Comparison of Military and Commercial Field Data: Best Practices for Higher Quality Reliability and Maintainability Data

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SUMMARY & CONCLUSIONS

Reliability and Maintainability analyses rely on quantitative data in order to identify high risk failure modes, assess fleet health and identify areas for improvement. Although different types of data are available to engineers and analysts, field data is one of the most prevalent sources. The data is usually captured utilizing a Computerized Maintenance Management System (CMMS) that includes coding such as when discovered, malfunction, action taken and work unit code/equipment identification. These data sets are often incomplete or contain much inconsistency in the problem-cause-remedy codes that are used. In a military context data is frequently captured within a deployed or combat environment, which further introduces potential error. Thus, utilizing field data poses significant challenges when the underlying quality is unknown. The U.S. military and several industrial sectors also utilize CMMS data in order to develop maintenance programs using methodologies such as Reliability Centered Maintenance (RCM). Methodologies may rely on manual sifting of the data sets in order to identify true failure events, or coding schemes are utilized to categorize the data. Both methods raise concern. Manual sifting of the data requires extensive domain knowledge and may also introduce error due to analyst subjectivity. Utilizing the second method of data coding assumes that all coding schemes are reasonably accurate – which may not be case. Additionally, these methods do not support enterprise level data quality analysis and cannot be implemented in a large scale capacity without significant man-power.

This contribution presents an analysis of several data sets to include a military aviation example, and two commercial data sets. The analysis is focused on how malfunction or failure codes are utilized within the field data and identifying practical recommendations for improvement of data supporting reliability and maintainability functions. The analysis further provides important recommendations in order to better equip engineers and analysts performing RAM analysis.

1 INTRODUCTION

Engineers, analysts and managers rely on data in order to improve decision making [1]. Within the context of reliability and maintainability these decisions typically involve identification of emerging failure modes, quantification and monitoring of existing failure modes or reduction in life cycle cost. Inherent in these analyses is the requirement to first identify failure modes defined as the physical state of a system/component/part that results in loss of function. Next, the failure mode probability of occurrence must be quantified followed by assessing of consequences in terms of cost, safety and operational impact. Analyses should not only quantify numeric point-estimates of parameters used to measure reliability (for example MTBF) but also statistical confidence bounds, if possible. Estimation of these parameters can be performed utilizing many different techniques or methods – however fundamentally field data is often utilized as input. Although field data is not available early in design; like system data may still be utilized in order to perform reliability and maintainability analyses. Field data becomes even more prominent once the design is fielded. Reports from operators and/or maintainers are input into maintenance systems. These records consists of a variety of events to include preventative maintenance, troubleshooting performed, administrative entries or actual failure events.

The maintenance technician's primary job is repairing equipment. They are not logisticians, reliability engineers or budget analysts. However, the repair process as a whole, provides vital data to all three of the segments. Having an efficient maintenance data collection system is important for the organization operating and maintaining the equipment. The system has to accurately collect failure data reflecting how an item failed-malfunction, when the failure was discovered, the system or sub-system that was effected, the parts or material required to return the equipment to operating condition and how long the repair process took. The maintainer is the key conduit of all that information.

As discussed, the maintainer's primary job is fixing the equipment but he or she is also the main cog in providing the maintenance and repair data to the Computerized Maintenance Management System (CMMS). It is incumbent of the organization executives, senior managers and database programmers to establish the various maintenance reporting coding (sys ID, how mal, when discovered, etc.) in a limited and manageable number. The most efficient system is a pulled down field, where the operator or repair technician can easily select the reportable data. Having codes for each metric is

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essential for operators and maintainers to quickly and efficiently report equipment maintenance and repair events. However, if we intend to use that data up line, (if not why even collect it) then the system should be developed to ensure the useable data is being reported.

Failure Reporting and Corrective Action Systems (FRACAS) are well known within the R&M community [2]. They are and should be utilized during design to ensure a closed-loop reporting system is in place to both identify failure modes, connect them to root cause analyses and ultimately corrective actions. However, these systems are a function of design – and usually not implemented at the field level. One of the major reasons for this is that field data are collected for a larger purpose to include logistics functions. Coding schemes such as Malfunction and When Discovered codes (to name a few) have been implemented in order to facilitate data analysis from an R&M and logistics perspective. The underlying data quality of field data in large military and industrial environments is critically important, since aforementioned risk analyses will likely utilize such data without the luxury of a FRACAS.

This contribution analyzed several data sets in terms of their data quality both from the military and commercial sectors. The primary goal of the contribution was to ascertain if data collection practices were similar or different when comparing the military and commercial sectors. Additionally, the analysis included comparison of two commercial data sets from different sectors. This, is followed by best practices focused on improving the quality and utility of reliability and maintainability data.

2 ANALYSIS

Data sets were obtained both from the commercial and military sectors and compared. The analysis considered application of failure codes within discrepancies, as well as overarching prevalence of conflicting repair codes (versus malfunction codes), delay time comparisons and component removals. The comparison supported the authors' experience that inconsistent application of failure codes in a CMMS and inconsistent uses of FRACAS-type systems are not restricted in any single industry, and that a combination of best-practices can improve data quality.

2.1 Military Aircraft

Is was not feasible to analyze the entire military data set. Thus, two samples were selected for analysis. The first sample consisted of all landing gear, and cockpit warning indicator work orders. This sample was selected since these are critical systems to the aircraft. The second sample was selected based on identification of a single component that is replaced often. This sample consisted of all work orders related to the Environment Control System Turbine Assembly.

The first data sample (landing gear) consisted of 1451 individual records which included 73 unique components. Variables included work order dates, several delay times (due to maintenance and logistics), discrepancy and corrective action narratives as well as malfunction and action taken codes.

Field data in a military environment is frequently utilized in order to identify degraders to readiness. This identification is typically performed by evaluating the total experienced delay and maintenance time. Delay time is measured in terms of awaiting maintenance hours, awaiting parts hours, non-mission capable hours and man-hours. Within sample one, four percent of man-hour fields indicated zero time taken, while approximately 50-65 percent of other delay time fields indicated zero time. It was assumed that the total non-mission capable (NMC) hours should match the summation of all other delay times. Thus, difference between the manual summation of delay times and the reported NMC hours was analyzed. On average there was a difference of 44 hours, with a large standard deviation 235 hours). This may indicate data error, or additional factors unknown to the authors.

In order to gain insight into malfunction codes utilized within the data set the component with the most reported work orders was analyzed (sample two). Specifically, the analysis focused on identifying the distribution of malfunction codes as well as any correlation between malfunction codes utilized and component replacement as indicated by the removed nomenclature data field. It should be noted that the nomenclature field was blank for a 57 percent of the records. The most prevalent malfunction code used incorrectly was 070, which denotes "BROKEN, BURST, RUPTURED, PUNCTURED, TORN or CUT [3]. When the code was compared against the work order narrative, only 46 percent were correct. For example, Of the 122 work orders documenting 070, 56 were correctly documented as a part of an assembly or system was broken. 15 work orders were documented for tire removals which have their own code for tread wear. The other prevalent miscoded corrective actions were cracks (10 work orders), wear/worn (including stripped, chafed, frayed failure modes), Seven work orders reported as 070 were actually electrical/electronic components which should have reported with the malfunction code W48 (Broken/open wiring). Overall, the 122 "070" work orders, after reviewing the discrepancy and corrective action narratives, the work orders should have been reported as failures under 21 different malfunction codes. Repair codes indicating removal/replacement of major assemblies did map to a non-blank removed nomenclature in the majority of records.

2.2 Wastewater Utility

The CMMS data for a major wastewater facility in the southeast United States was evaluated. The utility is considered within its industry as top tier. Three years of the most recent data was examined. The facility's CMMS is Maximo, and it has been actively used for more than a decade. The facility is relatively new for its type, but is aging. However, this particular industry has a high amount of redundancy related to its unit processes and this particular utility is very proactive in terms of capital replacement of equipment. There were 14 potential work types that can be assigned to any given work order. Preventative Maintenance (PM) was used 42,245 times, which correlates to 87% of all of the documented work orders. There were 75 problem codes within the data set. A comment column accompanied the problem code and was completed the majority of the time where a problem code was used. Cause and remedy codes were not provided. A total of 6,014 of all work orders had a problem code assigned to them. When used, the problem code ADJUST was used 1,575 times (26%) and BROKEN was used 1,278 times (21%). The other 73 failures codes were used the remaining 53% of the time, and many were used less than 10 times over the 3-year period of record. The three years of data contained 48,534 total work orders. There were 5,750 (12%) of the 48,382 work orders classified as CM and 1,361 (24%) of the CM work orders did not have a problem code. The combined PM and CM work orders in terms of percentage of the total work orders is 99%. The ratio of PM to CM work orders is slightly more than 7:1.

2.3 Biopharmaceutical

The CMMS data for a major biopharmaceutical facility in the eastern United States was also evaluated. Six months of the most recent data was examined. The facility's CMMS is Maximo, and it has been actively used for more than a decade. The facility as a whole is approximately 40 years old; however, as a state-of-the-art facility, the equipment is relatively new and well maintained. There were 14 potential work types that can be assigned to any given work order [4]. Preventative Maintenance (PM) was used only 5,895 times, which correlates to 23% of all of the documented work orders. There were 27 problem codes. A comment column did not accompany the problem code. Cause and remedy codes were not provided.
A total of 757 (3%) of all work orders had a problem code assigned to them. When used, the problem codes NOTRUN, NOTWORK, and NOWORK were used 637 times (84%) of the time. The other 24 failures codes were used the remaining 16% of the time.

The six months of data contained 25,181 total work orders. There were 10,222 (41%) of the 25,181 work orders classified as CM and only 50 (7%) of the CM work orders had a problem code. However, emergency (EM) work orders represented 4% of the total work orders but 86% had a problem code assigned to them. The combined PM and CM work orders in terms of percentage of the total work orders is 64%. The ratio of PM to CM work orders is slightly more than 0.6:1.

2.4 Comparison of Commercial Data Sets

The data sets provide good examples of: the wide variety of how a CMMS is used in practice; the range of data completeness of the data even for what are considered top tier organizations; the lack of consistent use of problem codes; and the wide variety of work order types and problem codes that may be utilized.

The utility data set is much more typical in terms of number of PM and CM as a percentage of the total work orders, PM:CM ratio and problem codes being assigned mainly to CMs. Nevertheless, only a few problem codes were used, which makes good analytics difficult.

Clearly the biopharmaceutical CMMS philosophy is different from both the traditional approach and that used by the utility a scan be seen by the extremely low number of PMs and the low numbers of problem codes assigned to CMs. A more detailed explanation of the potential logic is beyond the scope of this paper. However, even more dramatic that the utility data set, the use of only 3 problem codes 84% of the time is very problematic in terms of meaningful analytics.

Failure codes are typically entered and stored in the CMMS. Failure codes simply describe the reason that an asset failed and are typically included in a Corrective Maintenance (CM) work order. In most cases, they are input by the technician who performs the corrective action; in systems where a follow-up RCA is performed, the person responsible for the RCA may enter or update the initial failure code.
Traditionally failure codes literally have been either alphanumeric or numeric codes associated with a longer description of the failure. This is still predominately the case today; however, increased computing power and searchable comment fields have made it possible for several major CMMS vendors to make more descriptive fields available in the software.

Failure codes may be limited to simple a code associated with the reason the asset failed and a supporting comment column. Many maintenance programs also include cause codes and remedy codes, which when implemented and maintained properly provide additional richness to the analysis.

The CMMS and its associated failure codes are an essential component of the overarching reliability program. While the utility regularly used problem comments, neither of the entities have a formal FRACAS-type system or Root Cause Analysis process in place related to their maintenance program. FRACAS consists of a formal set of policies, procedures, goals, roles, and responsibilities for personnel who are involved in reporting and correcting failures. Root Cause Analysis (RCA) is a key component of it. Likewise, Computerized Maintenance Systems also are a key component.

As part of the reliability program, FRACAS provides insights to a wide range of reliability functions including design development, design, testing, production, operations, and maintenance. One major concern with current field data collection systems, are that they are not closed loop in nature. The data collection process is not closed loop – meaning that documented failures are not verified as true failures. For example, a failure may be reported resulting in replacement of a component. The following day, the same or very similar failure may be reported with another repair executed. Thus, it is not possibly to ascertain if the first event was truly a failure or rather inadequate troubleshooting.

The use of failure codes is just one aspect of a reliability excellence goal. Within a maintenance program, failure codes are primarily used as tool to optimize preventative maintenance (PM) programs. Other uses include insights and decisions related to design modifications and procurement of equipment and parts; however, in most organizations the depth and quality of the data, along with the necessary resources to performed detailed analytics, often make translating failure code data into design modification or procurement decisions elusive.

Reliability excellence is a culture. From the authors' experience, it is much less about an industry sector and most about organizational capacity and personnel commitment. There is some truth that many organizations lack leadership, commitment of resources, and vision for a culture of reliability excellence. In some others, the "pain points" are simply not high enough to drive the organization toward analytics and optimization. One example of this may be a new facility or new equipment, where corrective maintenance activities are low or not increasing.

Another reason is that quite simply a number of years of data is needed to make much of the required analysis meaningful. While FRACAS and RCA have been around for many years, it has only been in the past decade that most commercial-of-the-shelf CMMS systems have had default fields for failure codes. The ease of using the codes, including default codes, drop down selections, and highly searchable comments fields, is still relatively new.

3 RECOMMENDATIONS

It is best to have the data entered correctly closer to the event by those who investigated and corrected the failure. In most cases, this is the technician that responds to the failure. It is further important that technicians understand the overarching reliability and maintainability program goals to ensure ownership in the data. The malfunction or failure codes need to be developed and directed toward maintenance and reliability activities that can be realistically impacted or improved. Additionally, these codes should be developed by work order requestors, maintenance personnel who perform corrective action and enter the work orders, and by the reliability engineers who will perform the analytics. This will further ensure buy-in and cross-functional utility of the coding schemes. Lastly, the failure codes should be easily available and understandable.

The amount of malfunction or failure codes are important. There is a risk of over-complicating the number of codes, which likely erodes the data quality. For example, technicians will likely utilize codes they remember, or pick the first code they deem appropriate. Malfunction in Naval aviation have ballooned to over 225 different codes! There are no defined rules for the optimal number of failure codes. Some experts recommend between 20 to 30 failure codes, and ideally 6 to 8 for any given class or type of assets. We are aware of one facility that simply elected to use 8 failure codes in total, which was based on a combination of their types of assets, their desired level of analytics, and what they believed the staff would actually use. Generally, less is more in the world of failure codes. Drop-down selections in the CMMS should also be used to eliminate the need to memorize codes and make entry more efficient.

Procedures and processes need to be in place to assure that data entry is complete and valid. This should be coupled to a well-organized system/asset hierarchal structure that enables the full use of cause and remedy codes, which in turn allow for more constructive analytics and mapping to components and systems. This has largely been accomplished in military environments by utilization of work unit codes.

Analytics should be performed and reported to maintenance staff to validate that the data being collected is actually being used. Keeping the analysis simple – such as Pareto analysis of work order history, failure categories, and failure causes – can provide meaningful insights which can been done affordably and relatively quickly. Additionally, modern analytics and data quality rule-sets must be developed to automate this process as much as possible. Lastly, discrepancies are not described using a standard grammar and nomenclature. The discrepancy and corrective action narratives frequently contain spelling errors or utilize different nomenclature and/or descriptions. Thus, keyword searches may or may not capture all the desired records.

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