A web-based cost benefit analysis method for predictive maintenance

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1. ABSTRACT

Accurate and believable cost benefit analysis is critical to the success of predictive maintenance programs. Currently, it is up to each organization to determine internal costs, develop an analysis method, and convince their management of the validity of their results. Unfortunately, these figures are frequently dismissed as biased or inflated, and do not result in the intended support from management for the program. This paper discusses a method of enabling a universal generic cost benefit calculator that can be accessed from the Internet. The calculator prompts the user for information about the industry, equipment type, and PdM costs. The database provides statistical means for the given industry and equipment types, and allows the user to make modifications. The calculator also prompts the user for a number of scenarios for the identified anomaly, and requires that they be rated as a percentage of probability of occurrence. The calculator then performs the Cost Benefit Analysis, which the user can print or save to file. The CBA also gives statistical information about how this analysis falls among the statistical distribution of analyses specific to that industry or equipment type. The calculator does not query the user for identifying information such as Company Name or Individual Name. The inputted data is used for statistical purposes only, thus preserving the confidential nature of company information. The resulting CBA is a non-biased document that can be used as an independent tool to assess program success.

Keywords: Cost benefit analysis, CBA, predictive maintenance, financial justification.

2. INTRODUCTION

From the first day that the expensive equipment of a diagnostic technology is purchased, or the contract to outsource the service is signed, the individuals responsible for overseeing the program constantly fight the battle to justify the expenditure of funds and commitment of manpower. Even in those cases where an organization enjoys the sponsorship of a key individual in upper management, the day soon comes when that sponsor has moved on, and the new management begins to question every aspect of the organization.

Unlike capital production equipment, or raw materials used in production, the benefits of applying diagnostic technologies to monitor the production process are not easily assessed for financial impact. In order to generate product, it can be determined that a site must be acquired or designated, that production equipment must be purchased and installed, and that the raw materials must be obtained and processed. The “direct” costs include the production manpower and the raw materials. The “indirect” costs, commonly referred to as overhead, include the sunk costs of facility construction and the labor and part costs of process machinery maintenance. Not only is a predictive maintenance program an indirect cost, but the effects on the per-unit cost of production are extremely difficult to ascertain.

Managers are trained and educated to use existing economic and accounting models to assess production efficiencies and costs to make sound management decisions. These decisions are nearly always made in the context of the known or anticipated effect on the per-unit production cost or impact on overhead costs. It is not logical to take on increased indirect costs, unless it can be shown that there is an anticipated reduction in direct costs, or increase in productivity. Predictive maintenance programs are no exception, and are subject to the same scrutiny as other financial management decisions. It is not enough to “wow” people with the diagnostic capabilities of technology, unless it can be shown to provide the needed return on investment.

Investment or commitment to predictive maintenance programs can begin in a number of ways. Sometimes the vision or insight of key company personnel is enough to convince management of the need to invest in diagnostic technologies. Other times, the response to chronic failures or other production problems initiates the search for technology-based solutions. Whichever the initiating event, it is inevitable that in the long-term the commitment to the program is likely to be challenged, and the challenge will always include the need to financially justify the manpower and funding invested in the program. At these times it is critical for the predictive maintenance program manager to be able to provide reliable, believable financial data on the impact of the use of diagnostic technologies.

3. DEVELOPING THE METHOD

The first and most significant aspect of building this proposed web-based system is the calculation method used to arrive at the cost-benefit for a predictive maintenance program. The calculation method includes three areas: program costs, direct cost savings, and indirect cost savings. By calculating the total cost savings from direct and indirect sources, and subtracting the program costs, we arrive at the net benefit for the investment in the program. This is a common method of expressing the cost benefit of a predictive maintenance program, by tallying the net benefit and reporting it on an annual basis, to influence company funding to maintain or possibly expand the program.[1] These calculations can also be used to illustrate financial benefit in more traditional managerial accounting parameters such as IRR (internal rate of return) and cost-benefit ratio. Most importantly, the company management must believe that the methods used to calculate these values are based on sound, conservative (not exaggerated), and accurate data inputs and algorithms.

1. Calculating program costs

While program costs may seem to be a fairly straightforward calculation, there are hidden costs that must be accounted for in order for this to be accurate. Program costs typically include equipment, supplies, manpower and overhead. The equipment costs are either rental fees or a depreciated capital investment schedule. Rental fees are a simple direct cost, for the time period of payment. The capital investment in equipment must be depreciated on a typical useful-life time period to arrive at an annual or monthly cost. Supplies, both consumable and durable, must be calculated on anticipated usage and consumption rates. Manpower can be the most easily accounted for, but one must be careful to allow for all hours in support of the program, and they must be calculated using the company’s internal manpower costs for the job classification of the individuals working in the program. Finally, overhead, which is the most difficult to account for, must include support services, supplies, and other benefits provided to the program which would otherwise be utilized productively elsewhere.

The calculation of program costs is the first step in establishing the cost benefit model, and is usually reduced to a time period that corresponds to the reporting period for management. If management requires a quarterly accounting of the program benefit, then the program costs are calculated for a typical 3-month period, and included in the cost benefit analysis. A query of expenses and costs are used to create an average monthly expenditure for maintaining the program, factoring out seasonal variations. The program costs should be recalculated whenever there is a significant change in any of the variables, such as an increase or decrease in manpower, acquisition of new capital equipment, or the assignment of additional or competing responsibilities for team members.

2. Direct Cost Savings

Sometimes referred to as the “hard” money, direct cost savings are the backbone of the financial benefit for a predictive maintenance program. Even the most skeptical of pundits has difficulty refuting the benefits cited for a program which reduces annual insurance premiums, or comprises the sole justification for revising the frequency or eliminating the task altogether for preventive maintenance (PM) activities. These savings are recurring, and are factored in as an annual direct cost reduction. In some cases, proposed and budgeted design changes can be tabled or cancelled based on new information generated by diagnostic monitoring. These are generally one-time reductions, but the savings can be significant.

A core value for direct cost savings is developed based on the recurring insurance premium reduction, and the permanently removed preventive maintenance activities. This core value is modified as additional credits for insurance are granted, or as a program of continuous reliability centered maintenance (RCM) provides additional reductions in PM tasks. Occasionally, diagnostic data indicates the need for increased PM, and in those cases, that must be subtracted from the benefits assigned for reduced PM. The trade off is then manifested in the indirect cost savings of increased equipment reliability.

3. Indirect Cost Savings

Inevitably, indirect cost savings are subject to the most scrutiny, since they require some conjecture to arrive at values. However, to credit the program with only the measured direct cost savings is overly conservative, and does not reflect the true benefit of the company's investment in the program. Because the indirect cost savings associated with avoided failure and increased reliability are based on events which did not occur, there is no "actual" cost savings, since there are an infinite number of possible scenarios for latent failure propagation. The most meaningful and usable values are those calculated from a finite number of different scenarios, with a weighting system based on likelihood of occurrence.

Within the category of indirect savings or "soft" money, exist both equipment-based and production-based calculations. Each avoided failure has the effect of avoided maintenance costs from the reduction of severity of equipment damage, unless the equipment is designated as a run-to-failure component by RCM analysis. Even in those cases where there would be little difference in the extent of damage between the predicted failure and an unanticipated failure, there can still be significant savings based on maintenance being performed in a thoroughly planned and scheduled environment. Indeed, advanced maintenance programs derive the greatest benefit from reduction in costs associated with unanticipated or "emergent" maintenance repair activities. This planned maintenance working environment results in reduced overtime, parts procurement costs, and impact to facility operations. These cost savings are reflected in the variation of maintenance costs associated with planned versus emergent maintenance activities.

4. Spreadsheets—Inputs and Calculations

Three input spreadsheets are required to address the calculation of program costs: direct savings due to both insurance premium reduction and PM baseline changes, and indirect costs from avoided failures. Traditional weighted scenario calculations for the avoided failure costs include categories for catastrophic, moderate, and loss of performance failures. These three areas are each calculated and then assigned probability percentages to arrive at the weighted failure avoidance benefit[2]. A source of error with this model is that separate calculations are made for equipment damage and performance loss, while in reality, the two are often coincident. Also, the two classifications of equipment damage (catastrophic and moderate) does not take into consideration the reduced costs of providing warning to a failure, and thus allowing a lower cost planned and scheduled maintenance to occur.

The proposed modified calculation integrates the loss of performance into the equipment damage scenarios, since for a given postulated equipment failure there is a corresponding loss of production performance. Additionally, an equipment damage scenario of "minor" is added to indicate costs associated with a damage level similar to the actual repair scenario, but reflective of the reduced costs of early detection, planning and scheduling. The spreadsheet shown in **Figure 1** illustrates this new configuration, with typical data inserted for an avoided failure. These spreadsheets are developed on an ongoing basis as PdM surveys indicate latent equipment problems, when the problem is corrected and the cost data becomes available.

The second spreadsheet is used to provide calculations for the Direct Cost Savings. Data on cost savings from deferred, reduced, or eliminated PMs is generally available from the RCM data, and may be used for those calculations. When such data is absent, it is required that the PdM personnel maintain records on those tasks which are modified or deleted based on the adoption of diagnostic monitoring. A close working relationship with the individual or group responsible for PM baseline changes is necessary to obtain awareness of those changes, and for the PdM program to receive proper credit. Also in this sheet is the insurance premium reductions earned through applied PdM.

Program costs are captured in the third spreadsheet, which can be, like the second sheet, a fairly static document. It is generally compiled once at the beginning of the cost-benefit analysis effort, and updated as necessary to reflect changes in the program expenses due to personnel changes and responsibility changes, acquisition of capital equipment, or changes in costs of supplies. The total Cost-Benefit Analysis, then, consists of the combination of these three spreadsheets, which identifies the sum of the Direct and Indirect Cost Savings, and subtracts from it the Program Costs. This final analysis can be maintained on an ongoing, live-time basis, but is usually calculated periodically to provide regular updates to management.

INDUSTRY	Power Generation
PRODUCTION	Megawatt-hours
INCIDENT #	200051001
EQUIPMENT	Substation 500kV Disconnect
SURVEY DATE	August 3, 1999

Estimated Severity	*Catastrophic*	*Moderate*	*Minor*	*Actual*
LOST				
Total Lost Product, units	8000	2000	0	0
Replacement Cost of	$ 25.00	$ 25.00	$ 25.00	$ 25.00
Lost Revenue ($)	$ 200,000.00	$ 50,000.00	$ -	$ -
MAINTENANCE				
Parts ($)	$ 10,000.00	$ 4,000.00	$ 1,500.00	$ 1,000.00
Labor Hours (hrs.)	40	30	20	16
Labor Rate ($/hr)	$ 50.00	$ 50.00	$ 50.00	$ 50.00
Labor total ($)	$ 2,000.00	$ 1,500.00	$ 1,000.00	$ 800.00
Total Maint. Costs ($)	$ 12,000.00	$ 5,500.00	$ 2,500.00	$ 1,800.00
TOTAL COSTS				
Total Costs ($)	$ 212,000.00	$ 55,500.00	$ 2,500.00	$ 1,800.00
Actual Diagnosed Event	$ 1,800.00	$ 1,800.00	$ 1,800.00	
Benefit Differential ($)	$ 210,200.00	$ 53,700.00	$ 700.00	
Probability (%)	75%	15%	10%	
Occurrence Benefit	$ 157,650.00	$ 8,055.00	$ 70.00	
COMPOSITE BENEFIT, TOTAL		$ 165,775.00		

FIGURE 1

4. WEB ENABLING FOR SIMPLE ACCESS AND INFORMATION GATHERING

Many systems have been developed for performing cost-benefit analysis, and it is a common calculation for engineering projects. It allows the analyst to choose among possible alternatives of differing costs for a given project. It also allows for feasibility studies, to determine if a proposed project is profitable compared to the company's own established internal rate, or $i^{\star}$ (eye-star). The internal rate of return (IRR) for a given project must exceed the company's established $i^{\star}$ for the project to be considered viable. With predictive maintenance programs, however, the decision to implement PdM technologies is usually made without a specific economic analysis, and is based instead on regulatory requirements, industry trends, or in response to specific reliability issues. The problem lies in the fact that PdM seems to "put itself out of a job", meaning that the reliability problems that initiated the commitment to the program diminish when the program is properly implemented, and questions can arise about the continued need for the program. It is in this environment that cost-benefit analysis is important to illustrate to management the value and impact of the program through financial and technical analysis.

Since production environments vary greatly, there has been no one catchall system for performing this analysis and it has fallen to the PdM program managers to implement their own system to provide this financial justification. Many have done so successfully, developing systems customized to their industry or company. There has been, however, no consistent basis for comparison, and therefore no way of gauging the relative success of a program with respect to industry norms. With the advent of the common use of the internet in the industrial setting, the doors are opened to the possibility of developing a web-based system to provide this common basis. By offering to the user ease of operation, usable reports, and statistical information on industry norms, the web-based system stands to attract a sufficient number of participants to enable a commonality in predictive maintenance cost-benefit analysis.

This system utilizes a database with a browser enabled interface that allows both the collection of data from the technicians performing predictive maintenance, and the presentation of standard reports and statistical data that are of value to the technicians and company managers as well. **Figure 2** shows the typical interface form that is used to gather data from the user visiting the website. Data collected from the user includes industry and equipment classification from a selectable list, and numerical inputs of labor costs and lost production costs. Users provide a description of the incident, including the nature of the equipment anomaly, and the potential consequences. Classifications of Catastrophic, Moderate, and Minor are used to speculate on probable scenarios in the absence of intervention. For each of these classes, estimates of lost production, labor hours required to repair and cost of replacement parts are included. To achieve the weighted figures for the overall benefit calculation, the user estimates a probability of occurrence. The last item is the Actual costs of lost production, labor and parts, including resources used to perform the predictive maintenance inspection.

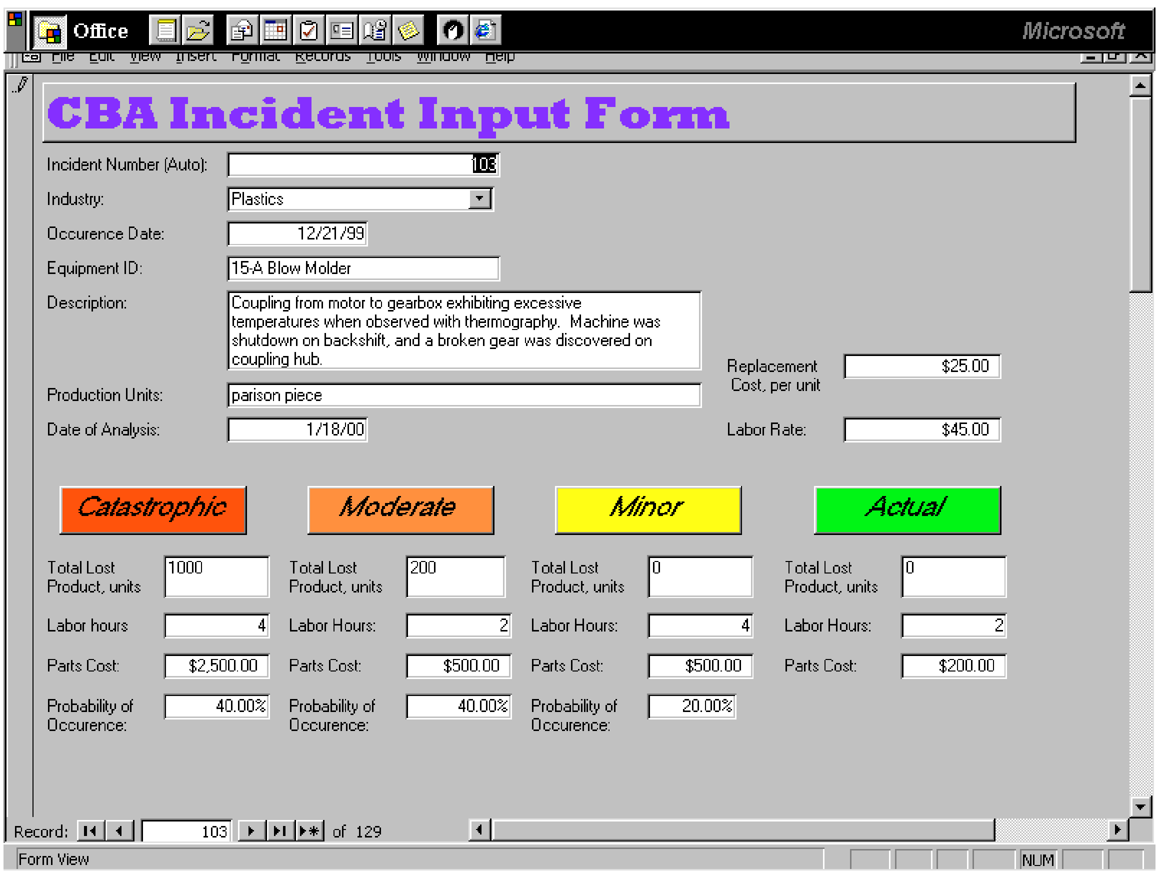

Figure 2

When these values have been entered, they are recorded in the database by means of an active server page interface through the browser. The use of this interface simplifies the necessary actions on the part of the user, and allows the data to be collected in a uniform manner that will enable subsequent statistical analysis.

5. STATISTICAL METHODS

A primary benefit of the standardization of data collection in a common database is the ability to perform statistical analysis. Like many natural phenomena, it is expected that solid cost-benefit data, when compared among a sufficient population of a given industry or application, will provide a Gaussian distribution of values assigned to savings. The use of statistical means will enable a given analysis to be rated with respect to the established mean for that industry/application combination, and enable users to refine estimates to be more in line with industry norms. This normalization of cost-benefit analysis, coupled with a remote and unbiased accounting method, should serve to increase the "believability" of values produced in cost-benefit analysis reports. While not all program managers face skepticism when presenting their analyses, many err on the side of conservatism in their cost-estimates to avoid scrutiny. The normalization process should allow those conservative users to use more representative values in their calculations, possibly providing even greater benefit numbers without risking the appearance of inflating their figures.

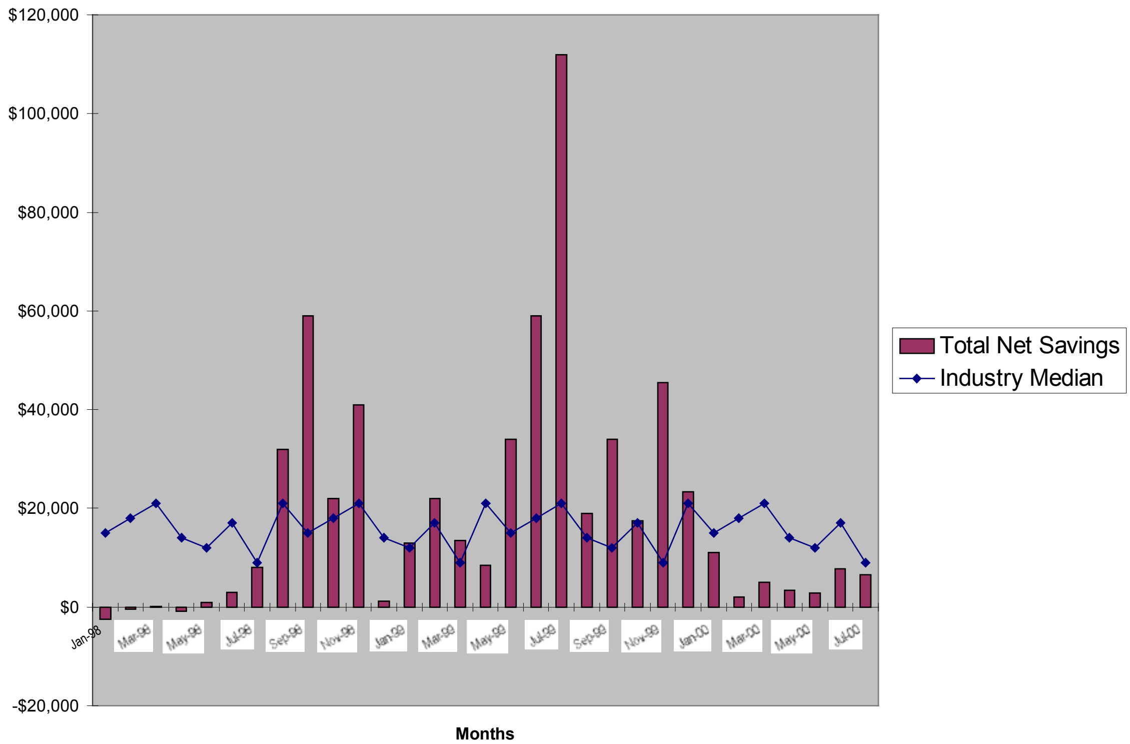

Figure 3

6. REPORTS

Part of the hindrance in maintaining a consistent cost-benefit analysis program for predictive maintenance is in the time required to produce meaningful and presentable reports. In order to attract and hold the attention of the intended audience, usually a manager, the report must be eye-catching, brief, concise, and with a minimum of data. We are aided by the fact that predictive maintenance can be a very visual medium, and it is usually beneficial to include images and graphical data in these reports. **Figure 4** illustrates the marriage of the supplied and calculated data, with an infrared image that supplies immediate impact. The image is directly related to the incident, and supplies with a single picture the story of a latent anomaly that could have lead to a significant equipment failure and plant shutdown. Microscope images from oil analysis can have a similar impact where severe wear and damage is evident by the morphology of the particles. The effectiveness of higher power magnifications in elevating the perceived urgency can not be underrated. Visible light pictures of the disassembled

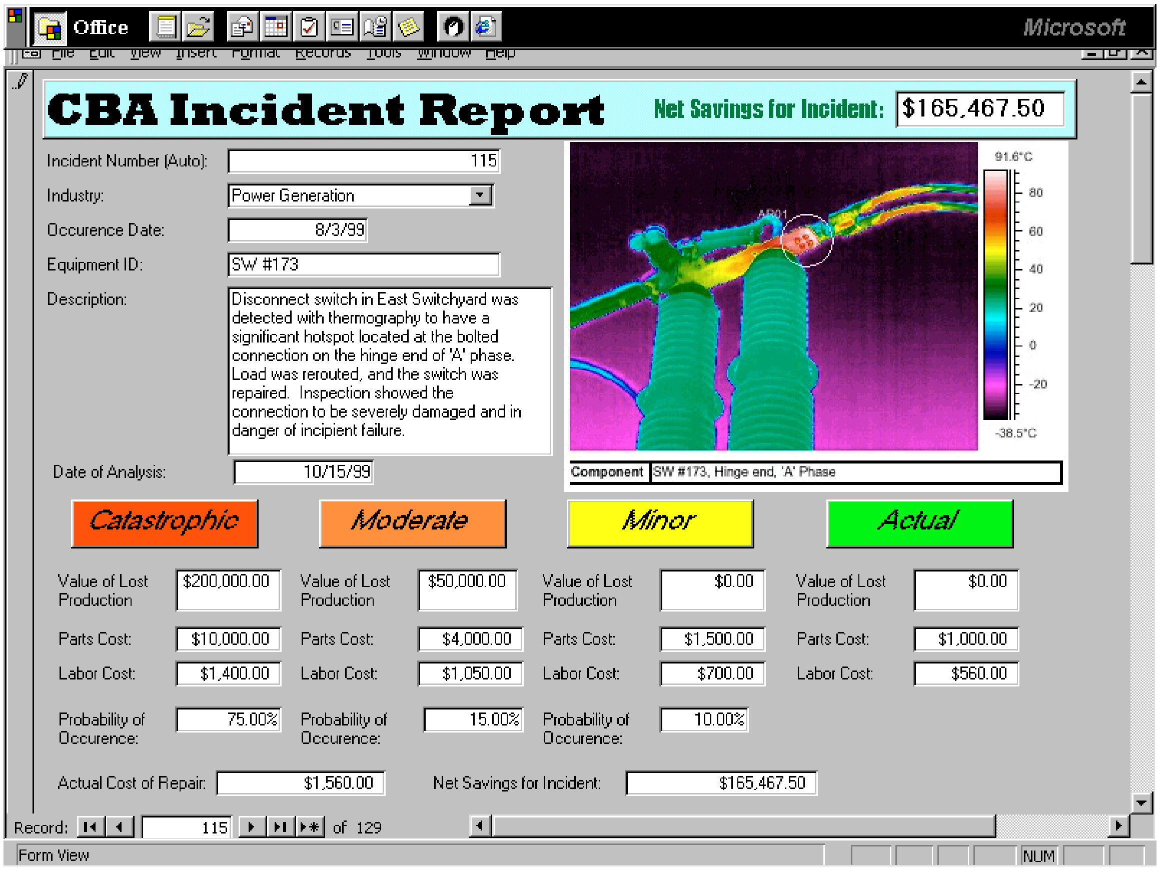

Figure 4

equipment during the repair can also be very effective. Other diagnostic data, while not as visual can still effectively communicate equipment conditions and trends. Vibration spectra usually require more expertise on the part of the report recipient, but significant trends of overall values can be quite obvious.

The web-enabled system will include a number of report formats from which the user can choose, and the final product can be customized. In addition to the incident report, which relates information from a single occurrence, the use of the database will also allow individuals to compile a periodic summary report. This report, perhaps on a monthly or quarterly basis, would include a summation of cost-benefit savings for that time period as well as monthly trends and industry comparisons.

7. CONCLUSION AND SUMMARY

Utilizing a web-based cost benefit analysis can be an effective way to provide independent and salient input to lend credibility in the eyes of management. Predictive maintenance programs are a considerable commitment of funds and resources, and by nature require continual justification in the eyes of management. By using a system that "speaks" in the financial language of management, the cost benefit analysis can bridge the gap between the jargon of applied technologies, and the dollar-oriented decision making of present-day business management. When managers begin to realize the actual dollar benefits of predictive technologies, it ultimately strengthens the support for the program, and allows the company to enjoy continuing benefits from the systematic application of diagnostic technologies.

8. REFERENCES

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