	20	
	3	60	
	4	25	
	5	20	
OT-0000633	1	20	160
	2	25	
	3	70	
	4	25	
	5	20	
OT-0000635	1	35	210
	2	35	
	3	85	
	4	30	
	5	25	
OT-0000711	1	30	250
	2	35	
	3	110	
	4	40	
	5	35	
OT-0000721	1	35	280
	2	40	
	3	120	
	4	45	
	5	40	
OT-0000748	1	20	165
	2	25	
	3	70	
	4	25	
	5	25	

3.6.3.2 Task classification

The tasks reported are classified accordingly in Table 14. There are no avoidable tasks to be deleted. In addition, task number one (arrival to the maintenance place) is the only unavoidable task. The rest of the tasks are productive and also variable. The only constant task is the first one

Table 14. Task Classification for clogging tubes

Task No.	Description	Classification by type	Constant or Variable
1	Arriving to the place	UA	C
2	Disassemble toilet or sink	P	V
3	Unclog the sanitary line	P	V
4	Assemble toilet or sink	P	V
5	Verify right functioning	P	V

3.6.3.3 Time Requirement calculation

As it was mentioned earlier, the parameter value equals to one (1) sink or toilet per order. Thus, the weighted average is calculated from the data shown in Table 15. The results are summarized in Table 15:

Table 15 Averages for tasks durations

Task	Time Estimated	Standard Deviation	Coefficient of variation
1	24.39	8.78	0.36
2	29.53	3.57	0.12
3	86.88	29.81	0.34
4	33.13	8.52	0.26
5	28.44	4.53	0.16

Thus, the constant part (C) is the duration of the first activity: 24.39 minutes. The variable part (V) is the sum of tasks 2, 3, 4 and 5. The time average is 202.36 minutes, per order. There is no variation on the frequency and all the tasks were reported in all the examined work orders.

The variability of tasks is low because the largest coefficient of variation was 36 percent. Among variable tasks the largest CV was 34.3 percent, corresponding to task number 3 (unclog the sanitary line). For the repairing of one sanitary line, the number of work orders projected to receive in a week is 7.875 orders. Thus, the weekly time required to perform the orders is 1593.60 minutes per week.

3.6.3.4 Available time calculation

As in previous examples, the values of the parameter to calculate the AT were:

- Shift duration: 480 minutes (S)
- Breaks: 30 minutes per day (B)
- Number of days in a week: 5 (D)
- Percent of day dedicated to Work Orders: 65.23% (estimated from historical data)

The available time per worker of this section is 1467.68 minutes per week.

3.6.3.5 Number of workers required

The number of workers required for this case result from the division of the time required and the available time obtained previously. For the case there are more than one employee (NW=1.08 workers) for the whole week. This means that a worker should be assigned full time during 5 days of the week. It is recommended for this case to determine what variables different to the number of units cause a variation in the time of execution.

The three examples analyzed were special cases presented in the jobs performed by FD. The data and models were validated, and it can be concluded that the proposed method, based on regression analysis models, is useful to estimate task durations and to assign people to execute different jobs.

3.7 Database benchmarks

The software developed, WOS, was compared to other web-based databases used for maintenance. There is a wide range of softwares in the market. Examples of work order databases are Workorderama, Comm One and IFS among many others. The programs have a cost between 10,000 and 20,000 USD. Cost varies depending on the number of PC's, type of network and if it is used by internet or intranet.

This cost analysis was important because the licenses and the updates of the databases represent a significant cost and typically the personnel training is the major cost component as the software evolves. This research allows the university to benefit from the low cost in development and deployment. On

the other hand, most systems in the market are designed for people that have computer experience. Software friendliness was a major driver to ensure the Campus users can become acquainted with the system with the least effort possible.

Similar systems in the educational environment are available in universities home pages such as Penn State Hershey Housing, Texas A & M and University of Michigan among others. In Texas A & M, they have information about the Facilities Department and Physical Plant. Users have access to an online work order form that can be printed; however, the requests are not processed online. The second web site studied was Penn State which have online applications; however the site does not describe if the maintenance activities are classified by section.

The last web site analyzed was the University of Michigan plant operations. This is a complete site where the user can select from a list of 170 job possibilities. They have a complete guide for users describing the services provided by the Physical Plant department.

3.8 Discussion of results and benefits of proposed solution

The data collected in the original system was inaccurate and could not reflect the real contribution of FD personnel from the various sections. However, some comparisons were made using the data available. During system implementation, positive feedback was received. For example, the activities coordinator said that an order that used to take him 15 minutes to be processed, takes now 5 minutes.

Table 16 presents a comparison of time requirements for the previous/original versus the new system.

Table 16. Example of the Improvements of Proposed System

ALPHA SYSTEM		WOS SYSTEM	
Task	Time	Task	Time
Receive letter and write the Work Orders (including the time to search for the Work Orders form)	7 minutes	Receive letter and input information into the electronic Work Order system	4 Minutes
Write the number of orders in Control Work Book	3 Minutes	Print the orders and file in Control Work Book	1 minute
Publish the orders in the Bulletin Board	5 Minutes	Work Orders are sent electronically to the super-visors.	0 minutes

The time required to respond to orders was reduced:

- *Average time for secretaries to receive an order:* savings of 24 percent (call elimination), in average 36 minutes per day. In the remaining 76 percent: savings of 2 minutes per order, representing 45.6 minutes per day.

- *Average time for a supervisor to check an orde*r: From 3 days (in the original system) to 1.5 days or 12.2 work hours.

The use of the phone for placing work requests has been reduced by the use of the web page. During the first two months of system implementation 2272 requests have been made; 1562 by phone and 710 by internet. The daily requests, presented in Figure 37, illustrate that the use of the Web page has increased steadily. Customers have reacted positively to the fact that they can

check the status and follow-up on pending orders. Currently the system has 579 total customers and 20 percent of them registered through the web page.

Finally, Table 17 summarizes other benefits of the new system perceived by the BPR leader. The Table presents the problems in the original system, the improvements achieved with WOS, and the benefits of the proposed solution.

The Change Management and BPR surveys have not been distributed after the WOS deployment. After two months, FD personnel (more than users) are still learning the features of the new system. Some supervisors are still learning about the use of personal computers. Hardware such as PC's and printers are still being added throughout the Facilities Department for ease of access. Surveys regarding to BPR, change management and customer service presented in chapter 3 should be distributed before the end of the 2004 calendar year to make an objective comparison between the original versus the proposed system.

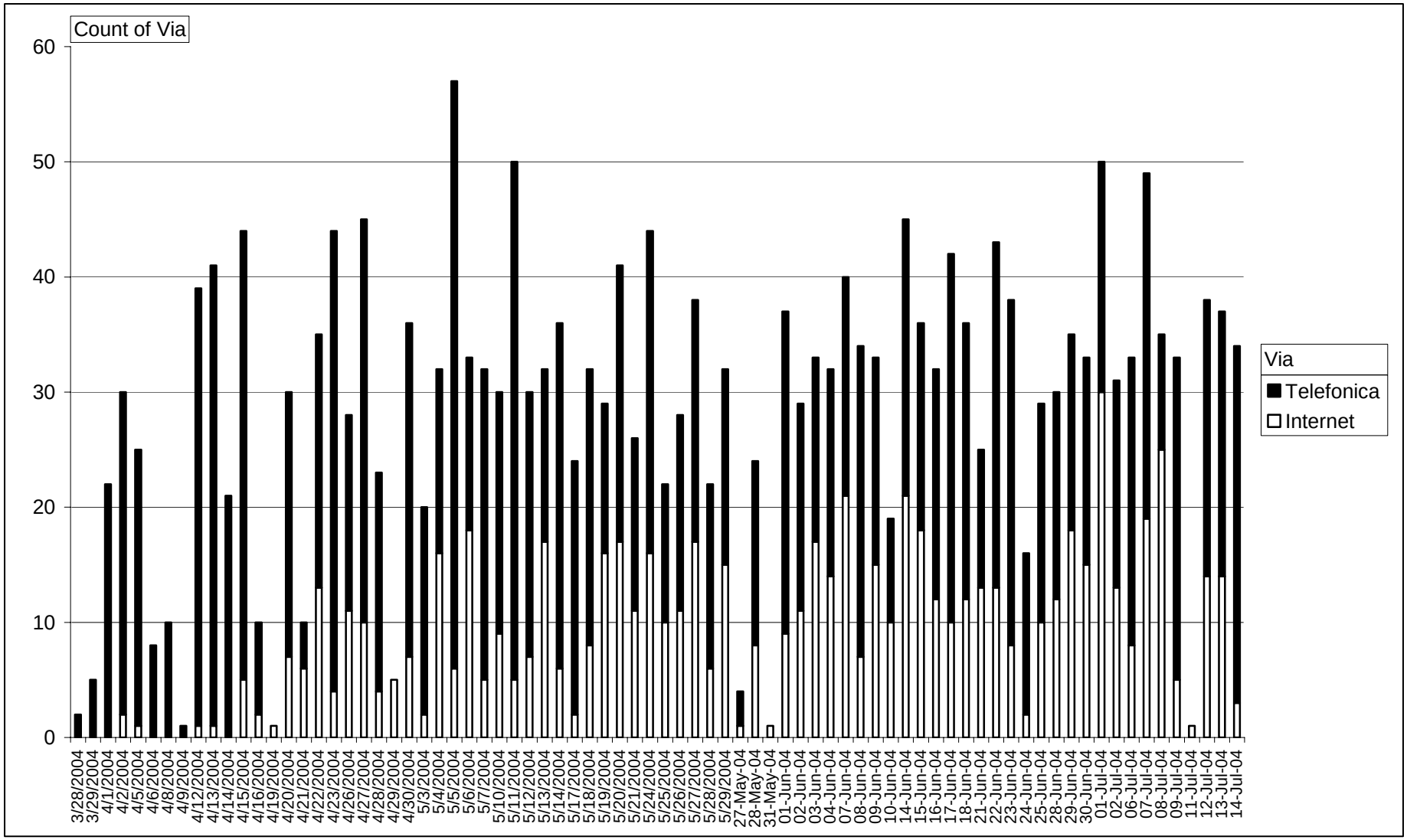


Figure 37. Internet vs Phone requirements

Table 17. Improvements and benefits summary

Problem	**Improvement**	**Benefit**
The secretaries and activities coordinator waste much time in the phone receiving requests	The customer can input an order by using the web	Save time to secretaries in data entry Gives confidence to the customer because the system provides the number and date of the requirement.
The supervisors have to go to the bulletin board of the central office to pick up the pendent orders.	The work orders arrives to the supervisor electronically (by using the database)	The work orders are received once the secretaries checked them. They can consult the orders in any part of the day.
There is no information about the tasks performed by employees. It is difficult to predict and analyze the time of execution of a work order	New work order format more detailed and proposed time estimation methodology.	The tasks of each order are recorded by employees, and the work orders times by using the proposed methodology can be predicted. It allows establishing goals to provide the service giving the customer the planned date of finish the work in a long time.
There are three physical files of work orders used to make searches and queries.	The use of the database allows having the information electronically and making queries and searches more efficiently than a physical file.	There is only one Physical file with the orders.
People do not feel to have participation in the work order process (Survey)	Redistribution of tasks and trainings given to supervisors, secretaries, employees, directors.	Improving the interaction with the system because it increases the participation of people, a better motivation and the improvement of the work quality. Each supervisor can print his own statistics and reports.
There is a wide quantity of data that is duplicated.	Data standardization by using the database and the model	A high efficiency in the information.

Table 19. Improvements and benefits summary (continued)

Problem	**Improvement**	**Benefit**
The activities are paper based and this means waste of time and money. Some copies are destroyed.	There is no paper based activities. The only operation in the process that is paper based is recording tasks executed by employees	The process of a work order is faster. There is only one copy saving paper.
The supervisors spend time in document orders and there are so many orders delayed because of it.	The system calculates automatically the time spend and additional features.	Save time on the documentation and the supervisors can spend time in activities more related with their technical tasks.

Conclusions

The original work order process was radically redesigned using business process reengineering principles. A new work order system (WOS) has been deployed. Given the importance of Campus customers, emphasis was placed on ease of work order completion and order status verification.

Information technology and usability issues fully addressed on this research include:

- Task definition for each user of the system
- Active participation of customer to simplify and accelerate data entry
- Use of database mechanisms for improved dataflow (e.g. sending information electronically from Campus customers to FD)
- Accuracy improvement through the availability of automatic database reports.

In spite of the few data available of the original system, comparisons between the original and the proposed processes were made. Results indicate some perceived improvements were made.

On the other hand a method for estimating the duration of maintenance services was developed and validated. It is based on the data collected through the work order and the classification of tasks. Regression analysis models are used for the variable activities. The time standard model developed was used in three different jobs by identifying the tasks and the

parameter values for each. The method estimates the time and the number of workers required. After the job is completed, the actual time can be compared to the estimate and a productivity measure can be tracked in a control chart.

Meetings with management, supervisors, office employees, union members, and Campus customers/users helped significantly in the understanding and involvement of all in the development and deployment of WOS. The implementation of the database is a radical change in technology and culture into a union environment. Following the BPR methodology helped in minimizing resistance to change. Key elements for the increased participation of all stakeholders were: interviews, surveys and training. Open communication channels have proved critical in the successes achieved.

Finally, it is important to mention that the BPR methodology and the model to predict job durations could be applied not only to maintenance, but also to indirect labor and general service areas. Thus, by the characterization of tasks, definition of work parameters, involvement of users, and use of information technology tools new processes can be proposed and new metrics for performance evaluation can be established.

Recommendations

Some recommendations to assure WOS institutionalization:

- *Training is needed in the Facilities Department*. Personnel should become knowledgeable on WOS functionality to maximize usage. A system administrator should become owner of the web and database application. Typical tasks include maintenance, backups and trouble shooting.
- *New computers, printers and server*. New equipment is needed to improve efficiency and stability of the system. Anti-virus software is critical to prevent "attacks" by outsiders.
- *Apply the method to estimate job duration to the remaining jobs performed by FD sections*: A method has been defined to estimate job durations but only three jobs have been studied as part of this research.
- *Evaluation of constant versus variable activities*. The constant component dominates in terms of time usage. Avoidable delays should be minimized and unavoidable delays should be challenged. It is important to revise the tactics followed by FD to achieve much higher productivity levels.
- *Evaluation of the new work order system*: It is important to follow up to the proposed process by applying the three surveys used when the system reaches a steady state (approximately after six months of use). The objective is to have a second opinion of the same population surveyed to the changes and benefits of WOS.

- *Enhancement of FD reporting tools*: The amount of data that can be collected with WOS permits better reports on FD contribution by section. The models proposed to estimate job durations, should provide accurate section productivity estimates.
- *Analysis of the constant component in job duration models:* The constant component in the job duration models is the most dominant in terms of time consumption. Unavoidable delays should be challenged if different approaches for interacting with customers and FD personnel logistics are defined.
- *Development of a tool for personnel allocation to be used by the supervisor*: After the method to estimate job duration is applied to most jobs, a software tool could aid supervisors in assigning resources to maintenance requests.

Appendix A. Work Order Original Report

Cont.

TALLER: FILTRACIONES DE TECHO

DURACION PROMEDIO TRABAJADO EN ORDENES DE TRABAJO

RESUMEN DE DURACION POR DIA:

(-...<- -4)	0
(-3 - -1)	0
(0)	137
(1 - 5)	63
(6 - 10)	5
(11 - 15)	2
(16 - 20)	2
(21 - 25)	0
(26 - 30)	0
(31 - 35)	1
(36 - 40)	0
(41 - 50)	0
(51 - 100)	0
(101 - 365)	0
(366 ->...)	0
	=====
Total en O.T.M. ==>	210

207 O.T.M. Significativas

PROMEDIO DE DURACION:
323.5 Total Trabajos en O.T.M.S./TALLER/AÑO

PROMEDIO TRABAJOS POR O.T.M./AÑO:
1.56 Hrs/O.T.M.S.

COSTOS ESTIMADOS DE ORDENES DE TRABAJO:

HRS. TRABAJADAS:		
DIESTRAS ..... ===>	$ 4,713.50	
AUXILIARES ..... ===>	+ 8,417.25	
	==========	
TOTAL EN HRS. TRABAJADAS ... ===>	$ 13,130.75	$ 13,130.75
TOTAL DE COSTOS EN MATERIALES ..... ====>		+ 24,130.94
		==========
TOTAL EN COSTOS ESTIMADOS DE ORDENES DE TRABAJO =		$ 37,261.69

TIEMPO DISPONIBLE PARA TRABAJAR:

TOTAL DE HRS. NETO DISPONIBLE/AÑO/PERSONA ..... ==>	1,470
CANTIDAD/EMPLEADOS REGULARES QUE TRABAJAN EN O.T.M. ===>	2
TOTAL DE HRS. NETO DISPONIBLE/AÑO/TALLER .....===>	2,940
PORCIENTO DE HRS./AÑO/NETO TRABAJADO/TALLER EN O.T.M. =>	0.11

LEYENDA:
O.T.M. = ORDENES DE TRABAJO DE MANTENIMIENTO
O.T.M.S. = ORDENES DE TRABAJO DE MANTENIMIENTO SIGNIFICATIVAS

Appendix B. Change Management Survey[2]

Name (optional) _____

Title _____

		Yes	No
1	I am doing much more of what is required from me to help this organization through numerous changes		
2	I co-operate actively to realize the change		
3	I encourage actions to support the realization of the change		
4	I promote the change with enthusiasm		
5	I try to convince others to the opportunity of the change		
6	I sustain with vigor the change in public decisions		
7	I make considerable effort so that my subordinates understand the change		
8	I am critical about the change in public discussions		
9	I am critical about the change with my superiors		
10	I support union activities against the change		
11	I support the action of my colleagues against the change		
12	I report complaints about the change to my superiors		

Comments

_____

_____

_____

_____

[2] From "Conceptualization and operationalization of resistance to change" by A. Giangreco. 2002:

Appendix C. BPR Survey[3]

1. How efficient is the current Work Order System?
No Opinion
Poor
Bad
Acceptable
Good
Excelent

2. How efficient are reports of the current Work order System?
No Opinion
Poor
Bad
Acceptable
Good
Excelent

To next questions please express your opinion regarding to each afirmation in the given scale

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	No Opinion
The database is a Central part of the Work order System						
The database is known and it is accessed by persons involved in the Work Order process						
The users of the system knows how to collect the information						
Currently it is easy to assign the right quantiity to the jobs to finish the Work Order on time						
The cost to performed jobs is known.						
The form indicates the Work Order deadline						
It is common to identify and implement improvements to the Work Order process						
The customers help to identify and implement improvements to the Work Order process						

4. Identify some changes that you could make to the Work Order system

5. Identify some changes that you could make to the reports of each section

6. Are you in the Labor Union?(Yes/No)

If your answer was yes in the last question, please answer:

Identify proposed changes that could go against the workers Union.

How the union could help to implement the proposed changes successfully?

[3] From "Successful predictors of business process reengineering (BPR)" by M. Terziovski et. al.2003.

Appendix D. Customer Service Survey[4]

The administration dean is working to improve their systems and the customer service given. It is important for us to know your opinion about the current system.

Instructions: Next you will find a list of sentences which you can be Strongly Agree, Agree, Disagree and Strongly disagree. No answer applies to cases where the customer has no experience.

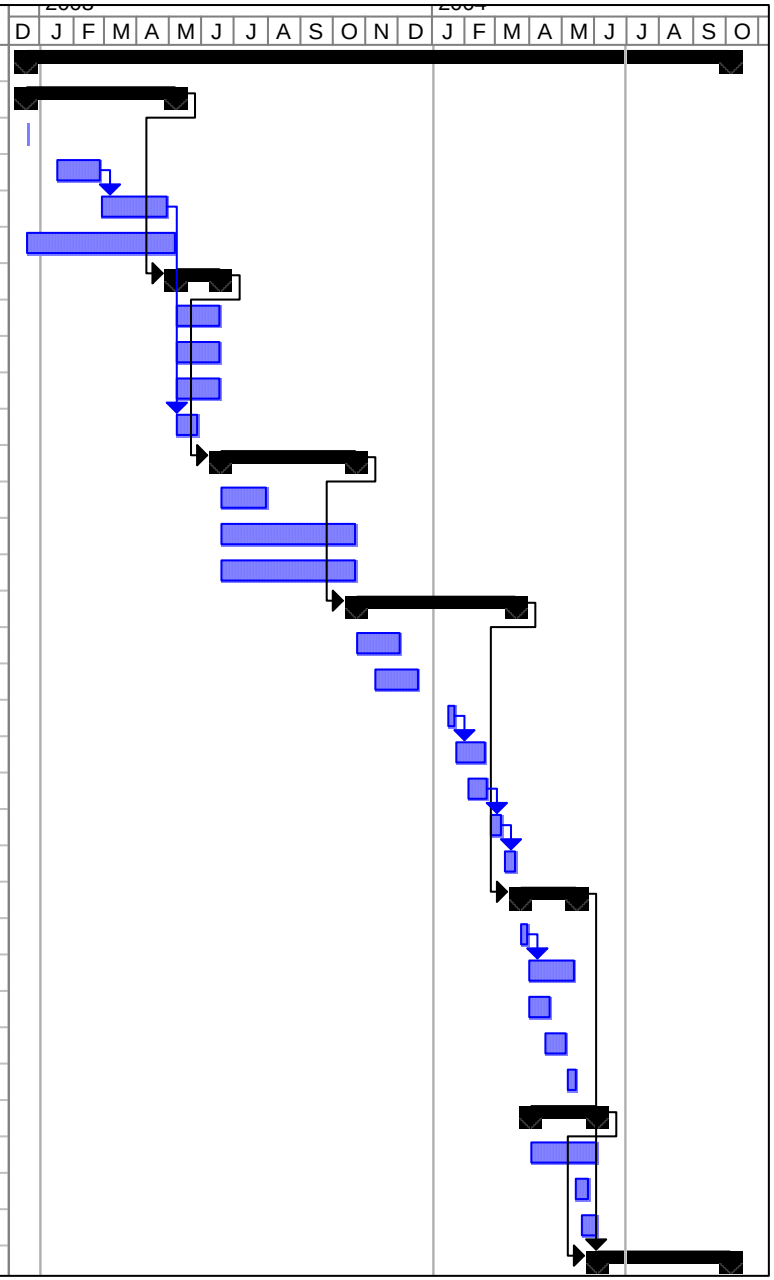
	Strongly Agree	Agree	Disagree	Strongly Disagree	No Answer
1. The phone requirement is taken in a professional way					
2. The WO is made on time					
3. You are satisfied with the service given					
4. The employees pay the right attention to give the services					
5. The supervisor respond in a ritght manner.					
6. The procedures used are good					
7. You are satisfied by the services given by the FD					

Additional comments

[4] From "Customers First: Using process improvement to improve service quality and efficiency" by C. Larson.

Appendix E. General Schedule of the Research

1	**METHODOLOGY FOR CONTINUOS IMPROVEMENT BASED ON BPR PRINCIPLES**
2	**Familirizing Stage**
3	Directors interviews
4	Supervisors interviews
5	BPR survey and customer service survey
6	Problem definition and collecting data (proposal)
7	**Basic information analysis**
8	Flow Diagram elaboration and fine tuning
9	Data Flow Diagram elaboration and fine tuning
10	Document the tasks performed by each section
11	Analysis of surveys
12	**New process definition and fine-tuning**
13	Design of proposed work order form and fine tuning
14	Database and fine-tuning with users design and development
15	Web page and fine-tuning design and development
16	**Pre-implementation process**
17	Personalized training to the Facilities Department users and developing manuals
18	Develop manuals, brochures and quick queries references for users
19	Present project to the Customer
20	Personalize training with customers
21	Determine needs of software and equipment
22	Install the Work Order database and the Home-Page in the server and make tests
23	Create accounts for database users
24	**Implementation process**
25	Install database on each computer and make tests
26	Personalize trainings and support using the system online
27	Meeting with employees of each section to reinforce the righ ouse of the proposed form
28	Fine tuning on manuals
29	Surveys Analysis
30	**Performance measurement**
31	Collect work orders with tasks reported
32	Analyze data collected and select key jobs
33	Estimate times of duration in three key jobs
34	**Document development and research presentation**



ID		Task Name	Duration	Start	Finish	Predece
1		**METHODOLOGY FOR CONTINUOS IMPROVEMENT BASED ON BPR PRINCIPLES**	**471 days**	**Tue 12/17/02**	**Tue 10/5/04**	
2		**Familirizing Stage**	**101 days**	**Tue 12/17/02**	**Tue 5/6/03**	
3		Directors interviews	2 days	Tue 12/17/02	Wed 12/18/02	
4		Supervisors interviews	30 days	Wed 1/15/03	Tue 2/25/03	
5		BPR survey and customer service survey	45 days	Wed 2/26/03	Tue 4/29/03	4
6		Problem definition and collecting data (proposal)	101 days	Tue 12/17/02	Tue 5/6/03	
7		**Basic information analysis**	**30 days**	**Wed 5/7/03**	**Tue 6/17/03**	**2**
8		Flow Diagram elaboration and fine tuning	30 days	Wed 5/7/03	Tue 6/17/03	
9		Data Flow Diagram elaboration and fine tuning	30 days	Wed 5/7/03	Tue 6/17/03	
10		Document the tasks performed by each section	30 days	Wed 5/7/03	Tue 6/17/03	
11		Analysis of surveys	15 days	Wed 5/7/03	Tue 5/27/03	5
12		**New process definition and fine-tuning**	**90 days**	**Wed 6/18/03**	**Tue 10/21/03**	**7**
13		Design of proposed work order form and fine tuning	30 days	Wed 6/18/03	Tue 7/29/03	
14		Database and fine-tuning with users design and development	90 days	Wed 6/18/03	Tue 10/21/03	
15		Web page and fine-tuning design and development	90 days	Wed 6/18/03	Tue 10/21/03	
16		**Pre-implementation process**	**108 days**	**Wed 10/22/03**	**Fri 3/19/04**	**12**
17		Personalized training to the Facilities Department users and developing manuals	30 days	Wed 10/22/03	Tue 12/2/03	
18		Develop manuals, brochures and quick queries references for users	30 days	Fri 11/7/03	Thu 12/18/03	
19		Present project to the Customer	5 days	Thu 1/15/04	Wed 1/21/04	
20		Personalize training with customers	20 days	Thu 1/22/04	Wed 2/18/04	19
21		Determine needs of software and equipment	15 days	Mon 2/2/04	Fri 2/20/04	
22		Install the Work Order database and the Home-Page in the server and make tests	10 days	Mon 2/23/04	Fri 3/5/04	21
23		Create accounts for database users	10 days	Mon 3/8/04	Fri 3/19/04	22
24		**Implementation process**	**40 days**	**Mon 3/22/04**	**Fri 5/14/04**	**16**
25		Install database on each computer and make tests	7 days	Mon 3/22/04	Tue 3/30/04	
26		Personalize trainings and support using the system online	30 days	Wed 3/31/04	Tue 5/11/04	25
27		Meeting with employees of each section to reinforce the righ ouse of the proposed form	15 days	Wed 3/31/04	Tue 4/20/04	

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