UPR/MIT Tren Urbano Professional Development Program
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Civil Engineering Department

The application of Total Productive Maintenance to the storage and maintenance area of *Tren Urbano*: Case Study: Motor Bogie

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Introduction

Quality, Productivity, Client's Satisfaction, Security, Cycle Time Reduction, Equipment Conditions, Production and Maintenance are some of the must important aspects and challenges of nowadays industries. In an operational system, as the one presented in any industry, a total maintenance can be the key to success. Therefore, different programs and techniques have being developed to control the maintenance of almost any kind of operational system.

Tren Urbano (TU) is Puerto Rico's largest infrastructure project. Consequently, is one of the must interesting and main industry of the island. The approach of TU has been to combine the strategic tools of DBOM (design-build-operate-maintain). One of the stages that have to be design for the successful of TU is the operational one. No design has been planned for the maintenance of the operational system of the train, which is almost ready to use. This fact is important and indicates that an application of some maintenance technique must be necessary to follow up the complete and successful implementation of TU.

The research proposed is a development of a maintenance program. There is a state-of-the-art technique called Total Productive Maintenance (TPM). TPM has the potential of being applied to any operating system, including the TU Storage and Maintenance Facilities (S&M) located at Martinez Nadal, in Güaynabo, Puerto Rico.

TPM is a maintenance program, which involves a newly defined concept for maintaining facilities and its equipment. Actually the existence of diverse equipment, centralized control, few operators, high-energy consumption, poor working environment, shutdown maintenance and high accident and pollution risk are unique features and concerns that reclaim for TPM implementation.

Objectives

- Investigate TPM strategies for its application to the Motor Bogie to increase the efficiency, effectiveness and security in the operations of TU's vehicle.
- Generate a specific format or formula including all processes, parts and maintenance given to the Motor Bogie.
- Apply TPM to all possible processes in the S&M of TU using the specified given format.
- Involve all the people working in the S&M to built an adequate environment that will minimize breakdowns, improve quality and motivate workers to increase their involvement in the suggestions to improve the system.
- Aim for world-class quality for the S&M of TU.

Scope

Initially the main objective of this research was to analyze every process and every part in the S&M at Martinez Nadal. A Top View and a Layout of this area are included in Appendix 1. This objective was modified because it was too broad on account of TPM strategy that analyzes each process by each part in its minimal detail. Focusing on the Motor Bogie if the vehicle, including the specific parts allowing the research to obtain a more concise and meaningful results. These results include a specific formula or format that can be applied to other process with other parts.

Methodology:

To achieve the project objectives the following activities were done:

I. Gathered Information.

The development of the TPM implementation to the S&M facilities of TU, require a complete knowledge of the strategy. Therefore some books were studied to develop a **Literature Review.**

1. **Total Productive Maintenance: The factory management notebook series.**

   - Nikkan Kogyo Shimbun

TPM combines American maintenance practices with Japanese quality control concepts and small group activities to revolutionize plant maintenance. It is an innovative system for equipment maintenance that optimizes effectiveness, eliminates breakdowns, and promotes autonomous operator maintenance through day-to-day activities.

Part I TPM: The Six Major Losses. Introduces TPM, its relationship to JIT manufacturing and the 6 major losses in manufacturing.

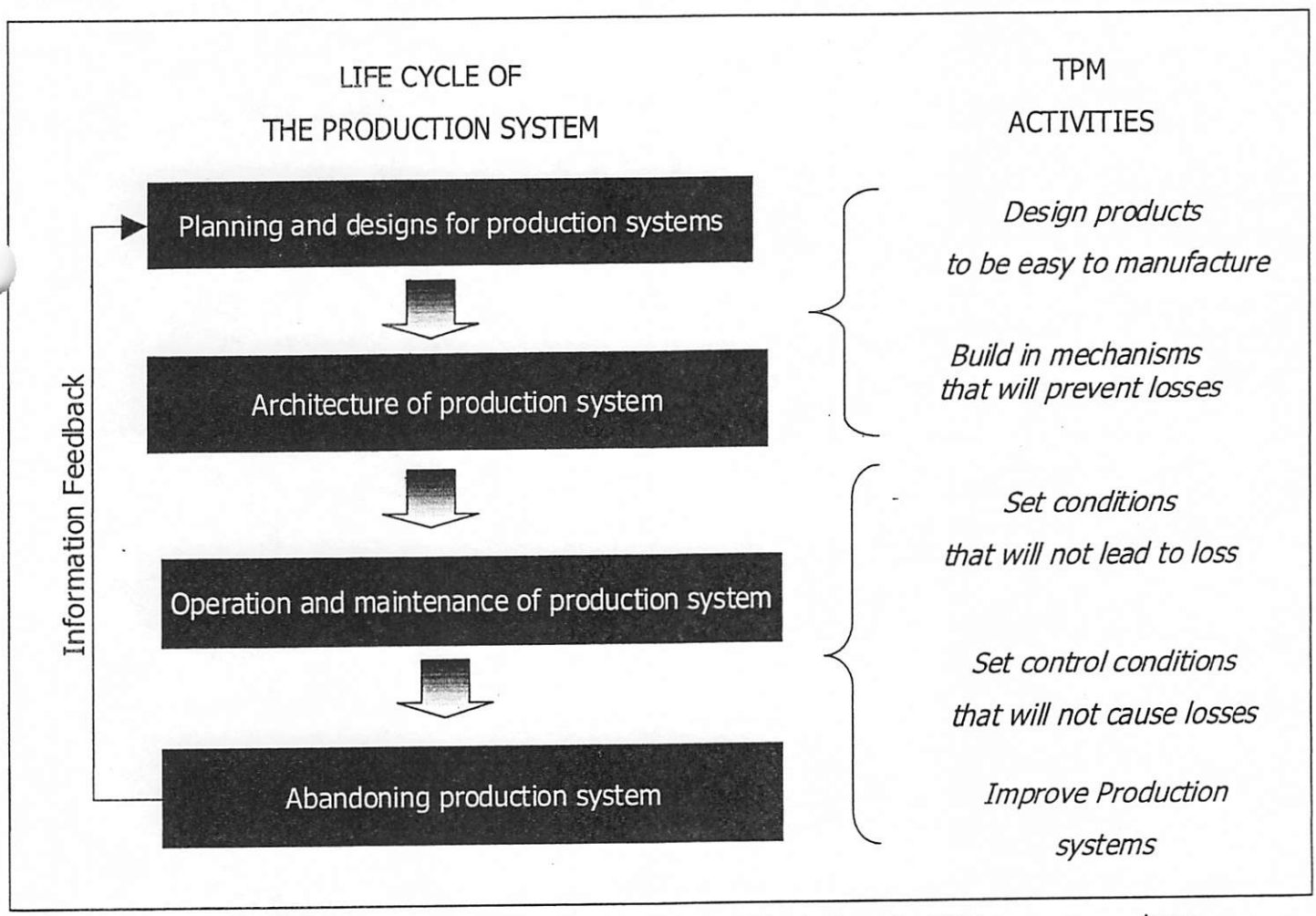
TPM: Definition	Characteristics of TPM (basic concepts)
1. Goal is maximizing equipment production rates (overall production rate)	Pursuit of a more economic way of operating
2. Establishment of a *total PM system* covering the entire life of the equipment	Philosophy of prevention (stop problems before they happen)
3. Activities spread throughout all departments, including those, which design, use, and maintain equipment.	Overlapping small group activities
4. All employees participate, from top management to line workers	
5. PM is spread through the use of motivational controls, which is to say autonomous small group activities.	

It's preferable to introduce JIT before TPM incorporation. TPM focuses on equipment, its goal is the "building in of quality at the equipment level" and by controlling the factors in the cause-and-effect chain; it attempts to maximize output.

There are six major losses identified by TPM:

- √ Loss from equipment failure
- √ Loss from setup adjustments
- √ Loss from brief stops
- √ Loss from speed drops
- √ Loss from process defects
- √ Loss from startups

The relationship between TPM and the life cycle of production system:



Part II Reducing the Six Major Losses. Next steps in TPM program, where action against mistakes and the six major losses are developed. Improvements

throughout the entire manufacturing environment are laid out and plans for the future are formed.

Part III TPM Case Studies. Case studies where the workers' TPM programs are developed in order to combat continued problems and improve plant, machine, and operator productivity and efficiency. Cases like "Improvements to stop breakage of welding robot cable" this was a loss due to failures, "One-Touch Setups Using Common Fixtures for sharpening Cutting Tools" loss due to Setups, "Shortening Setup Adjustment Time for Bend Reinforced Glass" a loss due to Setups and others.

TPM Is:

1. Aimed at creating corporate structures with maximum efficiency in the production system (overall production rate).
2. A workshop architecture that allows the elimination of loss before it happens, through the total elimination of "disasters, defects, and machine failures" within the entire life cycle of the production system.
3. Applied to all departments in the corporate structure including development, sales, and management as well as production.
4. The participation of all employees, from top management down to the line workers.
5. A means of achieving zero loss and zero defects through overlapping small group activities.

2. **Organización del mantenimiento preventivo**

- José V. Peiró

The application of Preventive Maintenance facilitates the development of the equipment in its maximum capacity and eliminates surprising risky situations, which had a high and unexpected cost.

Part I includes general topics of the philosophy, composition and other aspects. It contains an explanation and an example of an annual-work plan (p.30) and a monthly-work plan (p. 38). It clarifies how to use additional assistance and how to control it. A demonstration of a Center of Maintenance

from the definition throughout inspections and codification is clearly explained, including formulas and process for its competition. Finally Part 1 includes the theme: Center of Work-Control, which includes control panel formulas and distribution of assignments month by month.

Part II starts with the replacement of equipment including alternatives to consider before making the substitution:

- √ Repair of the existing equipment
- √ Request of new equipment with similar characteristics to the existing one.
- √ Request of new equipment better than the existing one.
- √ Maintain on service the equipment
- √ Rent an equipment

It continues with the description of cyclic works, which are works to be done in an annual frequency. A formula of cyclic works including the work description is shown with require hours for its modification. Next the equipment maintenance is presented: Preventive Maintenance, Selection Criteria, Maintenance Action, Installation of New Equipment, Cost, Control of Maintenance, including examples and others. TPM must be a permanent service, that's why a call-service must be involved. The utilization of this service must be regressive; this means at the time the preventive action for that element is accomplished the number of calls for it must decrease. The calls must be group, classified, documented in a distinct formula and registered in an additional formula. These formulas are prepared based on the exigencies of the company. Following this chapter a description of Work-Orders with its importance, configurations, classes, priorities and process is contained. Succeeding the Orders of Actions is demonstrated.

Part III embodies evaluation and identification of tasks or jobs, material supply and some recommendations of preventive order along with negative attitudes, advises and personal comments.

3. Maintenance Management for Quality Production

- John L. Winter & Richard S. Zakrzewski

Total Productive is a uniquely Japanese approach to maintenance. Productive Maintenance is a management tool learnt from the US after the World War II. However a similar concept was arranged in Japan in 1860's to adopt and adapt to the advanced industrial techniques of the Western Countries.

Using the equipment to its fullest extent, for manufacturing to the desired quality and efficiency are the first steps towards maintenance-oriented plant management.

TPM tries a positive investment in human resources in order to fully utilize existing equipment through improved availability, through more assured quality and through laborsaving as a result of plant modification. TPM gives:

- Assured quality of the product
- Improve equipment availability
- Met delivery times
- Eliminate environmental and safety hazards
- Establish throughout the company equipment consciousness and maintenance-oriented management

The 1st motive, *Improving productivity through a highly motivated workforce,* recommends to devise a program of multi-craft work or job enlargement in which all workers are given a range of challenging jobs in an effort to develop their skills at different crafts. Having this in mind the job would not be monotonous, repetitive or production line work.

The 2nd motive the life-cycle approach to improve the overall performance of equipment. It establishes the gap or lack or information flow between those who project and design the equipment, those who manufacture it, those who maintain it and those who used it for production. The technical aspects of TPM emphasize Maintenance Prevention (MP), which implies the design of highly reliable and easily maintainable equipment with subsequent feedback form maintenance and operation to design.

The 3rd motive is the voluntary small-group basis of TPM. QC circle and ZD Group are widely practiced in Japan regardless of the size of the company. Naturally TPM followed the same route focusing small-group activity on the "5S Activity":

- Neatness - *Seiri*
- Tidiness – *Seiton*
- Cleanliness - *Seiketsu*
- Stainless - *Seiso*
- Orderliness – *Shitsuke*

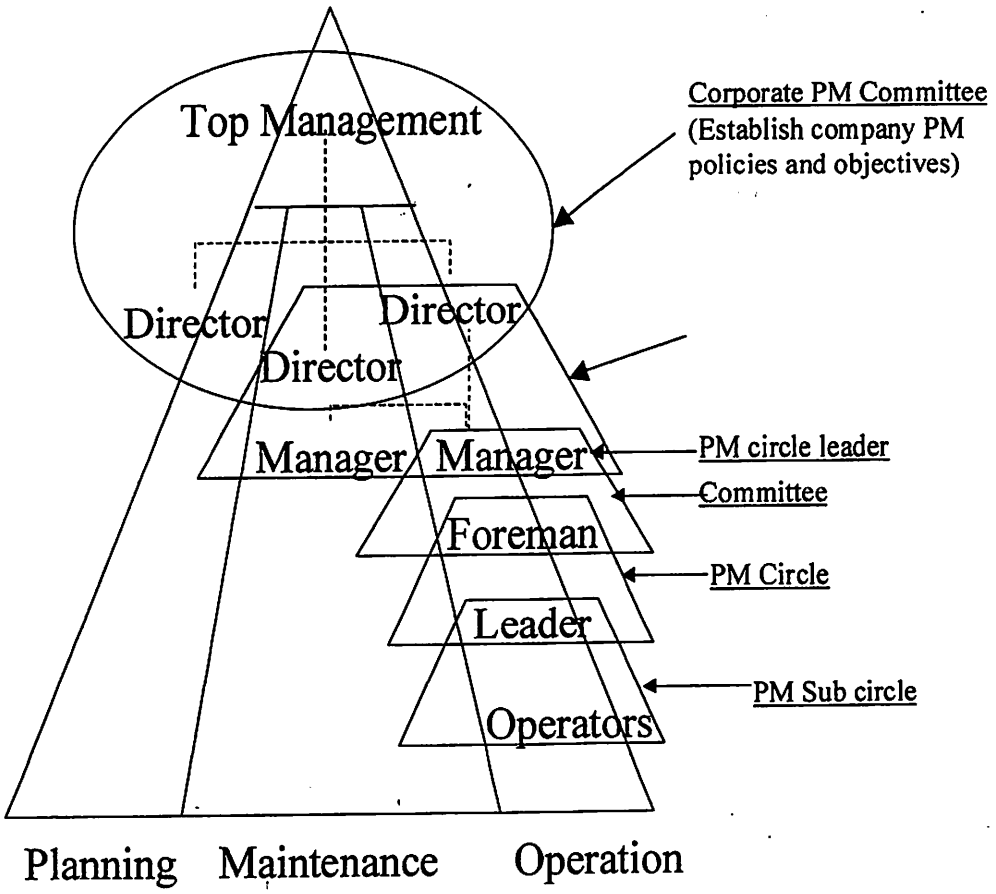
TPM application must have **equipment** at the center of thoughts, answering: how to improve its availability, how it can contribute to energy and resource conservation and hence to reduction in overall costs, and how this can be achieved through maintenance-oriented plant management as part of a total system approach.

4. **Maintenance Planning and Control.**

- Anthony Kelly

It explains how Toyoda Gosei Co. Ltd., a medium-sized company supplying plastic injection moldings and rubber moldings to the automobile industry, used TPM in order to improve plant availability, product quality and resource utilization. They used "small group cycle" or TPM promotion system.

A TPM Promotion Committee was created; they conclude that relationship between production and the Maintenance Department must be closer, like it shows:



Also that the new plan must concern all people involved in a positive matter.

5. Introduction to TPM – Total Productive Maintenance.

- Seiichi Nakajima

The must important features of TPM are:

1) Activities to maximize equipment effectiveness – requires complete elimination of failures, defects and other negative phenomena. Alludes to zero defects (ZD) and its relationship to TPM.
2) Autonomous maintenance by operators – it depends on the prevailing labor organization.
3) Company-led small group activities – people oriented management models

The book presents how profitable can be for a company if it implements TPM. It gives examples of TPM's effectiveness in productivity, quality, cost, delivery, Safety/Environment and morale. On each category the changes are in a positive way. The author mentions some history of how TPM was developed and its strong relationship with Preventive Maintenance (PM). A complete definition is given of TPM:

i. TPM aims to maximize equipment effectiveness (overall effectiveness). *Total Effectiveness*
ii. TPM establishes a thorough system of PM for the equipment's entire life span. *Total Maintenance System.*
iii. Various departments (engineering, operations, and maintenance) implement TPM. *Total participation of all employees*
iv. TPM involves every single employee, from top management to workers on the floor. *Total participation of all employees*
v. TPM is based on the promotion of PM through *motivation management:* autonomous small group activities. *Total participation of all employees*

The equipment effectiveness must be measure correctly. The operating rate of equipment must be measure by its availability:

$$Availability = \frac{\text{operation time}}{\text{loading time}} = \frac{\text{loading time - downtime}}{\text{loading time}}$$

TPM can be "profitable TPM" and pursue optimal equipment effectiveness if:

- Accurate equipment operation records are stored so that the appropriate management and controls can be provided (with narrower targets)
- A precise scale for measuring the equipment operation conditions must be devise.

The author explains how breakdowns and minor stoppages impede automation; a comparison between preventive medicine and preventive maintenance is presented, only that the last case instead of people is the equipment that matters. He mentions how useful preventive maintenance can be, however if the purpose is to eliminate breakdowns it can't work alone. To eliminate failures hidden defects must be expose and equipment must be treated before it breaks down. To eliminate failures:

1. Maintaining well-regulated basic conditions (cleaning, lubricating, and bolting).
2. Adhering to proper operating procedures.
3. Restoring deterioration.
4. Improving weakness in design.
5. Improving operation and maintenance skills.

The successful implementation of TPM requires:

√ Elimination of the six big losses to improve equipment effectiveness
√ An autonomous maintenance program
√ A schedule maintenance program for the maintenance department
√ Increased skills of operations and maintenance personnel
√ An initial equipment management program

TPM requires 12 steps for its development. Motivation, Competency and Work Environment are requirements for Fundamental Improvement. The 12 steps are divided in three stages: preparation, implementation and stabilization.

Finally, integrating small group activities into the organizational structure is part of TPM implementation. The small group can be categorized in QC (Quality Control) and ZD (Zero Defects). The small group goals coincide with company goals and the maturity of small activities can be evaluated. Top management must inspire the small group activities.

6. **TPM – Development Program – Implementing Total Productive Maintenance.**

➢ Seiichi Nakajima

An introduction to TPM explains the course from Preventive Maintenance (PM) to Total Productivity Maintenance (TPM). It presents the history of TPM arrange by its era, approach and major events. Is evident the importance of the equipment effectiveness for TPM success. TPM starts by eliminating the six major losses and take action against breakdowns. Some case studies are comprehended; improving setup and adjustment, eliminating adjustment, improving unavoidable adjustments and correcting blockages are some of the themes attained. Operation and Maintenance are inseparable; and for TPM autonomous maintenance is required. Basic equipment conditions must be established like cleaning and cleanliness, activities that encourage equipment cleaning, promoting lubrication and promoting proper bolting. General inspections must be accomplished and autonomous inspection training and education. Finally some keys for Workplace Management are offered. Maintenance Activities ought to be standardized. There are some types of Standards: *Equipment design standards, Equipment performance standards* or *equipment specifications, equipment materials procurement standards* and *Test run and acceptance standards.* Some types of Maintenance Plans exits like Annual, Monthly, Weekly Maintenance Plans and Major Maintenance Project Plans; each of them are explain in details. It's important to keep these records because its maintenance records reveal the quality of a factory's maintenance. Spare parts must be controlled.

Maintenance Prevention (MP) is a significant aspect of project engineering that serves as the interface between project and maintenance engineering. Problems occur at startup stage and subsequent operations. The role of MP is to minimize these problems, however, by designing safeguards and countermeasures into the equipment before its fabrication and installation. To carry out TPM activities a company needs personnel with strong maintenance and equipment-related skills. Basically the operator conducts equipment, periodically checks it, scans the instrument panel and revises its lubrication.

TPM has a promotional structure that overlaps small groups, integrating organizational and small group improvement activity. Many companies had developed their own terminology and procedures for conducting small groups, categorized by QC circles and ZD groups. The group goals coincide with the company goals, this conducts to High Morale and High Morale conducts to High Profits.

7. **TPM –Total Productive Maintenance.**

   - Yoshikazu Takahashi and Takashi Osada

Equipment is the major means of production in a factory; management must be equipment-oriented. TPM requirements are

(1) Creating equipment with the greatest possible overall efficiency
(2) Establishing a total PM that takes into account the entire life of the equipment
(3) Maintaining motivation by utilizing small-group activities
(4) Covering the planning, utilization, and maintenance of the equipment
(5) Company wide participation, ranging from top executives to individual workers.

Analysis of:

- Current Realities of PM Activities and Management Standards
- The Relationship Between:
  - Production and Equipment

- Quality and Equipment
- Cost and Equipment
- Delivery and Equipment
- Equipment and Safety, Environment, and Pollution Factors
- Morale and Equipment

Key considerations to the fundamental of maintenance systematization:

(1) Sufficient weight should be given to simplifying the elements of the system

(2) The reliability of the components and the whole system

(3) System design and determination of its objectives

(4) When a system fails to function

(5) The system and its action standards

(6) The key to an efficient system

Self-Initiated Maintenance. Instead of limiting its scope to simple daily service maintenance, the workers' self-initiated maintenance program should aim at improving the productivity level and product quality by teaching the mechanics of the equipment.

8. **Facilities Planning**

➢ Tompkins/White/Bozer/Frazelle/Tanchoco/Trevino

This book refers to TPM as *Total Productive Maintenance team, which* had a tremendous role in contemporary manufacturing. Their main objective is to increase machine uptime and product quality. It entails TPM in the implementation of effective corrective, preventive, predictive, and autonomous maintenance programs, setup time reduction, tool management, visual management and housekeeping, and spare parts inventory control. The TPM implementation impacts material handling, storage alternatives, to move and store tools, preventive maintenance materials, testing equipment, and spare parts. It impacts workstation layout, too.

9. **Como instalar con éxito el TPM en su empresa.**

➢ Edward H. Hartmann

It includes a definition of TPM and presents TPEM, Total Productive Equipment Management. The equipment must improve until its highest level of performance and must be maintain on its highest level of performance and availability. Complete the new equipment with a precise level of high performance and low cost of life cycle. The goals of TPM are:

- Zero breakdowns – zero time of not expected stops
- Zero defects –zero defect products cause by equipment
- Zero loss of velocity of equipment

TPM-AM: Autonomous Maintenance- participation of operators in activities of small groups.

TPM-PM: Preventive and Predictive Maintenance – a total system of maintenance preventive for the whole life of the equipment

TPM- EM: Equipment Improvements – maximizing the effectiveness of the equipment.

10. **TPM in Process Industries.**

➢ Tokutaro Suzuki

Why TPM is so popular?

Significant Tangible Results

Transforming the plant environment

Transforming the Plant Workers

TPM Development

TPM is normally implemented in four phases (preparation, introduction, implementation and consolidation), which are usually broken into 12 steps.

Step	**Key Point**
Preparation	
1. Formally announce decision to introduce TPM	Top management announcement at in-house meeting; publish company magazine
2. Conduct TPM introductory education and publicity campaign	• Senior management: group training for specific management levels • General employees: slide show
3. Create a TPM promotion organization	• Steering committee and specialist subcommittees • TPM Promotion Office
4. Establish basic TPM policy and goals	• Set baselines and targets • Forecast effects
5. Draft a master plan for implementing TPM	From preparation stage to application for PM Prize
Introduction	
6. Kick off TPM initiative	Invite customers, affiliates, and subcontractors
Implementation	
7. Build a corporate constitution designed to maximize production effectiveness.	Pursue the ultimate in production effectiveness
7-1 Conduct focused improvements activities	Project-team activities and workplace small-group activities
7-2 Establish a deploy autonomous maintenance program	Proceed step-by-step, with audits and pass certificates at each step
7-3 Implemented planned maintenance program	• Corrective Maintenance • Shutdown Maintenance • Predictive Maintenance
7-4 Conduct operation and maintenance skills training	Group education for group leaders who then pass on their training to members
8. Build an early management system for new products and equipment	Develop products that are easy to use and equipment that is easy to use
9. Built a quality maintenance system	Establish, maintain, and control conditions for zero defects.
10. Build an effective administration and support system	• Increase production-support effectiveness • Improve and streamline administrative functions and office environments
11. Develop a system for managing health, safety and the environment	Assure an accident-free, pollution-free environment
Consolidation	
12. Sustain full TPM implementation and raise levels	• Apply for PM Prize Aim to even higher targets

Summary:

The prime objectives of TPM program are to Maximize the equipment effectiveness and productivity, and eliminate all machine losses; Create a sense of ownership in equipment operators trough a program of training and involvement and; Promote continuous improvement trough small-group activities involving production, engineering, and maintenance personnel.

TPM application must have *equipment* at the center of thoughts. In this case study the *equipment* is the Motor Bogie. And some questions must be answer: How to improve its availability? How it can contribute to energy and resource conservation and hence to reduction in overall costs? & How this can be achieved through maintenance-oriented plant management as part of a total system approach?

TPM had great benefits in industries, some are: Eliminate accelerated deterioration of the equipment, tries o eliminate failures and defects, operate profitably (no breakdowns), assured quality of the product, improve equipment availability, met delivery times, eliminate environmental and safety hazards, etc. The benefits aren't only in the industry; the effects are on the employees, too. Some of this benefits include pride, Improvement on abilities, more work satisfaction, less rotation, improvement on team-work, improvement on work environment, etc.

Different books were studied to develop a methodology. Additionally conversations with some entities [15 &16] has being established:

- Marjorie Mictil – Caracas Metro, Venezuela – This metro is well known because of the efficiency in its operations and maintenance facilities. The successfulness of Caracas' Metro has been the Preventive Maintenance (PM) given to the parts and process (this is only one component of TPM).
- José Colón – Intel, Las Piedras – This Company is distinguished for its good maintenance program, and José Colón is the Industrial Engineer in charge of this program.

II. TPM Organization – this is a dedicated personnel. These people are under the organizational structure of Siemens Transit Team Puerto Rico and UPR/MIT Professional Development Program. They are and will be helping with the TPM development and correct implementation. They are:

- ✓ Ron Mackay – Manager, Transportation
  - Siemens Transit Team Puerto Rico
  - Alternate Concepts, Inc.
- ✓ Lorraine Z. Lerman - Manager, Technology Transfer
  - Siemens Transit Team Puerto Rico
  - Soza & Company, LTD.
- ✓ Christian Fonta - Manager, Vehicle
  - Siemens Transit Team Puerto Rico
  - Siemens Transportation Partnership Puerto Rico
- ✓ John Morales -Siemens Transit Team Puerto Rico
- ✓ Sonia Bartolomei – UPR Faculty
  - Industrial Engineering Department
- ✓ Daniel Dávila – UPR Student
  - Mechanical Engineering Department
- ✓ Obed Santos – UPR Student
  - Mechanical Engineering Department
- ✓ Sara Rullán – UPR Graduate Student
  - Industrial Engineering Department

At this level, the students are gathering all possible information, the Siemens Transit Team is providing this information and the professor is driving the project for its good implementation.

III. Project Analysis. Various meeting were performed, and the same conclusion arises: Focus on the Motor Bogie. Some general information was given of the Tren Urbano vehicle, included in Appendix 2. However this information is form 1997 and specifies that it is steel in design. Specific information must be gathered from the TU bogie to continue with the TPM implementation.

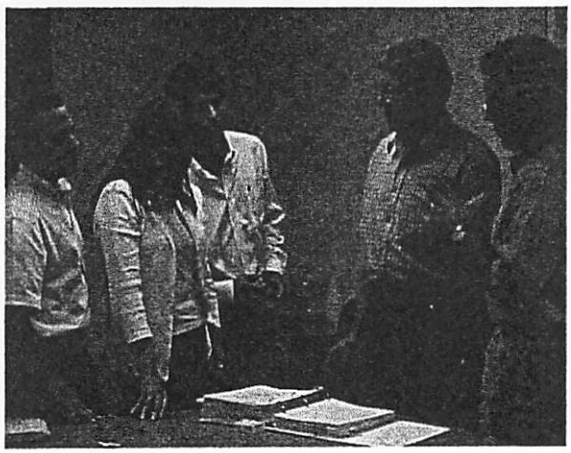
Activities:

The following table shows some of the activities done during the semester:

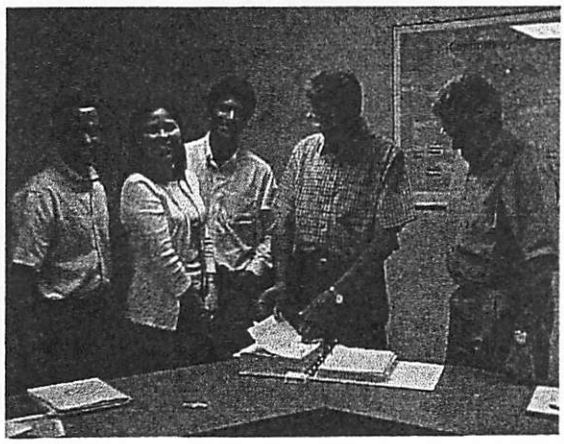
Date – Hour Location	Activities
August 21, 2000 – 10:30 am Industrial Engineering	Meeting with Sonia Bartolomei y Talía. Project themes discussions
August 24, 2000 – 10:30 am Civil Engineering	**First Meeting** Research needs
August 28, 2000 – 10:30 am Industrial Engineering	Meeting with Sonia Bartolomei y Talía. Project themes discussions
August 29, 2000 – 10:30 am Civil Engineering	Benjamín Colucci **Meeting**
September 5, 2000 – 10:30 am Civil Engineering	Proposal Presentation Workshop
Every Monday – 10:30 am Industrial Engineering	Meeting with Sonia Bartolomei
September 5, 2000 – 10:30 am Civil Engineering	Tren Urbano Meeting

September 8-10, 2000 Library	Literature Research
September 11, 2000 – 10:30 am Industrial Engineering	Meeting with Sonia Bartolomei & Iván Baigés
September 12, 2000 – 10:30 am Industrial Engineering	Tren Urbano Meeting
September 12, 2000 – 3:40-6:00 pm Civil Engineering	Meeting with Benjamín Colucci
September 28, 2000 – 6:00 am – 2:00pm Storage & Maintenance Facilities, Güaynabo, PR	Lorraine Lerman, Ron Mackay, Christian Fonta, Iván Baigés, Obed Santos and Daniel Dávila
September 25 – 30, 2000 Industrial Engineering	Proposal Preparation
September 30, 2000 Chemical Engineering	Research Proposal Presentations
October 2-6, 2000.	Proposal Changes
October 17, 2000. – 10:30 am Physics	How to Prepare a Poster Presentation

November 5, 2000 – 1-6:00 pm IBM Building, Rio Piedras	Lorraine Lerman, Ron Mackay, Christian Fonta, Joe Ferretti, Obed Santos and Daniel Dávila



Picture 1



Picture 2

November 14, 2000. – 10:30 am Civil Engineering	Graduate Students Presentations
Conversations by e-mail with:	Freya Toledo, Lorraine Lerman, Christian Fonta, Néstor Brea, John Morales, Ron Mackay

Future Activities:

The activities that will be performed are part of the complete TPM execution. Some parts of these activities were covered, however they are not complete.

- *Determine the performance and conditions of the actual equipment that will be used. The types of equipment, description, designer and location; data of the equipment. Include reference to a list of parts for replacement and drawings. Reference to manuals.*
    - Designer: Siemens
    - Location: The bogies were constructed in Austria and then brought to Sacramento, California.
    - Missing information is under search.
- *An effective system of PM must be used to maintain the equipment to its highest level of required performance. Inspection of Equipment. Maintaining equipment clean. Determine replenishment time. Study the steps required on the replenishment process. Assign a degree showing how critical it is. *Utilize the best two resources: maintenance and operators.* At this level some Preventive Maintenance plus experience is needed. Ronald Mackay is helping in this matter as some other literature source [2 &10]

➢ *Construct a list of PM Check. It would include the number of the equipment, the list of standardized tasks, show frequency (daily, weekly or based on lectures), show estimated necessary time, and*

assign the operator or the specialist and Running/Detention of Equipment.

- *Develop work orders based on predictive maintenance. Including number of equipment, list of tasks, list of materials, a plan or program can be necessary, assign skills, and show estimated necessary time.*
- *Develop PM routes. Only for the preventive maintenance of the maintenance department. Organize maintenance checklist or work-orders by area, kind of equipment and ability. Show frequency. Show estimated time for each route.*
- *Develop a PM program. Combine different PM cycles to do on the same day and then reduced production interruptions.*

  - In this activity the adequate time must be found. Meaning that the equipment must be revised at a practical amount of time and not every hour or every day because a preventive maintenance can carry out to a high unnecessary cost maintenance. Locate the critical and uncritical parts to establish this amount of time where the process will be dedicate to maintenance.

- *Maintain an equipment history. Number of the equipment, Parts and Labor costs; includes all the maintenance, repair and work done of PM (including equipment development and corrections completed). This history will help on feedback for adjusting the PM and to help the others TPM teams in activities of equipment advancement.*

  With a Good History of the equipment some of this data can be gathered in the future when the S&M facilities will be working:

  - *The equipment performance can be evaluated throughout time.*
  - *Repetitive failures can be detected.*
  - *Total Annual Costs for repair can be established and compare with the replenishment costs.*

- *Adjust its efforts on PM*
- *Develop a good focal point on the equipment development.*

➢ *PM Reports. PM Accomplishment, Costs, Evolution, Utilization and Productivity. Breakdown or Stop hours (by equipment) and if this follows a tendency. Finally the Middle Time between Failure (MTBF).*

Additionally to TPM, some communication has been established, Caracas Metro and Intel, PR. The purpose of this communication is to known their maintenance strategy, be familiar with it and applied it to TU. Some cities that had a good maintenance program were mentioned on the meetings. These cities were catalogued as good examples, those were: Japan, Portland, San Diego, Los Angeles, Atlanta, Miami and Washington, D. C.

Preliminary Recommendations

The selected case study: Motor Bogie includes the Suspension System, Friction Brake System and other electrical systems that are really common in mechanical environment. A useful recommendation is that at the time the design for a motor bogie is done; use the same design for future trains. Some other features may be change if the purpose is not to make same models. However if a standardized model is done for every train the operation and maintenance can be develop earlier without problem. Additionally some past experience can be helpful for not doing the same mistakes.

The vehicles that are in the S&M Facilities aren't the exact models that will be used. A helpful recommendation is to bring to the area the ones that will be used; then the operations and maintenance strategies can be established in a better way with a more accurate model.

Expected Results.

Companies practicing TPM achieve startling results, particularly reducing equipment breakdowns, minimizing idling and minor stops, lessening quality defects and claims, trimming labor and costs, shrinking inventory, cutting accidents, and promoting employee involvement.

All the benefits mentioned could be apply to *TU;* given the adequate maintenance:

- The equipment will not deteriorate = the cost of the requirement of new equipment will decrease.
- Eliminate failures = the occurrence of accidents will decrease
- Eliminates defects = no loss of time and resources, all the production is effective.
- Operate profitably = all this reductions and increases leads to profits for TU

A complete document will include each of the steps mentioned in the Methodology and Future Activities parts. This document will offer all the indicated benefits given at the beginning of this part. This document or formula will help as a model for different parts and processes that will be present in the Operations & Maintenance Facilities. With the theory, the process analysis and the experience a perfect a productive program of maintenance will contribute to the success of *Tren Urbano's Operations and Maintenance Yards* and at the same time to the TU entity at all.

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Appendix 1

Appendix 2

Table 3.1

Summary of Features of the Tren Urbano Vehicle

Vehicle concept:	Married pair, steel wheel on steel rail, for high level boarding, 2 powered trucks per car
Dimensions [L x W x H]:	23.0 m x 3.1 m x 3.8 m (per car)
Rail Gauge:	1,435 mm
Maximum grade:	6%
Minimum curve radius:	150 m (main-line), 80 m (yard)
Weight:	36.3 mt (per car)
Passenger capacity (per car):	72 (seated), 181 total (per car, at 4 passengers per m^2, excluding the operator)
Line voltage:	750 V DC, 3rd rail
Propulsion system:	AC propulsion (IGBT), regeneration capability
Power rating:	4 * 125 kW (per car)
Maximum speed:	100 km/h
Maximum acceleration:	1.35 m/s^2
Maximum deceleration:	-1.35 m/s^2 (service), -1.55 m/s^2 (emergency)
Friction brake system:	Pneumatic, spring-applied parking brakes
Suspension system:	Primary – chevron elastomeric springs Secondary – air springs
Doors:	6 double leaf pocket sliding doors (per car) 2 end doors (per car)

3.2. SIGNALS AND TRAIN CONTROL SYSTEMS

3.2.1. Automatic Train Control System

Tren Urbano trains are designed to be operated automatically. The Automatic Train Control (ATC) system will be comprised of safety proven components that have been used in existing Siemens/MATRA signal systems designs.

The purpose of the ATC system is to control, direct and coordinate all functional operations of the automated Tren Urbano trains. These operations include:

- Automatic speed regulation
- Train berthing
- Vehicle door opening
- Signal system communications
- Automatic route selection
- Automatic train protection

The ATC system will be divided into three functional groups which are described below.

- **The Automatic Train Operation** (ATO) system regulates the service performance and operations of the trains with a high level of efficiency. For example, the ATO allows for the smooth acceleration/deceleration of the trains and their exact alignment to boarding platforms in stations.
- **The Automatic Train Protection** (ATP) system enforces safe and reliable train operations. The system continuously tracks individual train locations and regularly recalculates safe operating parameters. Any train detected to be in violation of safe operating conditions or to be otherwise in conflict with the system parameters is immediately issued a maximum braking command.
- **The Automatic Train Supervision** (ATS) system allows the Operations Control Center (OCC) to view the real time conditions of the system regarding schedule adherence, train routing, electrification systems status and support/emergency systems status. The OCC will also have the ability to take control of the automatic system whenever an abnormality occurs.

3.2.2. Train Control – Yard Operations

A yard control system (YCS) will be provided that will allow controlled train movements in and out of the yard interlocking system. The YCS, which includes redundant programmable controllers for standby availability, will be designed utilizing fail-safe vital design principles with non-vital hardware.

3.2.3. Wayside Signals

Wayside signals are provided as a visual reference for the train operator to determine current operating conditions. In automatic mode, they serve only as a

reference since all commands are controlled systemically. However, during manual operations, the wayside signals function as the principle means of speed control to provide safe operation.

3.3. *COMMUNICATIONS EQUIPMENT*

A number of different communications systems will serve the Tren Urbano system, providing management, emergency, video, data and routine communications for operating staff and system patrons. TABLE 3.2 portrays the communications system components by principal function. The following section provides an overview and a short description of each component.

Table 3.2

Tren Urbano Communications Systems Overview

Major Components of Tren Urbano Communications Systems				
Element	Principal User			
	System Support	Operations Control Center	Operators	Passengers
Fiber optic transmission lines	X			
Computer Based Dispatch System (CBDS)		X		
Remote Terminal Units	X			
Cable Distribution	X			
Communications Bungalows	X			
Seismic Event Detection		X		
Station Supervisory Control		X		
Closed Circuit TV		X		
Public Address		x	X	X
On-Car communications		X	X	X
Variable Message Signs		X	X	X
Telephones & Intercoms		X	X	X

3.3.1. Fiber Optic Transmission

The voice and data communications backbone for all interrelated sub-systems is a Fiber Optic Transmission System. Fiber optic technology provides the capacity for vast amounts of data transmission throughout the system and beyond. Sub-systems served by the fiber optic lines include SCADA (the fixed facility monitoring system), fare collection, the reader board, public address, radio, train control, video and telephone.

3.3.2. Computer Based Dispatch System

Central control and coordination of all communications systems is carried out by a Computer Based Dispatch System (CBDS). The CBDS consists of two major components, the PCx Communications Control System and the Multi-channel Logging Recorder. The PCx Communications Control System is a redundant non-blocking audio switch matrix capable of controlling numerous lines and consoles. Line types include radio, telephone, PBX, fiber optic, microwave, intercom and telephone circuits. In the Tren Urbano application, the PCx is capable of integrating the control of 35 lines and 13 consoles. The matrix is capable of managing a total of 160 devices (lines and consoles). The Multi-channel Logging Recorder provides a tapped audio archive of all communications passing through the Communications Control Console to the OCC Dispatchers.

3.3.3. Remote Terminal Units

The Remote Terminal Units provide for supervisory monitoring and control of conditions and devices remotely located from the Operations Control Center. Examples of remote sites integrated into this system are Traction Power Substations, Bulk Power Substations, Station Facility Electrical Substations, Fare collection equipment, Fire and Intrusion Alarm equipment, Ventilation equipment, and Station equipment such as mechanical services, elevators, escalators, communications station equipment and security equipment.

3.3.4. Cable Distribution System

The cables required for the various communications systems are organized on Main Distribution Frames (MDFs) at the Operations Control Center Equipment Room, at each of the 13 communications bungalows and at the Rio Piedras Communications Room. The MDFs provide logical, orderly points for the interconnection and intraconnection of system components.

3.3.5. Communications Bungalows

At each station, communications systems are centralized in a structure referred to as a Communications Bungalow. This design places all key components in one location for ease of installation, service and security monitoring. Bungalows are manufactured to withstand appropriate climactic and seismic conditions.

- Traction and power distribution
- Train control
- Communications
- Rail vehicles
- Security and intrusion equipment
- Elevators and escalators
- Automatic fire detection and suppression equipment
- CCTV system

APPENDIX E contains a schematic of the current design concept for the Operations Control Center. This design is incorporating technical and ergonomic considerations in order to develop a modern, efficient, working OCC which provides the highest degree of control and supervision to the overall operation of the Tren Urbano system.

3.5. *TRACTION POWER*

3.5.1. Traction Power

Within the Tren Urbano system, traction power will be delivered to the cars via a third rail system. The third rail will be a composite rail consisting of aluminum strips fastened to the webbing of conventionally designed 85 lb ASCE steel rail. The steel rail will provide the height, wear surface, and base; the aluminum strip will provide high conductivity.

3.5.2. Power Distribution

Power will be delivered to electrical substations throughout the system. Each substation will be housed in a self-supporting transportable sheet steel building designed for outdoor installation. The building will allow for means of ingress and egress for personnel and support equipment. Equipment doors and accesses will be provided for major overhaul and equipment replacement. Substations will be designed to operate unattended with provisions for manual override and manual operations.

All equipment will be installed, wired and tested in a factory environment. The substation buildings will be delivered to the site and, with minimum assembly, will be ready for connection to the AC and DC distribution systems as well as the grounding system. To the extent possible, substations will be identical, facilitating routine maintenance and service.

3.6. *MAINTENANCE AND STORAGE FACILITY*

The maintenance and storage facility, located near Las Lomas Station, will contain all necessary equipment for scheduled and unscheduled maintenance, storage and any other mechanical requirements. APPENDIX F contains the most current diagram of the Maintenance and Storage Facility yard and building layout, which is still in the process of being designed.

3.6.1. Buildings

A set of specialized buildings will provide locations for each of the key functional areas of the facility. In addition, the track storage areas will provide storage for all of the Tren Urbano rail vehicles. Each of the Maintenance and Storage Facility buildings will be constructed to meet all fire and safety standards. A listing of the buildings and a brief description of their function is provided below:

- **Operations & Administration Building**

  The principle structure of the seven in the MSF complex, the Operations and Administration Building serves as the organizational center of all Tren Urbano's activities. All of the system's administrative functions will be headquartered at this location, as well as all of the maintenance activities associated with the vehicles. Additionally, a Customer Service Center will be included, the System Security Office, a Technical Training Center, and the Operations Control Center will all be housed in this facility.

  Most of the other buildings within the complex will serve to support the Operations and Administration Building.

- **Maintenance of Way Building**

  This building will support all the ancillary maintenance activities not directly related to the vehicle. All maintenance of way functions will be supported here, including track, train control, buildings, and A/C and D/C power. Additionally, all non-revenue vehicles and equipment will be maintained within the facility and will be stored on the tracks immediately adjacent to the building.

- **Guardhouse**

  This structure is located at the only entrance to the complex and will house the guard charged with controlling access and local security. It is outfitted with CCTV monitoring equipment for the entire complex, radio, and telecommunications systems and access control equipment controlling the three lanes of roadway access to the facility.

- **Traction Power Substation Building**

  The high-voltage power equipment and distribution network for the maintenance complex is contained within this facility. The incoming high-voltage is transformed to the locally required levels, rectified, and distributed through a series of high-speed circuit breakers to the various user locations inside the complex.

- **Secure Storage Buildings**

  Two such buildings are to be provided: one immediately adjacent to the main building, the other in the area near the Maintenance of Way facility. These structures will provide secure storage for items which are more volatile in nature and which could present a hazard.

- **Hazardous Material Building**

  This building is designed to safely store, on a temporary basis, all materials specifically classified as hazardous materials.

3.6.2. Equipment and Work Areas

Equipment for all scheduled and unscheduled vehicle, track and system maintenance will be stored in and dispatched from the Maintenance and Storage Yard and Facilities. APPENDIX G contains a listing of the anticipated equipment, and non-revenue vehicles which will be procured in support of the operation and maintenance of the Tren Urbano system.

The Maintenance Areas within the Maintenance/Storage Facility is organized into the following work-group areas:

- Periodic Vehicle Inspections and Unscheduled Vehicle Maintenance
- Wheel Truing
- Vehicle Component Replacement Heavy Maintenance
- Support Shops
  - Component Repair Shop
  - Electrical Equipment Shop
  - Air Conditioning Shop
  - Truck Shop
  - Machine Shop
  - Parts Cleaning Facility
  - Component Repair and Support Area
  - Welding Shop
  - Wheel and Axle Shop
  - Battery Shop

APPENDIX F contains floor-plan of the Maintenance Area, currently under design.

3.7. STATIONS

All Tren Urbano stations are being designed to function as transportation nodes for the areas they serve. Each station's design is intended to accommodate travelers accessing the station in various modes, including pedestrian, bicycle, automobile, and transfers from buses and publicos. All station designs will comply fully with the Americans with Disabilities Act (ADA) and the National Fire Protection Association (NFPA) guidelines.

A brief description of each station is provided below. APPENDIX H contains current diagrams depicting the location of each station within its surrounding community.

Elevators	2
Escalators	3
Nearest Major Roads	Fernandez Juncos Ave./Ponce de Leon Ave.

3.8. *MANAGEMENT INFORMATION SYSTEMS*

The Management Information and Decision Support System (MIDSS) for Tren Urbano will support the total organizational operation and maintenance effort. The MIDSS for Tren Urbano will use existing, service-proven systems in conjunction with maintenance-management and document-control systems that will be tailored specifically for the Tren Urbano vehicles and documents. With appropriate interfaces, these software products will form a comprehensive, seamless information system to support record keeping, performance monitoring, and decision making throughout the organization.

3.8.1. Goals of MIDSS System

The goals for the MIDSS system include the following:

- Provide daily, monthly, and annual statistics on:
  - ridership
  - vehicle hours and kilometers
  - maintenance activities
  - financial results
  - power consumption;
- Support performance monitoring in the areas of:
  - reliability of vehicles and service
  - safety and security
  - adherence to maintenance and cleaning schedules
  - cleanliness of facilities and vehicles
  - reliability of escalators, elevators, and fare equipment
  - responsiveness to failures
  - responsiveness to customer telephone lines;
- Facilitate quality control and quality assurance;
- Provide efficient processing of all information necessary to carry out the administrative and accounting functions of the organization;
- Enhance productivity and efficiency in operations and maintenance;
- Support information-based decision making throughout Tren Urbano and the Authority;
- Provide all reports necessary for the Authority and for submittal to the Federal Transit Administration;

3.8.2. Technical Approach

The MIDSS at Tren Urbano will consist of a set of interfaced modules, which will be customized to meet the specific requirements of the Contract and as is needed to meet the particular operating environment at Tren Urbano. Each of the major modules included in the MIDSS system is described in the following paragraphs.

3.8.2.1. Operations Management and Performance Reporting Module

The Operations Management and Performance Reporting System (OMPRS) will take data from other subsystems and produce clear, concise reports. These reports will supply all of the service and performance statistics required by the contract. They will also provide a wealth of information to support management decisions.

Specifically, the OMPRS will read data from sources such as the following:

- the train control system
- pull out and pull back times
- trip arrival, departure, running and dwell times
- the SCADA system
- the maintenance management system - both schedules and work completed
- the incident reporting module for (transportation, security and maintenance data)
- ridership and revenue data from fare collection equipment
- vehicle schedule files
- manpower schedule files

The data captured by the OMPRS will be used to produce performance monitoring statistics and reports in full compliance with Contract requirements. The performance statistics to be produced through this subsystem will include: daily ridership, vehicle hours, vehicle kilometers, preventive and corrective maintenance data, total person hours, electric power usage, daily and monthly on-time performance, daily and monthly missed trips, mean distance between failures, and other operating statistics as may be required.

3.8.2.2. Incident Reporting Module

The purposes of the Incident Reporting System will be two fold: 1) to provide rapid notification to the personnel responsible for responding to abnormal occurrences of all types, and 2) to facilitate the tracking, analyses, and identification of trends in the performance of the O&M organizational divisions, including security, cleaning, maintenance and transportation operations.

The Incident Reporting Module will record the following information about any event: time and location, delay/malfunction type, cause, delay duration, mechanical/structural unit affected, description, notifications

The Incident Reporting System will interface with the Maintenance Management Module and the OMPRS. Within the maintenance module (both vehicle maintenance and systems maintenance), the record of an "incident" occurring in the operation of a vehicle or out in the system will be fed back to the vehicle or system maintenance history file, so that accurate trends of vehicle or system performance can be generated. The design of the incident reporting module will most likely include sub-categories of recorded events such as vehicle failures in service, security incidents, cleaning and station maintenance events, and passenger and employee injury.

3.8.2.3. Maintenance Management System

The Maintenance Management System (MMS) will support all aspects of vehicle and facility maintenance, including:

- Scheduling and tracking maintenance activities
- Tracking components
- Tracking vehicle histories
- Issuing work orders
- Calculating costs
- Tracking statistics on the performance of repairs and maintenance other maintenance actions.

This system will be utilized for the maintenance of the vehicles, facilities, systems, and structures in the Tren Urbano system. The system will be designed such that each element in the Tren Urbano system is uniquely identified, and the maintenance, repair, and failure history of each element is uniquely stored. The maintenance system will also permit inspection intervals to be input, enabling managers to display the upcoming preventive maintenance schedules.

3.8.2.4. Inventory Control Module

All materials removed from the stockroom at the vehicle maintenance facility and the maintenance building will be properly accounted for by the assignment of a work order number. The work order number will provide a link to the Maintenance Management System for the purpose of tracking the costs of repairs and the performance of materials.

For parts and supplies, the inventory system will provide records of parts inventory and usage to assist in monitoring, control, and procurement of repair parts and other maintenance-related items. The system will automatically track balances and serial numbers and use exception reporting to provide advance warning of overstock or out-of-stock conditions.

The inventory control system will be fully integrated with the purchasing system. A wide array of reports will be available from this system.

3.8.2.5. Administrative and Financial Modules

The financial management component of the MIDSS will consist of standard financial management software packages as well as custom modifications necessary for the particular needs and requirements of Tren Urbano and the Authority. The required subsystems will include:

- Purchasing
- Accounts Payable
- Accounts Receivable
- Payroll/Timekeeping and Human Resources
- General Ledger

3.8.2.6. General Microcomputer Tools

In addition to the specialized applications for financial management, maintenance management, and management reporting, general microcomputer tools will be provided to support day-to-day operations of the management and maintenance offices.

These tools will include word processing, spreadsheet analysis, productivity tools, electronic mail, and database tools.

3.8.2.7. Messaging and Electronic Mail

Any user anywhere will be able to exchange mail between all other users on all systems. In addition, electronic mail can act as a transport for specific applications, such as work flow automation, and resource scheduling. The messaging strategy would allow a separation of message transport engine and message presentation, for optimum performance and manageability.

second train will use the crossover after leaving the station, crossing over to the right track for travel back in the direction of Bayamon.

4.4. *YARD OPERATIONS*

As depicted in APPENDIX F, the yard will consist of seven (7) storage tracks, able to store 82 vehicles. The storage tracks are located to the north of the maintenance facility, in parallel to each other. Connections exist at the end of each track which lead into and through the car cleaning tracks and the main maintenance tracks.

All yard activities which result in the movement of vehicles both in the yard and between the mainline and the yard will be supervised and directed by OCC.

4.4.1. Introduction and Removal of Vehicles from Service

Prior to the start of daily a.m. service, OCC will be provided with information from the Maintenance Division concerning which vehicles are available for revenue service. OCC will utilize this information--in addition to any information concerning the make-up of train consists--to direct the make-up of train consists for a.m. pullouts. As outlined in Section 2.7, the initial operating scenario will require the makeup of 14, 4-car train consists per peak period. OCC personnel will be responsible for verifying that sufficient train consists are constructed to meet the daily schedule requirements, and will coordinate the placement of each of these consists on the storage track locations which will best meet the order of pullouts. OCC will coordinate with line supervisory personnel in the assignment of train consists to operators in order to meet the schedule of daily pull-outs.

After being assigned a train consist, the operator will move the train from its storage track location out to the mainline under the direction of OCC personnel, in accordance with established procedures, the scheduled timetable, and the train control/signal system.

At the end of the assigned revenue service run, each operator will move his/her train into the yard according to the directions provided by OCC. OCC will be responsible for determining, in coordination with the maintenance division, which trains will be routed through the vehicle wash track, through the maintenance shop, or into the storage yard.

Based upon the initial service schedule contained in APPENDIX C, the following chart depicts the anticipated times of yard pullouts and pullbacks per weekday, per hour:

Table 4.1

Weekday Yard Activity and Storage Levels

TIME INTERVAL	NUMBER OF TRAINS PULLING OUT	NUMBER OF TRAINS PULLING BACK	TRAIN CONSIST SIZE (CARS)	CARS IN YARD/SHOP FROM FLEET OF 64 AT END OF TIME INTERVAL
4:00 - 4:59 a.m.	3	0	4	52
5:00 - 5:59 a.m.	4	0	4	36
6:00 - 6:59 a.m.	7	0	4	8
8:00 - 8:59 a.m.	0	4	4	24
9:00 - 9:59 a.m.	0	3	4	36
10:00 - 10:59 a.m.	0	2	4	44
11:00 - 11:59 a.m.	0	0	0	44
12:00 - 12:59 p.m.	0	0	0	44
1:00 - 1:59 p.m.	0	0	0	44
2:00 - 2:59 p.m.	2	0	4	36
3:00 - 3:59 p.m.	7	0	4	8
4:00 - 4:59 p.m.	0	0	0	8
5:00 - 5:59 p.m.	0	0	0	8
6:00 - 6:59 p.m.	0	7	4	36
7:00 - 7:59 p.m.	0	0	0	36
8:00 - 8:59 p.m.	0	2	4	44
9:00 - 9:59 p.m.	0	0	0	44
10:00 - 10:59 p.m.	0	0	0	44
11:00 - 11:59 p.m.	0	0	0	44
12:00 - 12:59 a.m.	0	0	0	44
1:00 - 1:59 a.m.	0	5	4	64

8. MAINTENANCE OPERATIONS

The maintenance philosophy for the Tren Urbano Project will be to optimize the mix of in-house and contract maintenance activities so that the system is safely and efficiently maintained in the most cost-effective manner. Maintenance personnel will carry out a controlled maintenance program that will encompass both preventive and corrective maintenance activities.

Preventive maintenance includes tasks scheduled on a routine periodic basis, and is designed to prolong equipment life and minimize overall system maintenance costs, reduce in-service failures, and assure safety and dependability. Corrective maintenance consists of troubleshooting, repairing failed equipment, and returning the equipment to service. The goal of the overall maintenance plan for the Tren Urbano system will be to identify the most desirable balance between preventive and corrective actions.

8.1. MAINTENANCE-OF-WAY, FACILITIES, AND SYSTEMS

The overall maintenance strategy will combine a blend of in-house and contracted services. In the case of the maintenance of way, facilities and systems, this concept will include close coordination with a number of subcontractors. Routine fixed facility functions such as track and light building maintenance will be performed by in-house personnel. All other facilities and systems maintenance functions will be provided through contracts. Separate contracts will be engaged for such services as maintenance and repair of: air conditioning and ventilation, fare collection equipment, elevators and escalators, and landscaping. A comprehensive contract will be put in place to address Systems requirements. One contractor will be engaged to provide the services to maintain train control/signals, AC and traction power, communications, safety and security systems. Combining these highly technical functions offers a coordinated and economical approach toward achieving the goal of fully functional, well maintained systems.

Facilities maintenance encompasses the preventive and corrective elements for all fixed facilities including, track, right-of-way, buildings, structures, elevators, escalators, air conditioning, ventilation, revenue equipment and landscaping. With the exception of light maintenance of track, buildings, and structures, these functions will all be performed as contracted services, utilizing local firms.

8.1.1. Track and Guideway Maintenance

Within the track maintenance program, the functions will be separated between preventive and corrective elements. For the most part, the track system is unavailable during normal service hours. Accordingly, the majority of the preventive maintenance program will be confined to the relatively short period of time between normal service hours. However, a corrective maintenance crew will be assigned and available to perform any corrective actions which may be required.

The track system will be inspected daily by qualified personnel who will observe the structure from the operator's cab of a scheduled train. In addition, daily walking inspection will be conducted, by segment, to ensure that the whole system is visually inspected at least once per week. During these inspections,

such items as rail wear, gauge, turnout points, fasteners and rail joints will be examined in detail to ensure compliance with acceptable railroad standards.

Minor track maintenance, including hand tamping and alignment, will be performed by in-house personnel. Major rehabilitative track work will be contracted out, including such activities as rail re-profiling, ultrasonic rail inspection, and corrosion control.

Guideways, bridges, tunnels, and support structures will be inspected annually to verify stability and strength. Detailed records will be collected and maintained on all structures for each inspection. All major structural repair work will be performed by contracted service.

8.1.2. Buildings and Grounds

A program will be established to assure that all stations, buildings, structures and grounds are clean, well maintained and operated safely. Station cleaning, landscape maintenance, major graffiti removal, pest control, trash and waste disposal, major building equipment repair, escalators and elevators maintenance and repair, ventilation, and revenue equipment maintenance will be contracted to firms possessing the skill and expertise to perform these tasks as specified. In-house maintenance personnel will carry out minor repairs and continually conduct routine inspections and will be available to respond to any eventuality should the need arise.

The cleaning of all stations and facilities will be subcontracted to a local cleaning firm. This contract will include responsibility for complete cleaning and maintenance of the Tren Urbano stations. The cleaning contractor will furnish complete cleaning on a daily basis for all stations including all rooms, station attendants' booths, signs, glass, ceilings, walls, columns, pipes, platforms, waiting areas, benches, lighting fixtures, stairs, passageways, entrances, restrooms, handrails, offices, lobbies, turnstiles, fences, deckboards of escalators, interior and exterior of elevator cabs, pits or track areas, planted areas, parking areas and plazas, pitwalls, emergency exits in stations, safety lines, headhouses, kiosks, and the operations and maintenance facility. The contractor shall also clean and replace all extinguished station lighting, and shall be responsible for periodic cleaning of small system buildings such as bungalows and substations.

Cleaning services will be required seven days a week. It will be the responsibility of the cleaning contractor to assure that the stations are free of dust, debris, stickers, posters, decals, unauthorized signs, and graffiti at all times, as well as gum and stains on platforms, walkways, steps, and escalator floor plates. Stations will be washed nightly and steam cleaned monthly. Station washing will be done only at night, minimizing the inconvenience to passengers.

8.1.3. Power, Train Control/Signals, Electrical, Communications, Safety and Security Systems

The proper maintenance of a transit system's Electrical Power, Train Control/Signals, Communications, Safety, and Security systems is vital to the overall safety and reliable on-time performance of an operating system. Any

malfunction in these systems can compromise the public and/or system safety, as well as create delays in operations.

The Siemens Team will contract with Lord-Mass (LM), a Joint Venture of Lord Electric Company of Puerto Rico and Mass Electric Construction Company of Boston Mass for the maintenance and repair of all signals, power, communications, fare collection, safety, and security systems in the Tren Urbano System. Maintenance of these systems will require an ongoing program of testing, repairs, emergency responses, preventive maintenance, and reporting, as required, to comply with the mandated levels of performance.

The maintenance activities within the Lord-Mass subcontract will be departmentalized into three areas that will provide primary maintenance responsibility for specific aspects of the facility's systems. A description of these departments and their responsibilities are as follows:

8.1.3.1. Electrical Maintenance

This department will be responsible for the overall reliability of the electrical power distribution, which is vital to operations of the system in providing motive power, train control, communications, and passenger security and comfort. The systems to be maintained by this area include the 13.2KV AC and 750V DC traction power substations and distribution systems, UPS backup power systems, emergency power systems, along with facilities electrical systems including stations, operations, and public/parking area power and lighting.

The maintenance responsibilities of this area will include regular scheduled maintenance, repairs, and emergency response. In addition to the maintenance and well being of the power distribution system, this department will be responsible for the continued maintenance of all lighting systems, and the serviceability of standard electrical equipment. Preventive maintenance includes routine observations, inspections, and tests to maintain established operating parameters. Preventive maintenance test and inspections are vital in eliminating, or at least reducing, service interruptions and will consist of set routines and practices to be carried out at varying time intervals (daily, weekly, monthly, or annually.) A comprehensive test and inspection program will be developed to assure adequate preventive maintenance intervals are complied with.

The personnel required for the Electrical Power maintenance portion of the program will be provided on a full time basis, with the exception of the Emergency Generator Technician, who will be provided on an on-call basis. Services of the Emergency Generator Technician, when required, will be provided complete with necessary vehicles, tools, and equipment, for the proper maintenance, repairs, and modifications to the equipment as required.

8.1.3.2. Train Control/Signal Maintenance

This area will be responsible for maintaining train control/signals, wayside system and cab signal interface components, including preventive maintenance, repairs, mandated testing and inspections, and emergency response requirements. Under the signal maintenance program, the system is divided into maintenance territories, containing track circuits, switches, AFO's, TWC's, and signal lights. An experienced signal maintainer, will be assigned to each territory, and headquartered at the maintenance facility. Each maintainer will be assigned a fully stocked and tooled radio equipped utility body truck which will serve as his principal place of work. Each signal maintainer will be responsible for the inspection, maintenance, minor repairs, and emergency response requirements within his assigned territory. Additionally, each maintainer will provide backup emergency response and minor repair assistance to other maintainers as required, and directed by management. All regulatory rules in effect for signal test and inspection frequencies will be complied with.

8.1.3.3. Communications, Safety, and Security Maintenance

This group will be responsible for maintaining all communications, safety, and security systems, including preventive maintenance, repairs, scheduled testing and inspections, and emergency response requirements. The personnel required for the communications, safety and security portion of the project will be provided on a full time basis, with the exception of Fiber Optics Technicians, who will be provided on an on-call basis. Services of Fiber Optics Technicians, when required, will be provided complete with necessary vehicles, tools, and equipment, for the proper maintenance, repairs, and modifications to the fiber optics system, including testing, splicing, termination, and repair of all fiber optics cable incorporated in the communication system. Preventive maintenance will include routine observations, inspections, and tests to maintain established operating parameters. A comprehensive test and inspection program will be developed taking into account all system suppler and/or equipment manufactures suggested maintenance practices and schedules.

The systems to be maintained by this area are the primary communications and safety systems including passenger station communications, station data gathering facilities, train control data gathering, and radio communications between the operating and maintenance personnel, data radio, microwave radio, fiber optics carrier transmission, PBAX, UHF, VHF, and ATCS Radios, Plant Telephone, Fire Alarm, Intrusion, CCTV, and Public Address systems.

8.1.3.4. System Manager

An overall Systems Manager will be assigned to the project with responsibility for directing the maintenance and testing activities for all systems to be maintained under the Lord-Mass Subcontract. The

Systems Manager will be responsible for, and will provide on a continuing basis, necessary supervision, office management, record keeping, training, field safety, safety training, and quality control to assure that proper maintenance, repairs, and modifications are performed to the complete power distribution, train signal, communications, safety, and security systems.

The Systems Manager will be responsible for ensuring that all Lord-Mass employees working on the Tren Urbano System are well trained self starters, capable of performing the mandated inspections and services, along with normal and extra ordinary maintenance, all within management determined sections of the system, and in compliance with regulations and work rules. In addition to working a scheduled 40 hour week, maintainers will be on 24 hour call from the operations dispatcher, and will respond to all emergency service needs.

8.2. VEHICLE MAINTENANCE

The vehicle maintenance program for the Tren Urbano vehicles will consist of preventive maintenance activities, including daily servicing and inspections and scheduled preventive maintenance inspections at designated time or mileage intervals. In addition, as needed, corrective actions and component overhauls will be undertaken. Additional details about the various vehicle maintenance components are included as follows:

8.2.1. Daily Service and Inspection

Each vehicle operated in revenue service will be inspected daily, prior to being placed in revenue service. Each vehicle will also be cleaned on a daily basis, after each trip in revenue service and at the end of the service day.

8.2.1.1. Car Cleaning

Car exterior washing will be conducted daily. Typically, vehicles to be washed at the end of their service day will be driven through the automated vehicle washer prior to being laid-up for the night. Each car's interior will be thoroughly cleaned and purged of all stains, spills and graffiti. All trash will be removed, interior windows will be washed, and any defects observed will be noted for attention before re-entering revenue service the following day. Heavier interior cleaning will be accomplished, at minimum, on a bi-monthly basis. In addition to this daily cleaning in the maintenance shop, vehicle cleaners will be assigned to the stations at each end of the line during all revenue service hours. The function of these cleaners will be to quickly remove debris that may have been left during a train's journey from the other terminus.

8.2.1.2. Pre-Departure Safety Test and Inspection

All vehicles, prior to being placed into revenue service, will be subjected to a pre-departure safety inspection ("circle check") by operating personnel. This inspection will consist of a visual inspection of all major exposed components to verify that there are no obvious defects. A pre-

departure test will also be performed to verify that all major equipment, including all safety related systems, are fully functional.

8.2.2. Scheduled Maintenance Program

Preventive maintenance of vehicles will be performed on the basis of kilometers of service or hours of operation as recommended by the manufacturer initially and modified with experience as needed. For purposes of illustration, the following schedule is shown:

- Type 1 PM Inspection: 10,000 kms (approximately, monthly)
- Type 2 PM Inspection: 60,000 kms (approximately, bi-annually)
- Type 3 PM Inspection: 120,000 kms (approximately, annually)

Additionally, time or kilometer based overhauls of components will be routinely carried out, again based on manufacturers recommendations and modified on the basis of experience gained over time. Specific vehicle inspection and repair forms and procedures designed particularly for the vehicle will be developed. These forms will be used at the shop level for all preventive maintenance activities. The information from each form (as well as information about any corrective maintenance), will be input into the MIDSS system, leading to a comprehensive database of vehicle and major component maintenance histories and activities.

8.2.3. Unscheduled Maintenance

The servicing and inspection process may uncover defects in the vehicles. Where possible, these defects will be corrected by replacement of components. Repairs in the inspection bays will be limited to those which are simple and can be accomplished in a short period of time in order to keep the inspection bay free. Should the problem require an extended period or specialized equipment, the repair will be scheduled and the individual car removed to the heavy maintenance area equipped with the required equipment. In addition, unscheduled maintenance to vehicles may be required because of equipment failure or accident. On-line troubleshooting will be performed by operations personnel as well as maintenance personnel. The primary objective will be to remove the vehicle from the system and to restore service to the public as soon as practicable. If an accident occurs, maintenance personnel will be dispatched to assess how the vehicle(s) can be safely moved. In the case of derailments, maintenance personnel will be dispatched with re-railing equipment to replace the vehicle on the track.

8.2.4. Overhauls

The program for component overhaul embraces the concept that there is no coincidental point in the useful life of a transit vehicle where all sub-assemblies require revitalization simultaneously. A program will be established which details a specific overhaul cycle for each particular vehicle sub-assembly. Thus, individual components would be continuously renewed on precisely defined, performance driven schedules assuring peak vehicle performance and avoiding

the more costly larger scale vehicle related programs. This program will be based initially upon manufacturers recommendations, and subsequently optimized over time, as more experience is gained on the vehicle and its operating performance.

8.3. MAINTENANCE EQUIPMENT

APPENDIX G contains a list of the maintenance equipment which will be procured for the support of maintenance activities in the Operations and Maintenance period.

8.4. WARRANTY

Warranty procedures to be followed by maintenance personnel will be developed prior to the delivery of equipment and spare parts. The procedures will outline the actions which are necessary in order to assure that all items under warranty are being properly tracked. Failure trend information from the MMS will be used to determine causes of failures and to evaluate the impact upon warranties.