

Improving the Use of Key Performance Indicators (KPIs) in Operations
Management

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Abstract

This thesis contributes to the knowledge of Key Performance Indicators (KPIs) with a focus on improvement for operations and maintenance.

Through literature research, gaps within the use of KPIs throughout different business areas of a functioning organization were identified. Then by conducting case studies, improvement to the implementation of KPIs are suggested.

A gap identified through research and observed through the authors work is how the use and even the definitions of KPIs used in operations and maintenance are not linked together for overall improvement.

Conflicting KPIs can have operations and maintenance going in different directions. While working at two different operating taconite facilities, the author observed the following: operations feeds into maintenance and maintenance feeds into operation. One cannot solely dictate to the other because the operation runs better when it is a two way street. This is why there is a need to formally tie these areas of work together.

This thesis offers suggestions as contributions to continuous improvement utilizing KPIs. Firstly, know your stakeholders, secondly, identify the “why” an improvement needs to be made, thirdly, describe the importance of KPIs, fourthly measure and communicate your success, and finally plan to make changes throughout your improvement process. Improving these identified factors are critical to the success of KPIs.

Five case studies were presented and suggestions were given based on these case studies. The case studies vary from non-profit, volunteer, employee owned, and private company working experiences.

Findings from this thesis are important to engineering management practice because the need for operational improvement continues to become more important.

Table of Contents

Acknowledgements.....	i
Abstract.....	ii
Table of Contents.....	iii
List of Figures.....	iv
1.0 Introduction.....	1
2.0 Literature Reviews.....	3
2.1 Importance and Development of KPIs	
2.2 KPIs in Maintenance	
2.3 Reliability While Using KPIs	
2.4 Summary	
3.0 Case Studies.....	19
3.1 Case Study #1 – Transfer Course Evaluation	
3.2 Case Study #2 – Engineering Club	
3.3 Case Study #3 – Operations Manager	
3.4 Case Study #4 – Maintenance Manager	
3.5 Case Study #5 – Marketing Manager	
4.0 Improving the Use of KPIs.....	37
4.1 Creating an operational improvement based culture will help develop KPIs	
4.2 Developing KPIs that are clear, organized, and easily measured will drive better implementation	
4.3 Empowering the five 9’s concept will improve the reliability of KPIs	
4.4 Generating quick-win KPIs with your team will lead to longer-term operational improvement	
4.5 KPIs need to be improved upon with targets being reevaluated and new measurements added.	
5.0 Conclusion.....	45
6.0 Bibliography.....	47

List of Figures

Figure 1: Leading and Lagging Indicators [7].....	5
Figure 2: The Use of Leading and Lagging Indicators Across Functional Areas [7].....	5
Figure 3: Procedure for Optimizing a KPI System [2].....	8
Figure 4: Six Step RCM Process for Implementation [23]	14
Figure 5: Probability of Failure [25].....	15
Figure 6: Availability Versus Cost [26]	16
Figure 7: GE Model for Improvement	27

1.0 Introduction

The concept of Key Performance Indicators (KPIs) is nothing new. KPIs make up the measuring block for improvement, whether it be in operations or maintenance. Every area of an organization needs improvement with this thesis focusing on operations and maintenance. KPIs allow the gathering of knowledge and exploring the best way to achieve organization goals, however many companies are working with the wrong measures, many of which can be incorrectly named and metrics that are not tied together. In addition, very few organizations really monitor their true KPIs. That is because only few organizations know what a KPI actually is [1]. By definition, KPIs can be described as a measurement tool of performance and such measure is commonly used to help an organization define and evaluate how successful it is, typically in terms of making progress towards its long-term organizational goals [2]. The KPIs can be as small as measuring how many pieces of paper are printed everyday to as large as process management measuring how many million gallons of water are used everyday.

As observed through prior career experiences and research around these subjects of work, there is one gap that stood out the most. The noticed gap is how areas like maintenance and operations KPIs are not tied together. Using conflicting KPIs have work in these areas going in different directions. When the author of this thesis worked at two different operating taconite facilities, the following was observed: operations feeds into maintenance and maintenance feeds into operations. One can't solely dictate to the other because the operation runs better when it is a two way street. This is why there is a need to formally tie these areas of work together and to develop the right KPIs to drive improvement to both at the same time.

The thesis discusses the importance of properly organizing and defining a KPI for improvement and make suggestions on how to improve the implementation and use of KPIs in organizations. It is organized as follows:

Section 2 reviews literature in three different areas: importance and development of KPIs, KPIs in maintenance, and reliability while using KPIs. Section 3 presents five different case studies in transfer course evaluation, engineering club, operations manager, maintenance manager, and marketing manager drawing on lessons learned from the case studies. Section 4 proposes suggestions for improvement while utilizing KPIs. Section 5 concludes with contributions, limitations, and future work.

2.0 Literature Reviews

2.1 Importance and Development of KPIs

KPI is a measuring tool of performance and such measure is commonly used to help an organization define and evaluate how successful it is, typically in terms of making progress towards its long-term organizational goals. KPIs are the basis for decision making and illustrate structures and processes of a company. The main functions for KPIs are to support planning in various areas (strategy and budget), requirement to set goals and to control the implementation and help control incentives for employees [3]. Business decisions for an operation are based primarily on KPIs. Maintenance dollars need a more rigorous justification in financial terms [4]. In today's world, KPIs are essential for planning and controlling through consolidating information, creating transparency and thereby supporting decision making of the management [3].

For designing the KPI system on performance management, it should comply with the principles of SMART where "S", "M", "A", "R", and "T" represent specific, measurable, attainable, realistic, and time-bound [2]. These principles allow for a KPI to be effectively used for business improvement goals. KPIs quantify the success of a business process or activity. Guidelines for the definition of KPIs exist for organizational functions such as sales and marketing, operations, and logistics. KPIs should be simple, non-financial, and reviewed regularly. They are typically prepared for a management team and should have a significant impact on the business directives [5]. KPIs give directions for an organization to highly increase performance [1]. KPIs can be used as an assessment method in different fields. This assessment is very important and valuable for improving an operation or field of work. Effective KPIs make this improvement even more profound.

KPIs are also used for the improvement of safety. By investigation into accidents, we can identify root causes of accidents and develop corrective actions to be implemented, which prevent accidents from reoccurring. Initiating

effective change is the reason for the investigation and corrective actions lead to changes. Effective corrective actions can prevent the accidents from reoccurring. Corrective actions, which are measurable KPIs, must be developed according to causal factors and root causes. They must be specific, measurable, accountable, reasonable, timely, effective, and can be reviewed [6].

In order to design the KPI system with scientific, reasonable, and feasible features, some basic principles should be complied with:

- Goal-Oriented: The design of a KPI system must be based on the strategy of the operation.
- Operability: KPI system should be operable technically and each indicator should be defined specifically and can be understood and accepted easily.
- Targets Balance: Relevant organizations should involve with and support each other to help the targets binding based on the strategic targets of power materials management.
- Process Control: Give priority to the establishment of KPI system on inputting and outputting processes and integrate both as a whole for process control [2].

One of two kinds of KPIs must be chosen for measuring any particular function of a business: leading indicators or lagging indicators (also referred here as leading and lagging KPIs). Leading KPIs lead to results, such as scheduled compliance while lagging KPIs are the results, such as maintenance cost. We use leading indicators to manage a part of the business, while lagging indicators measure how well we have managed [7]. These are both shown in Figure 1. A leading indicator can also be described as a KPI that measures activities that have a significant effect on future performance, which are causal roots of the outcome they influence, and actionable for the future performance against one or more lagging indicators which measures the output of past activities [1].

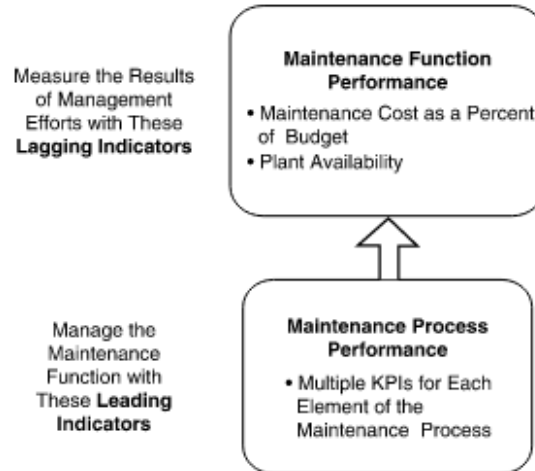


Figure 1: Leading and Lagging Indicators [7]

Statistical indicators should be described clearly. This includes the meaning, the model, the presentation style, data sources, and technical requirements of those statistical indicators in order to get a solid foundation for further analysis [2]. This foundation will help with process improvement once the KPIs are fully developed.

Figure 2 describes leading and lagging indicators, but more importantly shows how maintenance, production (operations), and engineering (consulting) are all tied together.

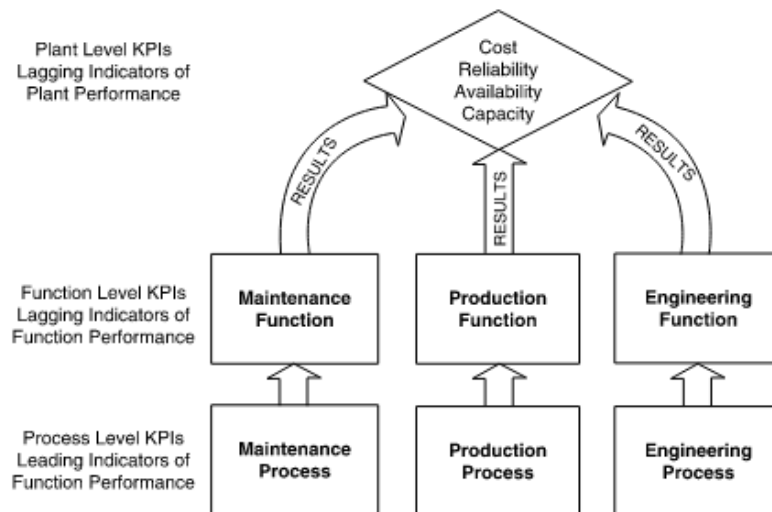


Figure 2: The Use of Leading and Lagging Indicators Across Functional Areas [7]

KPIs need to be time bound and there are two levels of time frames commonly used: Daily and Monthly. The daily data represents the calculated result associated to a particular day. The monthly data represents the moving average of the daily value and the previous month. This average reduces transient effects typical in daily data [8]. The average used is often time based on weekly data for around the clock continuous operations.

Designing a KPI system typically has four levels of KPI hierarchical structure: Measurements, Indicators, Objectives, and Macro-Objectives. Measurements are the elements are at the lowest level. They are the seed to calculate higher-level elements, and represent real collected data. Indicators represent the first abstraction level. Each indicator is related to an initiative of the project and shows the compliance of its purpose. Objectives evaluate the aggregate effect of some indicators which have got similar purposes. Finally, Macro-Objectives evaluate the final goals of the project [8].

Some qualitative requirements for KPIs can be used initially for designing when the “why” in KPI is needed: These requirements should be valid for all types, inclusive and holistic, wide-ranging, hierarchical, quantifiable, sufficiently simple and easy to interpret for different stakeholders, descriptive, inspiring, suitable for decision making support, representative, and flexible [9].

Businesses also use the following to describe the characteristics of their KPI design requirements:

- Sparse: The fewer KPIs the better.
- Drillable: Users should be able to drill into detail.
- Simple: Users should be able to understand the KPI. The KPIs should clearly indicate what action is required by staff.
- Actionable: Users should know how KPIs affect outcomes. Users need to know how to make improvements from what the KPI is telling them.
- Owned: KPIs should have an owner and be able to be acted on by the management team.

- Referenced: Users should be able to view KPI origins and context.
- Correlated: KPIs should drive desired outcomes and encourage appropriate action.
- Balanced: KPIs should consist of both financial and non-financial metrics.
- Aligned: KPIs should not undermine each other.
- Validated: Workers should not be able to circumvent the KPIs.
- Regulated: KPIs should be measured frequently.
- Distributed: KPIs should be measures that tie responsibility to a team [1].

KPIs in business environments are mostly quantitative information; it illustrates structures and processes of a company. Now KPIs are very important for planning and controlling through supporting information, creating transparency, and supporting management decision makers [1]. The practical integration between scheduling and control by combining output information from both systems results in KPIs that can be fed back to each system to further action [5].

The adoption of operations and maintenance improvement strategies is currently a concern of most organizations. The use of KPIs to drive these improvement strategies enables organizations to achieve business objectives. Maintenance management also plays a significant role in achieving the goal of improving overall efficiency in the services of an organization, helping to maintain continuity and avoiding costly downtime [10].

The design of KPIs also requires a method for identifying process signals. When selecting signals to log, it is better to select too many than too few signals. The length of the data and sampling time may vary depending on type of KPI and plant dynamics. The next step is to remove signals with zero standard deviation and to remove data in all signals for time periods when the plant is shut down or are working under abnormal conditions. After you calculate the KPI's and plot the data, search for signals or signal combinations in historical data that are strongly correlated with the KPI [11].

More knowledge built into the KPI framework results in more precise estimations of the effects of improvement actions. Decisions can be taken based on more precise estimations. Through smarter operational decisions, manufacturing production lines become inherently more sustainable by maximizing their efficient utilization of assets and resources [12]. Change process signals in the direction that the KPI improves, and verify the improvement [11]. The basic principle for optimizing a KPI system is shown in Figure 3.

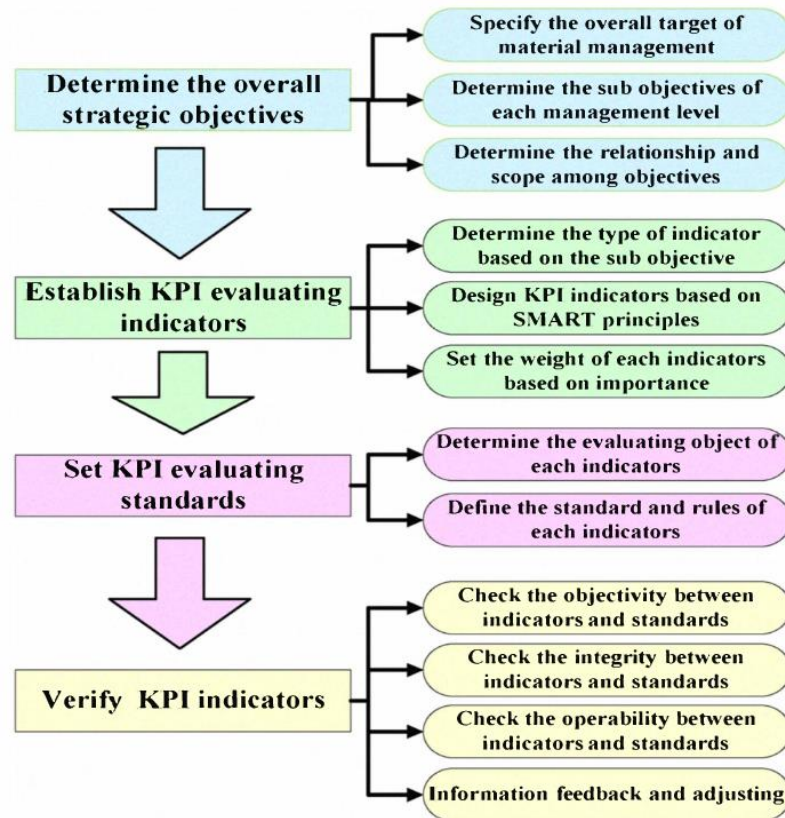


Figure 3: Procedure for Optimizing a KPI System [2]

An example for improving the use of KPIs proposed in literature is by going through a list of simple yes or no questions.

- Is the Arc Flash Hazard Analysis complete?
- Are there over-dutied devices in the substation?
- Have all arc flash incident levels been reduced below 40 calories/cm²?

- Have arc flash mitigation solutions been implemented for all Dangerous locations? [13].

The questions are all yes or no questions, which reduces the variability for answers. If any of the questions are unable to be answered, this is a sign that your metric needs to be improved upon so it is clear on what you are to measure.

Those questions were developed by a research program that tracked five KPIs to protect employees from arc flash hazards in all of their company facilities. The assessors utilized a standardized checklist to determine the level to which established KPIs have been implemented. The checklists were weighted and scored to validate compliance in a consistent manner [13].

KPIs are widely used in operations and maintenance. These two areas tie directly together, but need separate measurable data. As a result, the associated KPIs should be separate and differentiated to avoid driving work in these areas in conflicting directions. The main operations KPI is the Overall Equipment Effectiveness (OEE) measured by the percentage of scheduled operation time, over a time period, the percentage of actual uptime of the scheduled time, over a time period, the percentage of production rate of max rate for produced product type, over a time period, and the percentage of full quality products of the production, over a time period [11]. On the maintenance side, too little maintenance causes an excessive number of unplanned stops resulting in lost production and emergency maintenance, while too much maintenance causes large maintenance costs and lost production during each planned maintenance. Therefore, maintenance KPIs are measured by the maintenance costs divided by produced output over a time period and the maintenance time divided by produced output over a time period [11]. These currently conflict as they use the same time period, but currently use measurements that do not link back to one another.

In the next section, KPIs in maintenance will be discussed in detail.

2.2 KPIs in Maintenance

The three major types of maintenance are as follows: Preventive Maintenance (PM), Corrective Maintenance (CM), and Reliability Centered Maintenance (RCM) which is described as maintenance intended to improve the performance of an asset in its context, considered as an improvement over the conditioned maintenance, where identification of the change that can improve the asset's functioning is the key [10]. The goal for maintenance management is to take processes and indicators and analyze them for improvement actions. Some main objectives of implementing metrics through key performance indicators are the following: evaluation and comparison of performances; identification of strengths and weaknesses; planning strategies, procedures and actions and monitoring the evolution of changes over time [10].

Traditional maintenance consists of both CM and PM: CM in which the equipment is allowed to run until it fails and then repaired, PM in which periodic maintenance procedures are performed at regularly scheduled intervals, and PM in which certain types of monitoring, such as vibration or infrared scanning, is used to predict incipient failures [14].

High reliability (and availability) with low life-cycle costs are general goals for all maintenance programs. An effective PM regime balances the cost of maintenance with the elimination of degradation failure mechanisms through preemptive intervention [15].

There are four basic steps to optimize maintenance and they are as follows: understanding the current approach to maintenance and the resulting impact on mission and cost, developing a statistical approach to both PM and CM based on data, optimization of the maintenance process with established tools, and cost comparison of existing maintenance program to an optimized program [15].

The goal is to move from time based maintenance to condition based maintenance. Accurate data plays a huge role in making a reliability program a

success. Reliability based maintenance is defined as the statistical application of data to support the predictive nature of both CM and PM based on condition and performance history. Success of a reliability program is very dependent on organizational structure and approach to maintenance.

Accurate, reliable, and timely information is vital to effective decision making in every aspect of reliability assessment and maintenance. It is the essential component of any effort to persuade individuals or management, to change maintenance decisions from what has been done previously in the best interest of the organization. More importantly, accurate data collected and presented in support of maintenance optimization can be a powerful tool for the facility manager [15].

The whole process for optimization of maintenance and work scheduling is listed as follows: collect the history information, establish the degradation model and the inspection model, collect on-line data, perform data filtering, reset the boundary of the scheduling and the maintenance threshold, optimize the objective of the cost rate including the time before the last estimated time, update the optimal scheduling and the maintenance threshold based on system condition, compare the system condition with the optimal thresholds, and finally make decisions [16]. Making decisions based off your KPIs is often the hardest part to implement due to past knowledge of how the facility normally operates.

The need of an integrated maintenance strategy is to create and implement the ultimate maintenance program for the asset with the goal of increasing the reliability and profitability of the asset. In reality, no single strategy works on any asset. The challenge then lies in arriving at the right combination which will give maximum returns in the form of increased reliability, availability and safety at optimum cost [17]. Implementation of a maintenance strategy improves mean time between failures (MTBF) on an order of magnitude. The associated maintenance cost trend also goes down in an order of magnitude. The selection of a particular strategy depends on the nature of the problem [18].

Maintenance management is a critical issue amongst management activities of manufacturing organizations. It has rapidly grown into a very complex undertaking as technologies, competition, and product characteristics evolve. In order to achieve world-class performance, the maintenance strategies should be linked to manufacturing strategies such as lean and agile manufacturing. Selection of an effective maintenance strategy keeps a high degree of utilization, reliability, and availability of manufacturing facilities especially in continuous production process [19].

According to the management of many industrial enterprises 'benchmarking' is a powerful tool for the development of the plant operations. However, among many problems concerning benchmarking a challenge is to make companies or plants comparable. This challenge is sometimes used as an excuse to explain away the worse ranking in comparison [20]. Maintenance metrics are needed for the "benchmark" of the operation and can be fed back for improvement. The maintenance system break down is described as follows: maintenance planning, resource management and development, management of maintenance processes, execution, and follow-up and continuous improvement [20]. There are multiple steps for process improvement and they can be defined as follows: Describe the vision and get the management commitment, define the objectives and metrics, measure present status and define the desired status, diagnose the process by process mapping, find the bottleneck of the process and then prioritize the improved points to make solutions against these problems, take action, validate the improved process by measuring it using previous determined metrics, standardize the process and its related operations, and celebrate the success of improvement [21]. Action is needed to make the desired improvements.

In the next section, the reliability portion of KPIs in maintenance will be discussed in detail.

2.3 Reliability While Using KPIs

Reliability-Centered Maintenance (RCM) is a proven technology to optimize the maintenance processes and another logical step in improving the overall performance and reliability of the critical facility while reducing the total cost of ownership. RCM was developed by another “mission critical” industry, the airline industry. A joint airline/Federal Aviation Administration task force developed what became RCM in response to the ineffectiveness of the existing PM programs aimed at reducing or preventing failure, while the costs of doing the PM programs were soaring. What was discovered during the initial and subsequent taskforces was that PM was effective only for items having certain patterns of failure. For equipment with different patterns of failure, PM was ineffective or made matters worse by providing more opportunity for maintenance-induced failures [14]. Failure needs to be properly defined in order to measure it properly. Failure definition comes into play and how to properly define RCM. This can be divided into three categories: Failure classification; Problem Code; and Severity [22]. While in RCM, the objective of the maintenance is to preserve an item’s or system’s function(s), not just operability for operability’s sake. Redundancy may allow individual equipment to fail without impact to the overall system function; RCM focuses on the complete system and is more concerned with maintaining the overall function than the individual components; Reliability is the basis for decisions. The failure characteristics of the item in question must be understood to determine the efficacy of PM; RCM is driven first by safety and then by economics. Safety must be preserved, but when it is not an issue, the PM must be justified by economic benefits; RCM acknowledges design limitations. Maintenance cannot improve the inherent reliability of the design; it can only sustain the design level of reliability over the life of the equipment; RCM is a continuing process in which the information gained by actual operation and from failure characteristics experienced is used to improve the process [14]. When implementing a RCM program into a traditional PM program, maintenance

procedures need to be reviewed to make sure the correct maintenance is being performed and measured. The measurement is in the form of KPIs and these improve the reliability of the operation onsite with improved maintenance. The six step process for RCM implementation is shown in Figure 4.

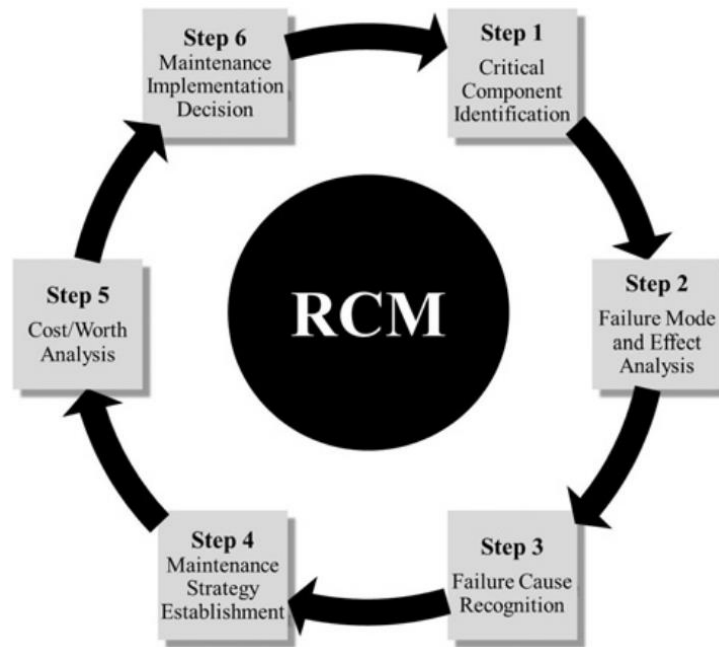


Figure 4: Six Step RCM Process for Implementation [23]

When the concept of reliability began to formally become an integrated engineering approach in the 50's, reliability was associated with failure rate. Today the term "reliability" is used as an umbrella definition covering a variety of subjects including availability, durability, quality and sometimes the function of the product. As shown in Formula 1, Reliability (R) is the probability that a product or service will operate properly for a specified period of time under design operating conditions without failure. In short, it is the "probability of success" for a given period of time. It is a metric directly related to how often (or how fast) the system fails [24]. Figure 5 shows a probability of failure over time. The longer the time, the lower the reliability, regardless of what the system design is. The better the system design, the higher the probability of successful operation for a longer period of time. There are five important factors to define

the “reliability” of a system; MTBF, MTTR, availability, reliability, and time. As shown in Formula 2, Availability (A) is the long-term average fraction of time that a repairable component or system is in service and satisfactorily performing its intended function. The failure rate (λ) is defined as the rate that a failure per unit time occurs in the interval, given that no failure has occurred prior to the beginning of the interval. As shown in Formula 3, Mean time between failures (MTBF), as its name implies is the average time the equipment performed its intended function between failures. Mean time to repair (MTTR) is the average time it takes to repair the failure and get the equipment back into service [24].

- Formula 1: $R(t) = e^{-\lambda t}$
- Formula 2: $A = \text{MTBF}/(\text{MTBF} + \text{MTTR})$
- Formula 3: $\text{MTBF} = 1/\lambda$

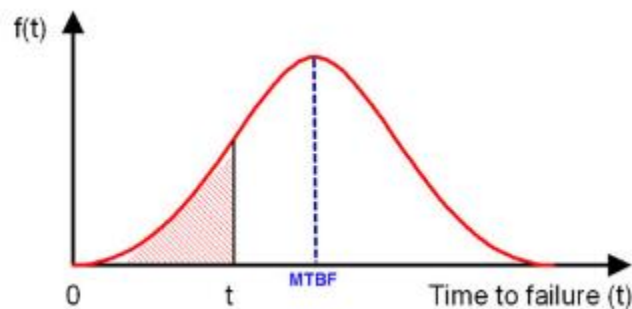


Figure 5: Probability of Failure [25]

When specifying an operating system capable of meeting 0.99999 of availability, it intuitively sets a design criterion identifying a specific level of redundancy. For example, an availability of 0.99999 cannot be achieved without the addition of redundant systems [24]. Five 9’s stands for a reliability of 0.99999 or better. Redundancy is what brings your operating system up in reliability to the level of five 9’s.



Figure 6: Availability Versus Cost [26]

The rise in reliability and redundancy does come with a cost that needs to be monitored and measured over time. This is described in Figure 6.

Maintaining a secure and reliable operation of power systems has been and will remain a priority for the electric sector entities and utilities. As a result, numerous research on RCM was conducted in the power industry. To maintain the power system, it is necessary to adopt modern, formal, structured, and efficient standards considering the particularities of each system while taking into account the main aspects that could place the normal operation of the system at risk. The steps for reliability improvement are as follows:

- Step 1: System Operation Review and Diagnosis.
- Step 2: Review of International Standards and Best Practices.
- Step 3: Analysis of Changes and Development of Additional Standards.
- Step 4: Validation of Candidate Standards.
- Step 5: Final Standards [27].

Electrical reliability can be measured by taking a systematic approach to documenting preventive maintenance (PM) records with a metric derived from its discovery finds. These finds, however minor, are leading indicators of equipment failures. Therefore, documenting and reviewing them can justify electrical PM programs, measure PM effectiveness, and optimize PM intervals. Electrical

reliability can be measured by taking a systematic approach to documenting preventive maintenance records with a metric derived from its discovery finds. When electrical repairs and PM results are consistently collected and effectively reviewed, the measure of electrical reliability is realized. Criticality and condition-based maintenance plans provide the balance needed to control PM costs versus repair and consequence of failure costs. It is worth noting that electrical equipment maintenance is inherently tied to safety in an industrial facility. Proof of equipment maintenance should be a focus of electrical safety programs [28].

When building a KPI system, a RCM system is tied directly to it. The primary order of business is to build a RCM system that an owner can launch company wide. This task requires the following to be developed in order to be successful: developing PM standards, defining critical electrical equipment, creating an asset-management system, creating pm plans and schedules, installing pm test data-management software, integrating PM records and asset management, developing condition assessment tools, obtaining baseline data, developing reliability KPIs, transitioning to condition-based PM intervals, and quarterly KPI review meetings with leadership [28].

Establishing KPI trends from data collected in a calendar-based PM cycle facilitates a confident transition to RCM maintenance strategies [28].

2.4 Summary

The literature reviews were summarized in three categories as follows: Importance and Development of KPIs, KPIs in Maintenance, and Reliability While Using KPIs. All of them have their place while improving the KPIs and the literature reviews helped identify the following gaps.

As discussed in section 2, most of the literature reviews are focused on maintenance and the subsection of reliability. Operations needs to be equally involved to properly develop KPIs. Several researchers only discuss KPI development and the limited use of them. From the author's experience, people were not developing KPIs correctly and were not using KPIs effectively for improvement.

Along with operations being equally involved, the areas of maintenance and operations were not directly tied together. Conflicting KPIs had these areas going in different directions. After working at two different operating taconite facilities; operations feeds into maintenance and maintenance feeds into operations. One can't solely dictate to the other because the operation runs better when it is a two way street. This is why there is a need to formally tie these two areas of work equally together.

3.0 Case Studies

The use of KPIs can be hard and ineffective. Even though people generally agree, as stated in the literature reviews, organizations do not use KPIs effectively. Through five case studies, the reasons will be explored and lessons learned will be discussed. Each case study will also include steps or suggestions for the use, development, and applications of KPIs based off of the authors prior working experience and expertise in KPIs.

3.1 Case Study #1 – Transfer Course Evaluation

Recently at a local university, a “transfer course evaluation” project was initiated due to a need to improve the evaluation timeline of coursework for incoming students. The university had a goal of increasing the number of transfer student enrollments by 20%. In order to do this, a process needed to be developed for streamlining the process of the transfer course evaluations. Transfer decisions are time consuming and some prospective students are lost due to this lengthy process. The objectives to meet the 20% increase goal for the project are set as follows:

- Shorten time for notifying students of transfer decisions to 14 days or less.
- Reduce completion time for the transfer course evaluation process by 50%.
- Improve transparency and communications for all stakeholders in the transfer decision process.
- Reduce the need to re-evaluate previous decisions.

This project brought out the DMAIC process for improvement which encompasses the following: Define, Measure, Analyze, Improve, and Control. The data for this case study consisted of the amounts of courses requesting evaluation during a calendar month broken out by days. One of the questions that came out of the initial review of the project was “How do we standardize?” Statistical indicators should be described clearly. This includes the meaning, the

model, the presentation, data sources, and technical requirements of those statistical indicators in order to get a solid foundation for further analysis [2].

As universities become more responsive to changing student demands, faster lead times are essential in all endeavors. In other words, the integrated approach of the DMAIC process and lean strategy will offer a more complete, holistic approach to moving the university forward on the road to achieve the best competitive position. Lean thinking can be incorporated into the activities through applying its principles and practices [18]. By definition, the main types of waste in lean manufacturing are:

- Overproduction: producing items too much or too soon, resulting in excess inventory.
- Defects: frequent errors in paperwork or material/product quality problems resulting in scrap and/or rework.
- Inappropriate processing: using inappropriate set of tools, procedures or systems, often when a simpler approach may be more effective.
- Excessive transportation: excessive movement of information or materials, resulting in wasted time and cost.
- Waiting: long periods of inactivity for people, information or goods, resulting in poor flow and long lead times.
- Unnecessary motion: poor workplace organization, resulting in poor ergonomics.
- Excess inventory: excessive storage and delay of information or products, resulting in excess inventory and costs.
- Underutilization of employee: Unused employee creativity and skills to improve the processes and practices this refers to wasting the available knowledge, experience or skill of the staff [19].

Triages were developed for breaking apart the work after initial review. Triage #1 consisted of the Office of the Register (OTR) checking each new course to see if a previous decision applies to any of the new courses on the list

and to forward any courses for review. Triage #2 consisted of the Curriculum Specialist (CS) reviewing and making decisions for specific courses or reassigning to the corresponding department evaluator. These two triages reduced the amount of staff that needed to see each course evaluation.

The team that was built for this project consisted of university staff from all departments along with champions for continuous improvement. “How do we make improvements that include everyone?” was a common question heard from the group. This is not uncommon with all departments being involved. The team further developed from this by learning why KPIs were being developed for the desired improvements. This helped people realize that everyone may not be included on day one, but over time everyone needs to be involved as the improvements are being made.

When developing KPIs, everyone’s idea matters. In the beginning stages of the KPI development, a good number of KPIs need to be brought up, vetted, and let the group decide on what KPIs are to be used to drive the improvement of the team. The chosen KPIs came from the discussions of what can be quantifiably measured for improvement. **Your team needs to know why a KPI is being developed and implemented.**

During the front end of this case study, multiple KPIs were brought up and discussed. Each department had their measurements without realizing how they may affect other departments. Cross departmental teams also determine how KPIs are used together. **Knowing how one KPI may affect another KPI.**

The implementation of KPIs are not to disregard the current work that is already being completed. A lot of KPIs are introduced into an operation that already functions and only needs a nudge in the right direction for improvement. **KPIs are sometimes used only for a streamline improvement of existing work.**

One misconception with continuous improvement is the addition of workload to certain people or departments. KPIs need to be viewed as less work

for all and to make the workload transition in a smoother fashion. This will help grow the culture within the group when this message is received. Buy-in is needed for the success of a KPI driven system as well. **KPIs and continuous improvement need to be the way an operation functions, not an addition to your existing workload.** This was what the champions for continuous improvement on this case tried to convey to the university staff members involved in the project.

This case study really worked through some of the soft skills of KPIs and not as much on the physical charted data. Setting up the existing staff for success in a cross departmental function is what really drove the success of the project. **Cross departmental teams bring value and a strong focus on the entire operation, not just a certain business sector.**

The lessons learned in this case study revolve a lot around the development of KPIs. This is the first part of starting a KPI driven system for measuring improvement. The steps needed to start developing a KPI are as follows:

- Clearly define what you want to improve.
- Communicate what the goal of the improvement is.
- State using the KPI is how we are going operate.
- Team involvement with all affected parties.

Overall, this case study shows how soft skills along with technical skills can be used for the development of KPIs.

3.2 Case Study #2 – Engineering Club

This case study project involves the membership of a smaller local engineering club based in northern Minnesota. The project evolved from declining membership along with low membership rates coming out of the 2020 COVID-19 pandemic. Working previously as the secretary and treasurer for a local engineering club, the author worked on retaining and gaining membership as one of the key priorities of the club.

There was a lot of data available for this project and it is broken out into four categories: Lifetime Lapsed Members; Lifetime Active Members; Regular Lapsed Members; and Regular Active Members. The membership list was transferred over to an online database at the beginning of 2020. Prior to this, the current members list was stored on a single spreadsheet without any historical data. You can't improve what you can't measure. This is the first step to describe the statistical indicators clearly and the data sources to build a solid foundation for further analysis [2].

The online data for membership was downloaded and, after initial review, it was determined that it needed to be standardized so all of the current data was clean, neat, and organized. The members list was categorized between active and lapsed. The lapsed member list was then categorized by the previous renewal year. Anything listed as 2020 was never renewed under the new database. Previous dues from 2021 were voided (the main missed year from the pandemic). By standardizing the current data, future memberships will be able to be tracked and improved upon. As previously stated, more knowledge built into the KPI framework results in more precise estimations of the effects of improvement actions. Decisions can be taken based on more precise estimations [12].

At the beginning of the project, there were a total of 349 members in the database, 114 active and 235 inactive. After completing the work as described in this case study, there is a current membership of 152 active members. Further

data review revealed that 54 members were found to not have an active email address on file. This took the project another step to send out snail mail to each one of these previous members. Further work was performed with the voided previous dues from 2021 as this shows the member was active after the 2020 database conversion and will be more likely to become an active member again.

All of the outstanding invoices for membership were emailed or mailed out again to the member list. This generated an increase of membership by 33% by simply resending out the existing outstanding invoices. There is a funnel effect for getting new members and ways to make the club more attractive for increased membership (Professional Development Hours (PDHs), improved presentations in the monthly meetings given by professionals, and etc.). This funnel effect is also a section of further work to be developed with the membership base to gauge how other improvements can be made to increase active membership.

While this section may seem trivial, sometimes getting the desired results comes from performing the same thing again. This does not mean that everything needs to be checked or redone, but in order to get data that can be interpreted properly, questions need to be asked. In this case, sending out the same invoice again drove improvement. This improvement can be measured and used for future yearly membership lapses. So as a lesson learned here is **don't be afraid to ask the same question twice.**

In order to improve on what is already being performed, data is needed for measurement. The spreadsheet information used in this case study was sorted and organized to make data more accessible. KPIs were then developed from this spreadsheet information. **KPIs are data/information driven.**

Once the original data was sorted for use, KPIs were developed in order to track membership. Once these new KPIs were set up, other areas that needed to be improved upon became more clear. This was revealed with the missing email addresses and seeing when the memberships were lapsed. **New KPIs can**

be further developed over the process of time as they cannot all be defined at a beginning of a project.

The lessons learned in this case study mainly involve data and how it can be used for the development KPIs. When starting on the front end of a KPI driven improvement system, data is one of the first items needed. This is due to improvements needing something to be measured against over a period of time. When looking for data in the beginning, it is important to ask the following questions regarding the details of the data:

- Can the data be measured?
- Can the data be measured over time?
- Can the data be stored for future work?
- Is the data accurate to the level needed for improvement?

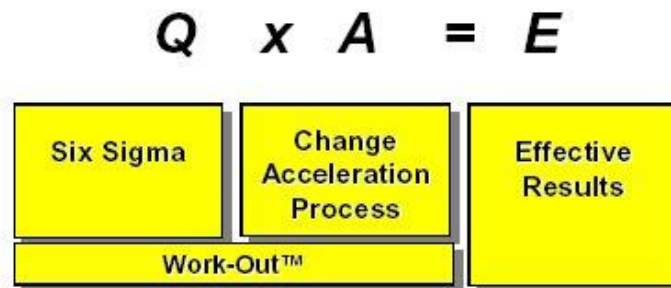
Overall, this case study shows that data is only as good as its interpretation. Data can come in different ways. For example, questions being asked twice or new KPIs developing over time during a specific project. This shows that KPIs need some sort of measurable data to be successful.

3.3 Case Study #3 – Operations Manager

Working previously as an operations manager at a taconite mining facility in Minnesota, the author observed a need for process improvement. A lot of work was performed in the area of operational improvement. Most of the KPIs used were already developed and minor changes were needed. The improvement part came from actually using the KPI's for sustained success. This started with verifying the numbers used were coming from an accurate source. After that, making sure they graphed properly with the correct upper and lower limits for control. The refinement of KPIs and incorporating maintenance into the operation strategy drives continuous improvement. The operations strategy was a rolling yearly calendar with planned equipment outages. Operations and Maintenance KPIs should be separate, but have links between the two.

When working with the operations team, defining and reviewing the bottleneck of the process helped guide where the most effort for improvement should be made. This was already well known with the operating group and just assumed it was in the maintenance group. It turned out, that the maintenance group was not very aware of the plants bottlenecks as this was not well communicated and maintenance staff changed over time. This showed how these two groups needed to be tied together. The operating group started to include different maintenance staff into the daily KPI review meetings to show how downtime affected the process, mainly in the bottleneck areas of the plant. At this particular facility, the ball mills in the concentrator were the bottleneck. Maintenance currently took one ball mill down once a week for 12 hours regardless if it needed maintenance or not. After the inclusion of the maintenance group, the scheduled ball mill maintenance schedule was improved upon by their input along with making sure the proper operating PM's were being performed on a regular basis. These changes improved the ball mill availability, operating time, and production rates. These changes were all measured over a period of a year.

This case study reviewed the variable of “why” in KPI, which represents the why a KPI is important and how to implement them successfully. This is similar to the adoption of the idea as shown in Figure 7. What makes a KPI important versus how well it is used is a variable that is difficult to control. The purpose of it is to accelerate change in a structured and systematic manner. It creates a shared need and shaping of a common vision to get everyone on board to support business improvements. This tied directly into KPIs and measuring your progress of implementation.



The Effective Result (E) of the function is equal to the Quality (Q) of the solution times the Adoption (A) of the idea.

A Proven Formula For Results

Figure 7: GE Model for Improvement

The process improvement work was performed at a well established company, so making improvements was welcomed and stressed. One thing that stood out was the need to change what metrics were being measured. This involved adding additional metrics to be measured without actually removing any of the current measured metrics. One measurement that was added was unplanned downtime. Planned downtime was already measured and how it effects the facility operating availability. The reason for adding the measurement of unplanned downtime stemmed from when it comes, how does the facility get as much maintenance performed in other ancillary areas of the facility when a certain piece of equipment is down. Some up front work involved additional planning and coordinating of the maintenance system to draft a working

equipment list that tied parent pieces of equipment with children pieces of equipment. Some minor side effects were the increase of parts onsite and available for the unplanned downtime, but this far outweighed the waste of not taking advantage of unplanned downtime. Unplanned downtime can never be 100% removed and being prepared for unplanned downtime increases productivity. This engagement helped reduce the planned downtime and improved the overall availability of the facility. **The maintenance strategy needs to account for unplanned downtime.**

KPI measurement precision plays a role for improvement, especially with all of the interdependencies of the various KPIs. Many times this comes down to what is physically taking the measurement in the field. The simple answer of adding more inventory in between different process steps is very expensive and not sustainable. Inappropriate processing is one of the types of lean manufacturing waste and is defined as using inappropriate set of tools, procedures or systems, often when a simpler approach may be more effective [19]. The measurement improvement involved replacing multiple conveyor scales and adding other redundant flow meters and density gauges. The process for vetting out where these improvements/redundancies needed to be made was very intense and involved all portions of the plant. This was worth doing as the measuring improvements increased production and reduced waste. **Verify the data/measurements you are using are accurate.**

These suggestions can be applied elsewhere outside of operations. This case study shows the equal participation from maintenance and how their involvement is needed for the success of KPI driven operational improvement. Along with maintenance, there are other areas where KPIs can be utilized such as:

- Accounting/Finance. This area garners a lot of attention as it is directly effects how a facility can operate. KPIs can be built for the amount

maintenance dollars can be spent in certain months/quarters. This is particularly important for publicly traded companies.

- Warehousing. Inventory levels can be tracked over time using KPIs. This allows for reduction to reduce carrying costs and also allows for increases in inventory due to low stock levels.
- Others. If there is an area that needs improvement and is measurable, a KPI can be used to track and improve your progress.

Overall, this case study shows how your data is measured and interpreted along with who is involved in interpreting the data will help with the refinement of KPIs.

3.4 Case Study #4 – Maintenance Manager

This case study is based on the authors previous work as a maintenance manager at a taconite mining facility in Indiana focusing on a need for reliability improvement. It was a new facility that just finished the process of building, commissioning, and operating. The experience involved building the maintenance department and developing the KPIs to measure the team's performance. These KPIs were completely different than operating KPIs previously used in a different role. The set up and measurement ability of them were the same.

There is always a point of diminishing returns, but getting as close to six sigma quality with the use of KPIs help drive up the reliability of an operation.

When times are good, there is no down time available for maintenance. When times are hard, there is no money available for maintenance. This is primarily true, but if your maintenance request is well defined and backed up with KPI driven statistics, it will garner more back up from management.

When these KPI goals were first brought up with the team, there were a few blank stares from the team as this was the first time KPIs were ever used with them. This was taken as a learning opportunity to start with the basics in defining what a KPI is and how they will make work easier. When the term "making work easier" was brought up, so did the attention spans of the team. This was a true team building exercise that further developed the culture of the team. There were quite a few younger engineers within the maintenance department that got coined with the term "we keep making engineers look good" from the electrician and millwright staff. At first, the young engineers did not like this term, then realized over time it drove them to be better engineers and better overall within the team.

The three main maintenance metric KPIs that were used are as follows:

- PM Compliance: Measure of how many work orders are scheduled in a week and are actually completed. Both work order amounts and work order hours are measured.
- Schedule Compliance: Measure of how many work orders are scheduled in a week versus how many are completed. Both work order amounts and work order hours are measured. Also measure how much work that is actually scheduled two plus weeks out stays on that week's schedule.
- Schedule Loading: Measure of hours scheduled versus man hours available. Includes Planning Accuracy and Man Hour Accuracy.

The KPI goals for each of the three maintenance metrics were: PM compliance of 100% for the week, Schedule Compliance of 85% for the week, and Schedule Loading to be 100% for the current two weeks and 85% for weeks three and four. These numbers were tracked from the beginning and slowly improved over time. There is additional amounts of knowledge the team learned from these KPI goals as not all "A" priority work orders can be assigned for the week as there would be no room for scheduling PMs. This really brought the team together in classifying the real priorities of work orders as they are all not "A" priority once they are looked at in greater detail.

The gap between operations and maintenance was lessened with the reliability maintenance metric having a direct connection with operations by including the operation uptime reports into the maintenance metrics over time. With the new start up facility, these baseline data metrics were needed to determine the proper maintenance intervals for the new process equipment.

When working with a startup company and on the front end of developing KPIs, knowing your teams capability is important. Not everyone comes from a background of working at an established operating facility and this was evident at this new facility. Very few organizations really monitor their true KPIs. That is because only few organizations, business leaders, writers, accountants, and consultants have explored and knew what a KPI actually is [1].The up front

information of what was going to be measured needed to be defined and well organized. **Standardized templates are needed for a new processing facility.**

It is easier for a manager to work at a facility where the current workforce has been established and knows what has to be maintained without being given a specific work order. This also goes for the up front work in developing KPIs. When the workforce has not worked on the current equipment, it makes it difficult for the team make KPIs for improvement if they have no basis of equipment knowledge. This takes time and extra needed care in the front end development of KPIs to make sure the required information for improvement are included.

Details are needed without any tribal knowledge onsite.

When building a maintenance system, there are inputs that are needed outside of your department. The operations department needs to have a plan that is communicated with other departments so the facility can be properly maintained. A lot of maintenance requires equipment to be down to be maintained. Timing this maintenance takes more work than most understand and being able to maintain as much as possible while the facility is down for maintenance. The practical integration between scheduling and control by combining output information from both systems results in KPIs that can be fed back to each system to further action [5]. The plan needs to include planned operating times and production rates on a calendar. **The operations strategy needs to have a rolling yearly calendar with planned equipment outages.**

To help build a successful maintenance KPI system, there are steps that can be followed for implementation. The steps to training teams of craft/maintenance personnel to utilize KPI's are as follows:

- Standardize the information. The information needs to bullet point and easy to follow step by step.
- Keep the team engaged throughout the process.
- Use tribal knowledge to your advantage. Ask questions that the craft only know the answers to. This will engage the team to participate.

- Make the idea of successful KPIs the crafts idea to own/celebrate.

Overall, this case study shows that having a plan for implementing KPIs will help drive your success.

3.5 Case Study #5 – Marketing Manager

Working currently as a Market Manager for an engineering consulting firm in Minnesota that provides engineering support to Mining facilities throughout the country, there was a need for client deliverable improvement. This is where a lot of work in the area of project management, quality assurance, and quality control was performed. KPIs were developed and are currently used for clients. The first KPI developed was simply client satisfaction. Data was collected as a touch point with the client after a project deliverable was met, which comprised of a simple phone call follow up or meeting in person while onsite at their facility. The second KPI developed was formal “Weekly Updates” with the client. Both of these are simple yes or no check boxes for the KPI, but project deliverables improved by implementing these for client deliverable improvement. Both of these were crucial to getting a quick-win and getting team buy-in for being measured for improved performance.

Though the use of KPIs is a standard practice for the author with an operating facility background, the introduction to KPIs in the engineering consulting firm proved to be challenging. The term “we have never needed to do that before” or “we have always done it that way” were often heard while presenting these improvement ideas to the internal team of engineers. Regarding themselves as the smartest people in the room, those engineers resisted to the idea of KPIs. The two keys to success in this case were the use of simple KPIs and letting the team have quick-wins. The ultimate buy-in benefit was receiving unsolicited client feedback about our improved communication, schedule improvements, and overall client satisfaction. The positive client feedback really changed perception to the use of KPIs for the engineers. After multiple years, the team continues to embrace this work while looking for ways to improve client satisfaction.

By having a previous background working at facilities where the consulting work is to take place, this helps develop the team in knowing what the client is

looking for. The saying “Ask what the client wants and perform the work the client asks for” may seem trivial, but is found to be very accurate. To take that one step further, is being able to help identify what the client is asking for helps the team design the solution correctly the first time. This helps with quality control and getting the team of both the client and consultant tied together. There is not an exact KPI for this portion of working and if there were, it would be a lagging indicator as the results would come after the work is already performed. The quick-win was the ability for the team to see the positives of using KPIs without a large amount of effort put into the data collection. **Quick-wins drive team buy-in.**

The feedback received from clients by simply having touch points and weekly updates was significant. This helped both parties as it keeps the consultant organized and on task and it also helps the client report out on the project progress to their internal team. Measuring these interactions are a simple yes or no on a check box, but make an impact on the team’s success. **Simple KPIs are ok.**

Working with a team that is not familiar with KPIs or understand their importance, keeping them simple, and getting buy-in play an important role in the team’s overall development. Not every measurement improves an operating process and there are more ways for driving improvement. **KPIs are a team development tool along with a process improvement tool.**

To help build a successful KPI system, there are steps that can be followed for implementation. The steps to training teams of engineers/consultants to utilize KPI’s are as follows:

- Make the KPIs simple and easy to understand.
- Get a quick win right away.
- Show the team how using KPIs will make their job easier.
- Challenge the engineers come up with future KPIs.

Overall, this case study shows building a KPI system can be simple while having a huge impact on improvement.

4.0 Improving the Use of KPIs

Building on the Literature Reviews presented in Section 2 and the Case Studies presented in Section 3, the lessons learned were organized into five specific suggestions for the organization to effectively implement and use KPIs.

4.1 Creating an operational improvement based culture will help develop KPIs.

Building a culture of operational improvement builds team development, creates more buy-in, and ultimately drives better results. This culture advances the improvement process for KPIs. Building an embracing culture for change and improvements within your organization will drive better results from using your KPIs.

Case Study #1 showed that one misconception with continuous improvement could be the addition of workload to certain people or departments. It is important to deliver the positive message that KPIs as less work for all and make workflow transition in a smoother fashion. KPIs and continuous improvement need to be the way an operation functions, not an addition to your existing workload. This way there will be more buy-in which is critical to the success of a KPI driven system. This kind of culture will drive continuous improvement.

Case Study #4 showed that when working with a startup company and on the front end of developing KPIs, knowing your teams capability is important. Not everyone comes from a background of working at an established operating facility and this was evident at this new facility. Organizations with a positive operational improvement culture embrace KPIs and know why they are needed. The beginning information of what was going to be measured needed to be defined and well organized. This up-front culture of building the right system helped develop the KPIs.

Management driving the improvement culture plays an important role in the teams overall development. Case Study #5 showed that working with a team

that is not familiar with KPIs needs managements guidance to understand their importance. However, as case study #1 showed, keeping the KPIs simple in such environment will help get buy-in and support the culture.

4.2 Developing KPIs that are clear, organized, and easily measured will drive better implementation.

The case studies show that being measurable is critical for KPIs to be implemented. KPIs need to be data/information driven. Accurate, reliable, and timely information is vital to effective decision making in every aspect of reliability assessment and maintenance [15].

Case Study #2 showed that in order to improve on what is already being performed, good data is a needed measurement. The spreadsheet information used in this case study was sorted and organized in order to be used. KPIs were then developed from this spreadsheet information.

Case Study #4 showed that when working with a startup company and on the front end of developing KPIs, knowing your teams capability is important. Not everyone comes from a background of working at an established operating facility and knows what a KPI is needed for. The up front information of what was going to be measured needed to be defined and well organized. Standardized templates need to be incorporated for a new processing facility to drive a better implementation.

4.3 Empowering the five 9's concept will improve the reliability of KPIs.

The reliability of a facility can be improved with the use of KPIs. With the team's understanding what five 9's stood for drives a better understanding of how to improve the reliability of KPIs. This will also improve the general KPI knowledge base of your team.

To enhance competitiveness, companies embraced variety of different management programs over last two decades. Currently, one of the programs is Six Sigma methodology which is another term for five 9's. Six Sigma focuses on improvement of complex business processes in order to reduce variations and solve process along with business problems. Applying Six Sigma management philosophy means to undertake strategic and disciplined, customer and process centric, data-driven approach to performance improvement. Its main objective is to improve processes to meet or exceed customer requirements and enable organizations to operate better, faster and at a lower cost achieving operational excellence. Six Sigma projects need to be carefully selected, planned, and reviewed, to maximize the benefits of their deliverables. In order to do so, the projects have to be feasible, organizationally and financially beneficial, and customer oriented. [29] Where this ties into maintenance is the improvement of reliability. The concept of implementation of Six Sigma methodology was pioneered at Motorola in the 1980s with the aim of reducing quality costs. Six Sigma methodology has evolved into a statistically oriented approach to process, product or service quality improvement. It is a business performance improvement strategy used to improve profitability, to drive out waste in business processes and to improve the efficiency of all operations that meet or exceed customers' needs and expectations. A performance level of Six Sigma equates to 3-4 defects per million opportunities, which leads to a 0.99999 performance rate. The sigma is a statistical measure of the amount of variation around the process average [30].

It is fair to state that the disciplined and systematic methodology of Six Sigma combined with the speed and agility of lean manufacturing will produce greater solutions in the search for business and operations excellence [18].

Case Study #3 showed that KPI measurement precision plays a role for improvement, especially with all of the interdependencies of the various KPIs. Many times this comes down to what is physically taking the measurement in the field. The simple answer of adding more inventory in between different process steps is very expensive and not sustainable. Inappropriate processing is one of the types of lean manufacturing waste and is defined as using inappropriate set of tools, procedures or systems, often when a simpler approach may be more effective [19]. Being more effective increases reliability and the concept of six sigma gets you closer to the 0.99999 measurement. This was worth doing as the measuring improvements increased production and reduced waste. Verify data/measurements for accuracy.

Case Study #4 showed that when economics are good, the company is hesitant to allocate down time to perform maintenance. It is also showed that when economics are poor, the company is hesitant to allocate money for maintenance. As a result, a strong maintenance request that is well defined and backed up with KPI driven statistics is needed to garner more back up from management. These KPI driven statistics have high reliability and when they are being measured can be improved upon towards six sigma quality.

4.4 Generating quick-win KPIs with your team will lead to longer term operational improvement.

The implementation of KPIs needs to have quick-wins associated with them for longer term success. Operational improvement was shown in three of the case studies and getting the teams involved in the beginning of KPI development drives better implementation and success.

Case Study #1 showed that KPIs should not be viewed as a burden for all and to make the team grow together for operational improvement. Buy-in is needed for the success of a KPI driven system as well. KPIs and continuous improvement need to be the way an operation functions, not an addition to someone's existing workload. This starts with getting quick-wins within your team.

Case Study #4 showed that it is easier for a manager to work at a facility where the current workforce has been established and knows what has to be maintained without being given a specific work order. When the workforce has not worked on the current equipment, it makes it difficult for the team to develop KPIs for improvement as they have no basis of equipment knowledge. This takes time and extra needed care in the front end development of KPIs to make sure the required information for improvement are included. The first developed KPIs need to be easily developed and have some up front improvements associated with them to help drive the implementation.

In Case Study #5, having a previous background working at facilities where the consulting work was to take place helped develop the team in knowing what the client is looking for. This in turn helped generate quick-wins for the team because the author had a good understanding of the client. The saying "Ask what the client wants and perform the work the client asks for" may seem trivial, but is found to be very accurate. The attitudes of the team members changed, embracing the KPIs after those quick-wins.

4.5 KPIs need to be improved upon with targets being reevaluated and new measurements added.

It is important that after improvements are made, KPIs need to be updated accordingly. This is because operations change over time and their measurements need to be updated too. People can become complacent and ignore the need to reevaluate the KPIs for operational improvement. The motto “Today’s records are tomorrows standards” is real in operations. In addition, improvements made in certain areas of an operation can lead to a different bottleneck that was never realized before. This brings the need for evaluating your KPIs overtime and making adjustments as needed. KPIs need to be improved upon to continue to drive operational excellence. This involves initial targets being evaluated over time and adding new targets as needed.

Case Study #1 showed that the implementation of KPIs are not to disregard the current work that is already being completed. A lot of KPIs are introduced into an operation that already functions and only needs a nudge in the right direction for improvement. KPIs are sometimes just a streamline improvement of existing work. This existing work needs to be evaluated over time.

Case Study #2 showed that KPIs were developed in order to track membership. Once these new KPIs were set up, other areas that needed to be improved upon became more clear. This was revealed with the missing email addresses and seeing when the memberships were lapsed. New KPIs need to be developed over the process of time as they are not obvious at a beginning of a project.

Case Study #3 showed that work was performed in the area of operational improvement. Most of the KPIs used were already developed and minor changes were needed. The improvement part came from actually using the KPI’s for sustained success. This started with verifying the numbers used were coming from an accurate source. After that, making sure they graphed properly with the

correct upper and lower limits for control. The refinement of KPIs and incorporating maintenance into the operation strategy drives continuous improvement. This refinement is continually needed to drive operational excellence.

In Case Study #4, KPIs used in a former working place were adopted to provide a starting point for the new startup facility when the author moved there. These baseline data metrics were needed to determine the proper maintenance intervals at the beginning. As the maintenance process continues at this new facility, the KPIs will need to be improved on over time.

5.0 Conclusion

Through literature reviews, it was realized that there are a lot of KPIs developed in maintenance, but not a lot in operations. The importance of KPIs is obvious and not new, but one can't just use maintenance KPIs in the place of operations KPIs. Maintenance KPIs can help operations better develop and use their own set of individual KPIs.

This work made contributions to operations improvements by suggesting ways for organizations at different levels to better implement KPIs. Suggestions drawn from the operations and maintenance fields are to improve relevance and use of KPIs.

Through case studies, suggestions were made for organizations at different levels. Specifically they are:

- Creating an operational improvement based culture will help develop KPIs.
- Developing KPIs that are clear, organized, and easily measured will drive better implementation.
- Empowering the five 9's concept will improve the reliability of KPIs.
- Generating quick-win KPIs with your team will lead to longer-term operational improvement.
- KPIs need to be improved upon with targets being reevaluated and new measurements added.

For companies to improve while using KPIs, this thesis helped develop a series of suggestions as my contributions to this important work; know your stakeholders, identify the "why" an improvement needs to be made, describe the importance of KPIs, measure and communicate your success, and plan to make changes throughout your improvement process. Improving these identified factors are critical to the success of KPIs.

This research has some limitations. Information presented in the case studies was mainly obtained from prior work experiences that tie into the

literature reviews. The analysis in which the suggestions were based on were mainly qualitative, which has minimal numerical data to support the suggested improvements. Exact data is not available for use. Future studies can perform quantitative analysis to test the suggested the series of steps in different business settings to test the effectiveness.

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