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Perception on Preventive Maintenance in Civil Engineering Laboratory

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ABSTRACT

Preventive maintenance as a component of facilities maintenance system is to maximize the useful life of all laboratory system. This descriptive study aimed to assess the effectiveness of the preventive maintenance program of Civil Engineering Department in FEATI University. The individual respondents were drawn from the engineering students and faculty members, and employees of the respondent institution. These are the respondents who used the civil engineering laboratory. It utilized validated researcher-made questionnaire, unstructured interview, and documentary analysis as its data gathering instruments. The data gathered were treated using frequency and percentage count.

Keywords**:** CE laboratory materials engineering management, maintenance management, maintenance planning, safety precautions

1. INTRODUCTION

With the complex nature of the equipment used today in the universities, the dependence of operating personnel on maintenance has become a greater part of the total cost of operations, and the maintenance services. They should as well be keen in determining when equipment must be overhauled or replaced. Department heads and supervisors must realize that they must maintain equipment adhering to professional standards in a cost effective manner while providing operation with the maximum availability.

Many discussions of maintenance relegate preventive maintenance to a small role, for example. "Preventive maintenance is defined in the maintenance management audit as periodically scheduled work on selected equipment, usually dynamic to provide for required inspection, lubrication, and adjustment" [1,3].

However, a broader application of the term "preventive maintenance" is desirable to avoid fragmentation of the maintenance system into multiple sub-components routine, preventive, regular, scheduled, recurring and other variations of maintenance each has their own definition.

Maintenance Management System (MMS) necessary for the universities. It is inevitable that the university must adapt to the new system of management [4].

It simplifies and facilitates operation in the civil engineering laboratory and engineering section and develop comprehensive equipment maintenance and replacement costs to maximize the availability of the production units; extend the useful life of the equipment by improved maintenance methods, ensure at all times the operational readiness of all equipment required for emergency use such as enable equipment to be maintained and operated safely and in compliance with statutory regulations.

Therefore, this study will greatly as to the present wealth of knowledge on Maintenance Management System that can serve as a basis for further research in engineering management among graduates in engineering and management

2. MAINTENANCE AND CALIBRATION OF LABORATORY EQUIPMENT

Preventive maintenance (PM) is the practice of maintaining equipment on a regular schedule based on elapsed time or meter readings. The intent of PM is to "prevent" maintenance problems or failures before they take place by following a routine and comprehensive maintenance procedures. The goal is to achieve fewer, shorter, and more predictable outages. Some advantages of PM are [8]: 1). It is predictable, making budgeting, planning, and resource leveling possible. 2). When properly practiced, it generally prevents most major problems, thus reducing forced outages, "reactive maintenance," and maintenance costs. 3). It assures managers that equipment is being maintained. 4). It is easily understood and justified. PM does have some drawbacks such as 1). It is time-consuming and resource intensive. 2). It does not consider actual equipment condition when scheduling or performing the maintenance. 3). It can cause problems in equipment in addition to solving them (e.g., damaging seals, stripping threads).

Despite these drawbacks, PM has proven generally reliable in the past and is still the core of most maintenance programs. PM traditionally has been the standard maintenance practice in reclamation. The maintenance recommendations are based on a PM philosophy and should be considered as "baseline" practices to be used when managing a maintenance program. However, care should be taken in applying PM recommendations. Wholesale implementation of PM recommendations without considering equipment criticality or equipment condition may result in a workload that is too large to achieve. This could result in important equipment not receiving needed maintenance, which defeats the purpose of PM management. To mitigate this problem, maintenance managers may choose to apply a consciously chosen, effectively implemented, and properly documented reliability-centered maintenance (RCM) program [9,10]. Whether utilizing a PM, RCM, or condition-based maintenance (CBM) program, or a combination of these, scheduled maintenance should be the primary focus of the in-house maintenance staff. This will reduce reactive (emergency and corrective) maintenance. Scheduled maintenance should have a higher priority than special projects and should be the number one priority.

RCM programs are gaining in popularity and have been piloted in a few Reclamation power facilities with good results [11]. The goal of these programs is to provide the appropriate amount of maintenance at the right time to prevent forced outages while at the same time eliminating unnecessary maintenance. Implemented properly, RCM can eliminate some of the drawbacks of PM and may result in a more streamlined, efficient maintenance program. RCM seems very attractive in times of diminishing funding, scarcity of skilled maintenance staff, and the pressure to "stay online" due to electric utility industry deregulation. Some features of RCM are [12] 1). It may be labor intensive and time-consuming to set up initially. 2). It may require additional monitoring of quantities, like temperature and vibration, to be effective. This may mean new monitoring equipment with its own PM or more human monitoring with multiple inspections. 3). It may result in a "run-to-failure" or deferred maintenance philosophy for some equipment which may cause concern for some staff and managers. It may require initial and later revisions to the maintenance schedule in a "trial-and-error" fashion depending on the success of the initial maintenance schedule and equipment condition. 4). It should result in a more manageable maintenance workload focused on the most important equipment. RCM is not an excuse to move to a "breakdown maintenance" philosophy or to eliminate critical PM in the name of reducing maintenance staff/ funding. However, to mitigate problems associated with a PM program, maintenance managers may choose to apply a consciously chosen, effectively implemented, and properly documented RCM program [13].

Proper maintenance and periodic calibration of laboratory equipment is a very important aspect of the entire quality control (QC) system itself for any construction project. QC labs for civil engineering experiments primarily have three types of equipment's [14]: a) Inspection equipment's e.g., theodolites, levels etc. b) Testing equipment's e.g., electric ovens, concrete cube or cylinder crushing machine etc. and c) Measuring equipment's e.g., digital or ordinary balance, digital or ordinary calipers, jars etc. The terms equipment, apparatus, and instruments actually differ to some extent in meanings even though one is used in place of the other quite often. In here, the term equipment is used for all purposes for the sake of simplicity.

Obviously, not all elements of a laboratory need serious maintenance and not all of these need calibration either. For example, cube molds need neither serious maintenance nor any calibration. While most need at least some maintenance, only a select few call for periodic calibration. The simple rule is that adjustable equipment's only sought calibration. A cube mound or a sieve can't or need not be adjusted and hence no calibration for them. An oven, a concrete cube or cylinder crushing machine etc. can be adjusted and hence need calibration for obvious reasons.

A unique identification number may be permanently assigned to each item in a laboratory and the item should be labeled with the number. This will facilitate preparing a list of all items in the lab identified by their respective assigned numbers Cleary mentioning whether calibration is required or not, the date of the last calibration, if yes, the date of next calibration due etc. for easy reference [15].

Usually, periodic calibration of such equipment's is performed as recommended by their manufacturers or as suggested by quality assurance plan. Calibration of all important items should be done by approved independent agency or third party. All valid calibration certificates are maintained as quality documents for future reference. Third-party calibration of survey equipment is normally prescribed annually. However, internal calibration should be done at lesser intervals. All items requiring calibration should have stickers/labels indicating up-to-date calibration status [16]. An up-to-date calibration register needs to be maintained showing calibration status of the items. It needs to show clear details like frequency of calibration, external and internal calibration dates, next calibration due, relevant specifications or manufacturer's recommendation, calibration document details etc.

Non-adjustable items are physically inspected upon delivery as well as periodically. Quality documents on these items should be insisted from the manufacturer or supplier wherever required and maintained as quality records. It is appropriate to maintain separate registers for surveying equipment and other items especially, electrical and mechanical (E & M) equipment. The formats of these register or the general process etc. are almost the same for all equipment [17].

Even though the schedules of calibration or checks for different categories of equipment are more or less the same, the type of calibration may vary from item to item. Also, a single item may require calibration of several aspects of it. For example, a theodolite calls for calibration of its line of collimation, centering, vertical and horizontal angles etc. Hence, proper records showing results of all calibration or tests must be maintained mentioning all important details including rectification done, if any. Quality records concerning maintenance and calibration of quality control laboratory equipment include Manufacturer's quality documents, registers of the survey, E & M equipment's, schedule of calibration, calibration tags/labels, calibration certificates etc.

Maintenance activities fall into three general categories [18]. These are routine maintenance, maintenance testing, and diagnostic testing. In routine maintenance, activities are conducted while equipment and systems are in service. These activities are predictable and can be scheduled and budgeted. Generally, these are the activities scheduled on a time-based or meter-based schedule derived from preventive or predictive maintenance strategies. Some examples are visual inspections, cleaning, functional tests, measurement of operating quantities, lubrication, oil tests, and governor maintenance. In maintenance testing, activities that are involve using test equipment to assess condition in an offline state. These activities are predictable and can be scheduled and budgeted. They may be scheduled on a time or meter basis but may be planned to coincide with scheduled equipment outages. Since these activities are predictable, some offices consider them "routine maintenance" or "preventive maintenance." Some examples are governor alignments and balanced and unbalanced gate testing. Diagnostic testing involves activities using test equipment to assess the condition of equipment after unusual events, such as equipment failure/ repair/replacement or when equipment deterioration is suspected. These activities are not predictable and cannot be scheduled because they are required after a forced outage. Each office must budget for these events. Some examples are governor troubleshooting, unit balancing, and vibration testing.

The maintenance recordkeeping system must be kept current so that a complete maintenance history of each piece of equipment is available at all times. This is important for planning and conducting an ongoing maintenance program and provides documentation needed. Regular maintenance and emergency maintenance must be well documented, as should special work done during overhauls and replacement. The availability of up-to-date drawings to management and maintenance staff is extremely important. Accurate drawings are very important to ongoing maintenance, testing, and new construction; but they also are essential during emergencies for troubleshooting. In addition, accurate drawings are important to the continued safety of the staff working on the equipment.

3. LABORATORY EXPERIMENT PREPARATIONS

Technical Services staffs are responsible for ensuring that all laboratory equipment, used by the undergraduate, is maintained regularly and functioning properly for its intended use [5,19]. Civil engineering laboratory equipment is to be inspected on a regular basis and proper preventive maintenance should be performed to ensure it is always in a good working condition. Prior to conduct an experiment, inspect all the required apparatus carefully to ensure that no hazards are apparent (e.g., electrical wires are connected properly without a short circuit, no cracks are found on valves and pipe components, safety shields are properly installed, etc.).

Technical Services staffs and Laboratory Supervisors are responsible for inspecting Personal Protective Equipment (PPE) required for each experiment to ensure that they are available and ready to be used. Experiments are not to be run without the proper safety equipment in place [20].

For new or unfamiliar equipment, the student should check with their supervisor, instructor, or technical services staffs to see if the apparatus or machine exceeds the power rating of the laboratory (i.e. current rating of the apparatus/machine exceeds the fuse rating of the laboratory). Technical Services staffs should be informed before a high-power apparatus or machine is run. Due to the power ratings and restrictions of the building, it may be necessary to schedule the operation of this equipment to off-peak consumption times to avoid power overloads or failures. Prior to conduct an experiment, the individual running the experiment, should inform everyone present about the experiment, equipment, required safety procedures, emergency procedures, emergency exits, and PPE to be worn during the experiment. It is the responsibility of the individual running the experiment and equipment to ensure that those present are kept safe and that hazards minimized [8,21].

The experiment should cease immediately if a concern, unsafe condition, or violation occurs and not to be resumed until the situation is corrected. Technical Services staffs are responsible for ensuring that all equipment is properly identified and that safety protocols and procedures are maintained and available to all laboratory users. All materials must be properly labeled and stored [3, 21]. It is the users' responsibility to ensure that they are properly trained before using the unfamiliar material. It is the user's supervisor's responsibility to ensure that users are properly trained on material use and documentation of this fact is to be maintained.

4. HISTORY OF CIVIL ENGINEERING DEPARTMENT IN FEATI UNIVERSITY

The FEATI University (Far East Air Transport Incorporated University) was established in 1946 in Santa Cruz, Manila with the opening of the Department of Civil Engineering to meet the country's and for top caliber Civil Engineers that will spearhead in nation building.

They develop education and research programs that focus on the societal needs and career objective [2,5].

Since its inception in 1946, the department has been headed by Filipino scientist Gregorio Zara (1946-50), Civil Defence Administrator Alfredo Eugenio (1951-56), Highway Commissioner Rodolfo Maslog (1957-70), Engineer Augusto Sta Maria (1971-88), Engineer Dioscoro Quiblat (1989-94), Dr. Tomas Ganiron Jr (1995-08), Engineer Gerardo Garcia (2008-09) and Dr. Amelia Marquez (2010-2013) [2,6].

In 1951, the department started on the four-year curriculum in its course headed by Engineer Alfredo Eugenio.

Under the administration of Engineer Rodolfo Maslog, large quantities of equipment for the various laboratories, particularly for structural engineering laboratory, surveying laboratory, material testing laboratory, hydraulics laboratory and soil mechanics laboratory were purchased. The improvised construction of Hydraulic Synthetic Machine and Ambuklao dam model were completed in 1959.

The later replaced Engineer Augusto Sta Maria who took over the newly completed Hydraulic Laboratory. In 1972, Engineer Sta Maria had been commissioned to design the Civil Engineering Laboratory equipment in which the improvised rain-gauge model was immediately constructed for model testing.

Rehabilitation of civil engineering laboratories still continued in 1989, particularly the hydraulic laboratory and material testing laboratory headed by Engineer Dioscoro Quiblat. Manuals in Engineering Drawing courses were authored by Engineer Quiblat.

In 1995, Dr. Tomas Ganiron Jr assumed the Civil Engineering department head following the petition to migrate in Australia of Engineer Quiblat.

The Civil Engineering course had become popular and it needed to be weaved away from geodetic engineering courses. In 1999, Dr. Ganiron Jr introduced the new Civil Engineering curriculum and courses such as Construction Project Management-Primavera, On Job Training and Senior Design Project was made in the curriculum. He also authored such manuals in Construction & Material Testing, Fluid Mechanics, Hydraulics and Soil Mechanics courses intended for the use of civil engineering students. The courses were approved by the Curriculum committees in 2007 [2]. The establishment of the course at FEATI seems to be consistent with a global trend where civil engineering departments seek to infuse innovations and technologies perspective to their traditional civil engineering curricula. Obviously, this development arose out of the worldwide recognition that the developers of civil engineering projects need not only the traditional skills of physical or operational design or construction but also the skills to evaluate alternative designs, construction processes, and operational/maintenance techniques on the basis of a wide range of "external" performance measures. The mandatory offering of the 2008 BSCE curriculum has called for the expansion and update of knowledge in the field by those who are tasked to teach the course.

After Dr. Ganiron Jr decided to leave the department because of his petition to migrate in New Zealand, Engineer Gerardo Garcia worked on the acquisition of books and laboratory equipment for civil engineering students, and the improvement of the civil engineering laboratory facilities.

In 2009, Engineer Garcia resigned as department head to migrate in Canada. He was replaced by Dr. Amelia Marquez. The new civil engineering rooms for laboratories were constructed under the term of Dr. Marquez.

The availability of new laboratory instruments, equipment and machines presented the department with new research opportunities. The department established cooperative initiatives with local industries. Students obtained the opportunity to work with local industry through their senior design projects. Keeping pace with the national trend, the department saw more computer and simulation applications in its curriculum. CE Students are exposed to industry standard software like STAAD Pro, ETABS, and AutoCAD [7].

The department enjoys research expertise in the field of construction engineering, geotechnical engineering, highway and transportation engineering, structural engineering and water resources engineering. The department is ready to face the challenges of the new millennium and is poised to emerge as a premiere civil engineering department in the country.

5. RESEARCH DESIGN AND INSTRUMENTATION

5. 1. Research Design

The study used the inferential and descriptive methods of research with questionnaires as the main data-gathering instrument. The subjects of this study were the engineering students and faculty members, and employees of FEATI University located in Sta Cruz, Manila. These are the respondents who used the civil engineering laboratory. The table below describes the number of population and the samples that were used in this study

Table 1. Sample of Respondents

Respondents	Populations	Samples	Percentage
Student /Employee	100	30	30
Faculty	50	30	60
Total	150	60	40

5. 2. Instrumentation

The major tool for data gathering was the questionnaire. The questionnaire was divided into 3 parts. The first part dwelt on the personal profile of the respondents. The second part focused on the level of effectiveness of the program. The third part signifies the level of conformance of FEATI University to the criteria set

The final draft of the questionnaire was pretested by an initial group of 7 prospective respondents and their comments and suggestions were incorporated in the final draft. The initial group, however, was not included in the respondent group whom the final questionnaire was administered.

To further ensure the validity of the questionnaire, the researcher read various books regarding institutional relations and corporate values in order to develop appropriate questions and choices. Likewise, the researcher also repeatedly went to the prospective respondents and asked them about the possible questions that could be asked in relation to the research topic.

The researcher also used the unstructured interview. It was administered to the respondents to further clarify the opinions reflected in the questionnaire.

The Statistical Package for Social science (SPSS) software was used to generate statistical data to arrive these findings and conclusions. A Statistical test of percentage values was used to enable the researcher to give the appropriate response to the problem.

6. SAMPLE CHARACTERISTICS

6. 1. Age

Table 2 shows that out of 60 respondents in this study, 51.7% fell within the category of 21to 30 years old., 28.3% were 31 to 40 , and 5% were 20 years and below, and 51-60 years old. Most of the respondents are in the middle age.

Table 2. Profile of Respondents Based on Age

Age Range	Faculty		Student/Employee		Total	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
20 years & below	0	0.0	3	10.0	3	5.0
21-30	4	13.3	27	90.0	31	51.7
31-40	17	56.7	0	0.0	17	28.3
41-50	6	20.0	0	0.0	6	10.0
51-60	3	10.0	0	0.0	3	5.0
Total	30	100.0	30	100.0	60	100.0

6. 2. Gender

In Table 3, 51 or 85% were male and 9 or 15% were female. Apparently, respondents are dominated by the male since the majority of students, employees and faculties have the desire for the independence and freedom from the command of others are typically a masculine trait.

Table 3. Profile of Respondents Based on Gender

Gender	Faculty		Student/Employee		Total	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Male	27	90.0	24	80.0	51	85.0

Female	3	10.0	6	20.0	9	15.0
Total	30	100.0	30	30.0	60	100.0

6. 3. Educational Attainment

The majority of the faculties shown in table 4, 43.3% obtained the master degree. and 30%, obtained a doctoral degree. Very few faculty, (26.7%) earned only a bachelor degree. Overall, the faculties appear to be highly educated holding a master degree beyond a bachelor degree.

Table 4. Profile of Faculty Respondents Based on Educational Attainment

Educational Attainment	Frequency	Percentage
Bachelor Degree	8	26.7
Master Degree	13	43.3
Doctoral Degree	9	30.0
Total	30	100.0

7. EFFECTIVENESS OF PREVENTIVE MAINTENANCE PROGRAM

7. 1. Service

Table 5 shows the perception of the respondents on effectiveness or perceive maintenance program based on services. Respondents expected to improve on existing product or service is 95% which is very high. Respondents' perception that is expected to develop a new product is 45% (student/employee) and 40%(faculty) . On the statement "Improved on existing product or service", 85% of the respondents responded "expected" 90% of the respondents chose expected to adopt new technologies.

The data implies that the respondents did not feel the impact of the existence of a program on product development, improvement of existing and adoption of new technology

Table 5. Percentage of Respondents on Effectiveness of Preventive Maintenance Program Based on Service

Statements	Faculty			Student/Employee		
	Resulted	Expected	Neither	Resulted	Expected	Neither
1. Improved on existing product or service	3.0	45,0	0.0	0.0	50	0.0

2. Developed a new product or service	0.0	40	10.0	5.0	45.0	0.0
3. Improved an existing process	2.0	43.33	3.33	5.0	41.67	3.33
4. Adopted new technologies	1.67	45.0	3.33	5.0	45.0	0.0

7. 2 Workforce

Table 6 describes the perceptions of respondents on the effectiveness of preventive maintenance program based on the workforce. Respondents expected to improve the relationship with existing customers is 95% which is very high. Respondents' perception that is expected to satisfy the customers is 95% .On the statement "Improved employee skills", 70% of the respondents responded "expected" 80% of the respondents chose increased employee salaries. Respondents expected to increase in management school earnings is 90% .On the statement "Greater Flexibility and/or team satisfaction employees", 75% of the respondents responded "expected" ".

The data implies that the level of respondent position has the same similar view on the level of effectiveness of the preventive maintenance program of the respondent in FEATI University based on the workforce.

Table 6. Percentage of Respondents on Effectiveness of Preventive Maintenance Program Based on Workforce

Statements	Faculty			Student/Employee		
	Resulted	Expected	Neither	Resulted	Expected	Neither
1. Improved relationship with existing customers	10.0	40.0	0.0	3.33	45.0	1.67
2.Satisfaction of customers	3.33	40.0	1.67	19.0	45.0	0.0
3. Improved employee skills	10.0	30.0	0.0	20.0	40.0	0.0
4. Improved management skills	7.0	40.0	3.0	5.0	45.0	0.0
5. Increased in employee salaries	3.33	40.0	1.67	10.0	40.0	0.0
6. Increased in management/school earnings	0.0	40.0	10.0	0.0	50.0	0.0

7. Greater flexibility and/or team orientation of employees	7.0	40.0	3.0	4.0	35.0	11.0

8. SUMMARY OF FINDINGS

It can be seen from the information provided that quality assurance in engineering education is primary importance globally. Accreditation of engineering programs is necessary for the mutual recognition of program globally and for public accountability.

Student respondents perceived that the preventive maintenance program is expected to improve productivity, increased attention to quality, greater use of computers, reduced breakdowns of machines and reduced downtime due to repair works and consumption of spare parts.

The following statements were as “Conforming”: 1) Evidence of the use of design fabrication and installation specifications that prescribe industry standards of practices; 2) Documented process for conferring the procured equipment conforms to applicable design and material applications.

Perceived as non-conforming by faculty members are the following statements: 1) Evidence that applicable equipment quality control; 2) Evidence that operating and maintenance procedures for equipment address any applicable assurance issues as requested by the design.

Expected of the preventive maintenance program are the satisfaction of customers, improved relationship with existing customers, improved employee skills, increase in employee salaries, greater flexibility and/or team orientation of employees.

9. CONCLUSIONS

The effectiveness of the program will remain to be seen as the perception respondents on its impact to service, to the workforce, on utilization, on the assurance of quality and insurance of mechanical integrity of equipment are still “expected”. The respondents were of the opinion that the philosophy, organization, reporting, monitoring and control and the preventive maintenance program are all “conforming” to standards. Both respondents expect the effectiveness of the preventive maintenance program in terms of implementation

Personnel involved directly in the implementation program be trained and should have sufficient experience to manage its proper implementation. Top management should strictly monitor the implementation of the program. Standards should be enforced in monitoring the program. Annual review of the program should be a part of the employee’s job description. Accountability in the implementation of the program should be pinpointed.

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Biography

Dr. Tomas U. Ganiron Jr received the doctorate degree in Construction Management in Adamson University (Philippines), and subsequently received his Master of Civil Engineering major in Highway and Transportation Engineering at Dela Salle University (Philippines). He is a registered Civil Engineer in the Philippines and Professional Engineer in New Zealand. Aside from having more than two decades of experience as a professor, department head and researcher in the Philippines and New Zealand, Dr. Ganiron Jr is a practicing Civil and Construction Engineer for 20 years, having designed and supervised projects such as sewerage and waterworks structures, ports and marine structures, water treatment plant, and structural buildings and bridges. He is also very active in other professional groups like Railway Technical Society of Australasia and Australian Institute of Geoscientists where he became the committee of Scientific Research. He has received the Outstanding Civil Engineer in the field of Education given by the Philippine Media Association Inc. (1996), ASTM Award CA Hogentogler (2008) awarded by International Professional Engineers New Zealand and Plaque of Recognition as Outstanding Researcher (2013) given by Qassim University-College of Engineering.

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