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—

Winter 2016

RMS Reliability, Maintainability and Supportability PARTNERSHIP

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Introduction

JAMES RODENKIRCH

Keeping Alert to Areas of DoD Where RMS Efforts Could be in Jeopardy

The National Defense Industrial Association's October, 2016 e-newsletter contained an article titled, "*Army stands up office to develop new capabilities*." With multiple alerts regarding our adversaries around the globe bolstering defense spending, DoD leaders are "standing up a slew of organizations across the Pentagon aimed at cutting red tape and rapidly acquiring new technology and capabilities." One of these organizations, the Army's rapid capabilities office, the RCO, "will expedite the acquisition of select capabilities to meet soldiers' immediate and near-term needs"…serving "as the breeding ground for ideas that enable a more agile and innovative acquisitions process," said Secretary of the Army Eric Fanning.

Mr. Fanning said the RCO's initial focus "will be on the execution of rapid prototyping and equipping within the areas of electronic warfare, cyber, survivability and position navigation." He also stated they "are not embarking on creating new systems or new platforms." They won't focus "on building a new helicopter, but we would turn to this office if some capability on an existing helicopter is no longer sufficient."

The RCO will have a short chain of command, making it more nimble and quick to respond when meeting operational demands, he said. It will have a board of directors, which Fanning will chair. Members include the Army's acquisition executive, Katrina McFarland, and Army Chief of Staff Gen. Mark Milley.

Mr. Fanning said "We're not aiming for the perfect solution that will field to the entire Army 15 or 20 years down the line." RCO Director Douglas Wiltsie emphasized "RCO differs significantly from the Army's already established Rapid Equipping Force (REF). The REF does "very little modification," and the RCO "will do some level of development, mostly integration pieces." Additionally, the REF's "sweet spot" is delivering a technology within a day to a year of receiving a request, he said. The RCO, on the other hand, is focused on addressing a capability within one to five years.

It seems like a positive approach to "speeding the development and acquisition process up," but any time I hear/see reports of speeding up development and integration, I'm reminded of the age-old heuristic, "You can have it faster, cheaper and/or better. Pick two of the three." I can see the "illities-engineering resources" falling off the "invited to meeting(s) lists." Let's hope not…but I found no wording such as Systems Engineering or any of the "illities" mentioned once…just a tad worrisome and something the RMS community needs to keep an eye on.

A STEM Address to Grade and High School Students

I've been watching what's going on in the area of Science, Technology, Engineering, and Mathematics (STEM) education at the grade and high school levels as well. First off, Ralph Tillinghast has been pushing me to join him in authoring a Stem-focused article for the spring 2017 Journal. It's an area where the more ideas out there for subject matter and the broadening of topical areas for the promotion of STEM the better.

Ralph and I see three notional areas ripe for articles:

1. STEM and ethics considerations
2. STEM - currently focused on S&E
    - suggest expansion in to the Systems Engineering (SE) realm

- Broad brushstroke look at SE and specific focus areas for STEM presentation

3. How to encourage 'baby-boomer generation' with STEM careers entering retirement to give back and promote STEM in their community

We're uncertain of which one to tackle first—but!—consider this a "call to author an article" across the readership, especially #2. If you have ideas on what's needed to present S.E. principles and approaches to a newly STEM-influenced group(s) of middle or high school, let me know your thoughts on an article and get on with writing something up.

I submitted an outline for a Systems Thinking presentation to the local county school board's STEM point of contact. The presentation can be modulated to fit the needs of middle or high school students and can be 30 to 60 minutes in duration. I received an invite to present to twenty five 11 and 12 year olds who had just finished their first trimester at learning how to program a 3D printer; their ultimate goal is to produce a device for use by people with disabilities. The students are not in the "top percentile" of their classes…just interested in learning more. I gave the 40 minute presentation in mid-November and here are my observations and Notes to Self:

- Eleven and 12-year-olds have a short attention span—shorten any presentation to 30 minutes.
- Use simplest terms/words e.g., *reductionist* stumped them, momentarily, until the teacher chimed in.
- A mixture of so-so and smarter type students—out of a group of 25 students, about six or seven really got in to it, e.g., asking questions, volunteering answers.
- The teacher told me they'd have their note-pads with the presentation so I said, "don't print it." Well, he didn't start handing out the note-pads until I started the presentation which caused lots of disruption for the first 5 minutes—*ensure teacher and you are in sync re coordination of potential disruptors*.

It was a learning experience and I'd do it again.

Summary of Journal Content

We have four articles ready for this Winter 2016 Journal. First up is R*eliability, Maintainability & Supportability Considerations for Constructing a STEM Outreach Organization* by Mr. Ralph Tillinghast and Dr. Mo Mansouri. Mr. Tillinghast and Mr. Mansouri focus on optimizing a STEM organization through a Systems Engineering lens. They delve into the critical roles Reliability, Maintainability and Supportability play in ensuring the organization's success and discuss three of its critical attributes—the organizational structure, the personnel operating within the organization, both running the organization and delivering outreach, and the STEM material being delivered. Ralph is a second time author and we look forward to future articles.

Our second offering, *A Simple Procedure for Grouping and Optimizing Preventive Replacement Times,* was authored by Sharon Honecker. Ms. Honecker establishes corrective and preventive maintenance strategies and looks at methods and approaches to optimize replacement times for individual components and groups of components. This is Ms. Honecker's first submittal and we hope to see more from her.

The third article, authored by Katherine Pratt, is *Global Supply Chain Management (GSCM)*. Ms. Pratt's focus is on GSCM and its vulnerabilities. However, bounding the context of GSCM so that specific vulnerabilities can be discussed became a monumental task— GSCM cuts a wide swath. So the decision was made to have Katherine provide two articles. This offering provides a comprehensive review of GSCM, from its infancy to present day. A second article on its vulnerabilities will be offered in our Spring 2017 Journal. Kate is a repeat author and member of the Partnership's Board—we are glad she enjoys researching and writing on the myriad topics she delves into.

Our fourth author, John Byler, provided an article on Reliability-centered Maintenance (RCM). John walks us through an introduction of RCM, its overall analysis process and a simplified decision logic approach. Especially note worthy is the observation that RCM methods should be implemented as part of the total life cycle process when evaluating systems from a life-cycle cost perspective. That is, "RCM is part of the early system design process that evolves during the development and continues through the production, and deployment phases of the life cycle process." This article is an excerpt from: "System Engineering Management, Wiley, 5th Edition, Benjamin S. Blanchard, John E. Blyler ISBN: 978-1-119-04782-7 February 2016 *http://www.wiley.com/WileyCDA/WileyTitle/productCd-111904782X.html*. Permission was received for us to reuse and we thank John for going the lengths needed to republish this article.

So there you have it—four articles, eclectic enough hopefully, to hold your interest—happy and, hopefully, informative reading. By the time we "publish" this Winter 2016 Journal, Thanksgiving Day will have passed and Christmas will be right around the corner. From the RMSP Journal staff and authors: best wishes to you and yours during this holiday season. Happy Holidays and Happy New Year.

Reliability, Maintainability & Supportability Considerations for Constructing a STEM Outreach Organization

RALPH TILLINGHAST & MO MANSOURI, PH.D.

Abstract

With the increased focus on STEM education and the growing number of organizations trying to meet this need, a better understanding of how these organizations should be constructed and operated is desired to ensure that their ability to promote STEM is optimized. Viewing a STEM organization through a Systems Engineering point of view can aid in this optimization. Within the Systems Engineering framework are three fundamental operating philosophies that are critical to the success of any system or organization: Reliability, Maintainability, and Sustainability (RMS). These three areas each play critical roles in STEM outreach organizations at multiple levels. Further, a STEM outreach organization can be broken into three distinct attributes; the organizational structure, the personnel operating within the organization, both running the organization and delivering outreach, and the STEM material being delivered. Each of these are required to deliver STEM content successfully to the target stakeholders and each of these is impacted by RMS. Overall this paper's goal is to highlight the role RMS has in any social system and present possible findings that may positively impact either an existing, or the creation of, a new STEM outreach organization.

Index Terms Classroom, Education, Maintainability, Reliability, Social Systems, Sustainability, Systems Thinking, Systems Engineering, STEM, Organizations, Outreach.

Introduction

Within the context of System Engineering the importance of Reliability, Maintainability and Sustainability (RMS) is well documented as applied to any system throughout its life cycle. These three systems philosophies apply to both utility and organizational systems. Utility being based on physical systems such as transportation or manufacturing systems and social being based on organizations of people working towards a purpose. This paper looks to focus on organizational systems, specifically Science, Technology, Engineering and Math (STEM) outreach organizations.

The need for STEM professionals is well documented[1] as our societal issues become more complex and technologies increase. To add to this urgency most Federal government agencies are required to hire only United States citizens. This poses a significant issue based on the decline in students graduating with STEM based careers.[2] This need has not gone unnoticed and measures have been put in place to aid in increasing STEM professionals. An estimated $2.95 billion was spent by the federal government alone in 2015, with further spending of $3.06 billion in 2016 estimated.[3] This only represents the federal spending to promote STEM, when you take into consideration other funding such as state, corporations and individuals the total number is vast. Because of its importance and the increased funding levels it is critical to ensure that the method for which funding is spent is optimized, which is an area in which some research has been conducted.[4] The methods that STEM outreach can be conducted are varied and well documented.[5,6,7,8] Each method servicing different stakeholders with a common goal to promote the overall interest in STEM. This paper looks to focus on the establishment or operation of a STEM outreach organization. Specifically an organization is established to provide outreach to its local community. This can be typically achieved by placing science and engineering (S&E) professionals into classrooms to provide workshops or support teachers,[9] providing summer camp activities,[10,11] supporting job fairs or science fair type events, conducting tours and other activities such as these. The purpose of this paper is not to go into depth on the different types of outreach but how RM&S can impact the operation of this type of organization. Throughout this paper, the Picatinny STEM office will be used as a base model of the organization and to provide examples of RM&S philosophies. This office has been previously documented[7] which is provided in Appendix A for further context and background. The following three sections briefly outline some of the RM&S philosophies as they relate to STEM organizations.

Reliability

Reliability is a critical characteristic of any system as it ensures that the desired performance of the system is delivered over time with no disruptions. A basic metric for understanding reliability is measuring the downtime of the system due to failure. Failure of an organization may be the result of physical items breaking. For example a car breaking down on the way to an outreach event would be a form of failure of the organization not providing outreach. The failure could also be more subtle or discreet, such as an outreach professional not answering a student's question in the best manner to ensure optimal learning. Both of these examples illustrate the need to fully understand the desired system performance to ensure the system is reliable. It should be noted that the system performance is related to the customer needs but these are not the only influencing factors. For example many STEM outreach programs are designed to provide STEM learning but also to act as a marketing tool for the operating organization. For some industry partners, this "marketing" system performance is more important that the actual learning provided. This also eludes to the many stakeholders who are involved, such as students, teachers & administrators, STEM professionals, family members, the local community, corporations and businesses that provide outreach. All of these have a different definition of what a reliable STEM outreach organization should look like and deliver. It is beyond the scope of this paper to discuss every stakeholder's reliability needs but will focus on the reliability of an outreach organization to meet its desired goal, mission and vision. Which as indicated above may be different for every organization.

Maintainability

Just as reliability is critical, maintenance of an organization plays a major role in ensuring that the organization has the longevity to meet the desired system performance. As commonly defined, maintenance revolves around a system's ability to be restored and repaired so that it is capable of continuing to meet its desired operational service. This may include using internal or external resources to conduct prescribed processes and procedures. Not only providing maintenance but optimizing the organization's operation to fully meet those system performances. This eludes to the many multi-functional tasks required for fully maintaining any organization, such as developing predictive models of possible failure points so they can be addressed during maintained processes. This also leads directly to the need to take measurements and metrics on your system so you have the ability to fully characterize the system to develop those predictive models mentioned above and also identify when the organization is not operating as desired. Lastly a cornerstone of maintenance is developing the needed philosophies and maintainability requirements to continue to operate and also adapt to changing requirements. It could be argued that social systems such as a STEM organization will have a more volatile change in customer's needs, which will require a maintainability philosophy that can adjust to these changes. This may be supported by the view that an organization can be more flexible and adapt quickly, compared to say an automotive assembly line for example, which requires new tooling and infrastructure to adapt to a new customer's desires. For this example, it is not too unrealistic to consider that part of the automotive industries maintenance philosophy is to closely maintain customer's conceptions of what a desired car looks like, so they can maintain the use of existing assembly lines with minor exterior changes to cars. Thus allowing for the manufacture to maintain the use of established factories.

Supportability

The third sibling of the RMS family is supportability, supportability is described as a system's ability to address issues, failures or anomalies within the system. This includes identification, classification, isolation and timely corrective action to resolve the issue. Further, many attributes fall within the supportability framework, such as the system design, technical data, methods to diagnose and prognosis issues so they can be resolved and keep the organization operating at its full strength. Just as the maintainability philosophy of an organization will need to continuously adapt to changing customer needs, the supportability philosophy will need to adjust also. For example, during a calendar year, technology trends may shift, bringing a new technology to the forefront, because of this an increase in outreach requests may be found. This has recently occurred with the increased capability of additive manufacturing. Many STEM organizations found themselves unable to support requests from teachers to aid in introducing this technology to their students. This resulted in many programs being developed[12,13,14] resulting in a quick response to support the change in requirements.

These last sections only outlined the high level role of RMS as related to STEM outreach organizations. To further explore the role of RMS within a STEM outreach organization three main attributes will be discussed in detail. These being the Organization, Personnel and STEM Materials. To aid in visualizing these three attributes, Figure 1 illustrates a high-level conceptagon for STEM outreach organizations.

As illustrated, the three holistically linked attributes of the conceptagon encompass the key components of the outreach system: the organization, the personnel delivering the content and the STEM content being delivered. Although each of the RMS disciplines can be treated separately, this discussion will highlight how they each impact one another within the context of Figure 1. Illustrating when all three are addressed, you can begin to optimize the organizational operation across the RMS disciplines.

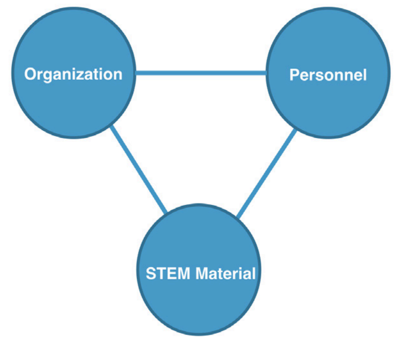

Figure 1 — Conceptagon for a STEM Outreach Organization Structure

Part I: Organization

The organization structure is described as the fundamental elements that allow for the organization to operate. For the Picatinny STEM office example the organization would follow the base structure as shown in Figure 2.

This example may not be the ideal organizational structure but does represent the base areas of an outreach organization. Within this model conducting outreach (on and off post), supporting teacher growth by providing training on methods of education and on the latest technologies and while providing consulting support to other stakeholders is all needed to promote STEM. The research element in the model is to ensure that the programs developed and utilized by the office are documented and validated as being effective, this also allows for documenting of best practices. Lastly the marketing and operations elements are to ensure that the office operates properly and continues to reach the correct stakeholders.

The overall RMS system is set in place by the overarching organization. As referenced above this is accomplished by clearly defining the desired system performance. Beyond defining the organization one must then maintain operations that meet the desired performance levels. To maintain operations many factors need to be addressed such as funding, staffing, scheduling, marketing and collecting feedback. These areas that need to be maintained will also influence the reliability of the system. Three of these factors are discussed below:

Funding

A reliable cash flow sets a base for operations to run smoothly, if funding is not provided the system cannot reliably

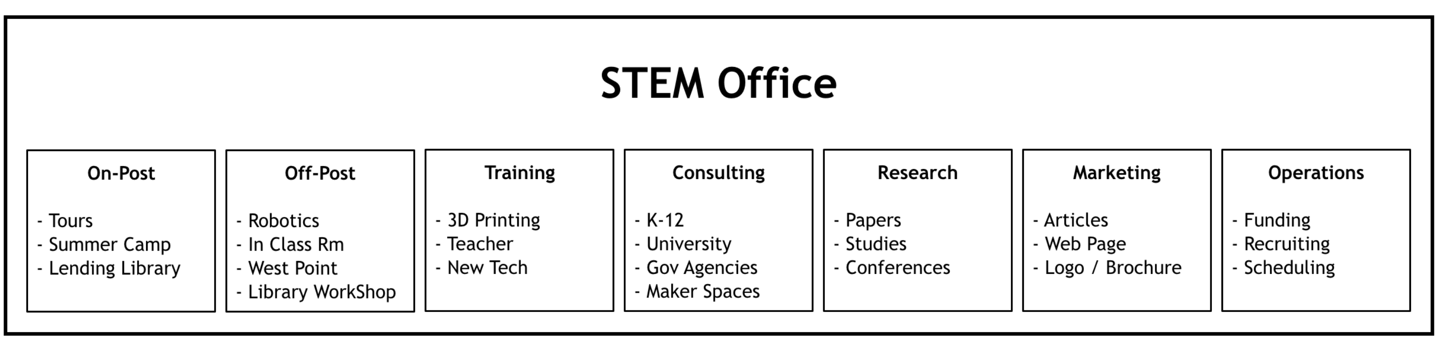

Figure 2 — Example STEM Organization Structure

provide the outreach required. This can occur by not having funds to pay for out of pocket expenses (materials or travel costs), but can also stress the system if an insufficient number of personnel are overworked due to funding shortages to hire more help. Because of this there needs to be clear structure within the maintainability plan to ensure that existing funding sources are maintained and also new funding sources are being identified.

Staffing

To ensure that the organization operates reliably the correct personnel positions need to be identified and the correct number of employees in each of these positions must be identified and managed. Further, systems need to be put into place that ensure these positions are being monitored in reference to the desired performance levels. This ensures an elastic organization structure that can add or reduce staff depending on event cycles. Following the Picatinny STEM outreach example, during the end of school year an increase in requests for post tours has been found. This results in an increased need of S&E professionals to support tours. By tracking these trends and ensuring staffing needs are identified we can increase support without disrupting reliability of operations. This is achieved by having a clear supportability plan and philosophy that predicts change and demand based on past metrics.

Scheduling

Using the Picatinny STEM organization as an example, scheduling is the number one driving factor for reliability of the system. This is due to the number of requests and customization of these requests. Meeting the teacher's needs allows for maximized teacher support. Because of this, each outreach program is unique to the teacher, with 100's of requests each year and over 100 S&E professionals providing outreach, coordinating and scheduling this level of support puts strain on the reliability of the system. In the past this strain resulted in poor reliability in providing outreach, it was very easy to miss requests and not fully develop the outreach desired by the teacher. To improve the systems reliability an automated request process was established, allowing teachers to submit a request for outreach. Within this request form metrics and the desired support levels are identified so the correct S&E professional can be identified and supported in scheduling the event. This also allows for flexibility and redundancy as multiple S&E professionals can be selected to support the same event or staffing can be shifted to ensure the same person is not overdoing it.

These three sub areas of the organization only highlight some of the RMS considerations. Another major area touched on in previous discussions is fully identifying the desired performance of the system which allows for the RMS philosophies to be fully developed and documented. This increases stability of the everyday operation but also allows the organization to adapt and grow as needed based on the systemic forces that are applied to the organization and all of the stakeholders.

Part II: Personnel

The personnel within the STEM organization can be broken into two groups, those operating the organization and those who are providing the outreach to the stakeholders. The model utilized for the Picatinny STEM office is a small full time operating staff (3–4 personnel), with a large part time outreach staff (~150 personnel). This latter group of personnel can be identified and tasked with providing a specific outreach as needed. For example if a teacher requests to have a workshop on astronomy, operating staff searches the index of 150 S&E professionals and finds the correct match. This increases the supportability and reliability of the program to meet the teacher's needs. It should be noted that this is an example of a large outreach provider but this model can be scaled up or down depending on the desired support.

As alluded to in the above organizational staffing section, your personnel play a critical role in the reliability of the system. This relates to both the number of the personnel available to meet the outreach needs and the S&E professional's ability to meet the teacher's specific needs. This could also be looked at as the quality of the S&E professional, or do they have the correct tools to work with all different demographics of students. Just within these areas a number of considerations related to RMS revolving around personnel can be identified, such as, availability, knowledge base, communication skills and dependability.

Availability

As referenced in the scheduling section, ensuring that the needed personnel are available will ensure the organization operates smoothly and reliably. Following Baxter and Harche's work[15] on constricting series and parallel systems to increase reliability, if one increases the number of S&E outreach personnel you increase the reliability as you have more resources to pull from. This can also be further optimized by sending multiple personnel to support events as a parallel model, resulting in both passive redundancy (large pool of personnel to pull from) and active (multiple personnel in

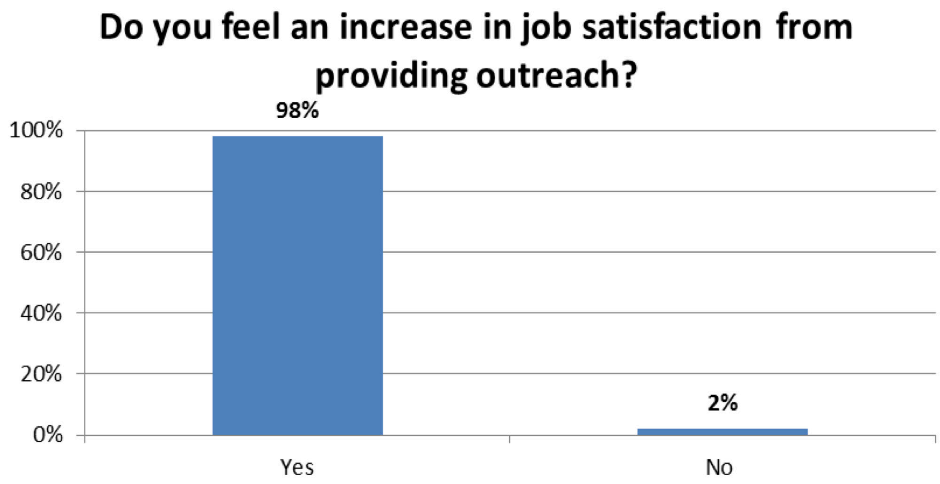

Figure 3 — Impact of Job Satisfaction from Providing Outreach

the classroom). Sending multiple personnel to an event also increases reliability for the outreach as it can mitigate failures such as the earlier example of the car breaking down. Lastly, having more than one person at outreach events insures that there is a feedback process as part of the outreach event. This allows for the material being delivered to be optimized and teachable moments are not missed due to S&E professionals supporting each other.

Dependability

Employee reliability can depend on many factors, both internal and external to the organization. Of these, job satisfaction, has the potential to impact the organization greatly. Much research has been conducted on understanding happiness and satisfaction.[16] From this research it is well accepted that a state of "flow" can be achieved if the person feels they are doing work for a greater good. Conducting STEM outreach can fall into this arena, as you are teaching and working with young minds for the overall betterment of humanity. This correlation was validated in a recent survey of STEM outreach personnel as illustrated in Figure 3, which showed a 98% of STEM outreach professionals felt an increase in job satisfaction from providing outreach.[17]

Lastly the Personnel of an organization need to be maintained, this includes annual reviews, continuous training (which will be further discussed in the next section) and ensuring they feel they are part of the team and are aiding in achieving the organizational goals. This comes back to your RMS philosophies, which need to lay out how personnel are treated and emotionally supported. For example this could include clear recognition strategies being established and maintained as part of your organizational maintenance plan.

Part III: STEM Material

The third component of the conceptagon originally illustrated in Figure 1, is the information or STEM material being delivered. This material is a very critical component of the outreach organization and must be carefully tracked and developed. This is due to multiple factors, one being the rapid change in technology which must be conveyed to the teachers and students so they are aware of the current state of the art. Which as mentioned before in the 3D printing example can occur very quickly, and often occurs due to disruptive types of innovation.[18] Beyond just the awareness of the information, the STEM material must be understood so that it can be delivered at different levels of complexity. This is to ensure it can be absorbed by all levels (Pre-K to Senior Citizens) that outreach is provided to. Within the same survey referenced in the last section Figure 4 illustrates the demographics supported by the same S&E personnel.

Not clear in the chart is that the "Public Events & Location" outreach included library workshops for older generations (parents, grandparents, aunts and uncles) in hopes to reach younger minds through their family members. Along with staying up to date on the technical information is ensuring that the outreach providers understand the teaching methodologies being utilized in the classroom outside of

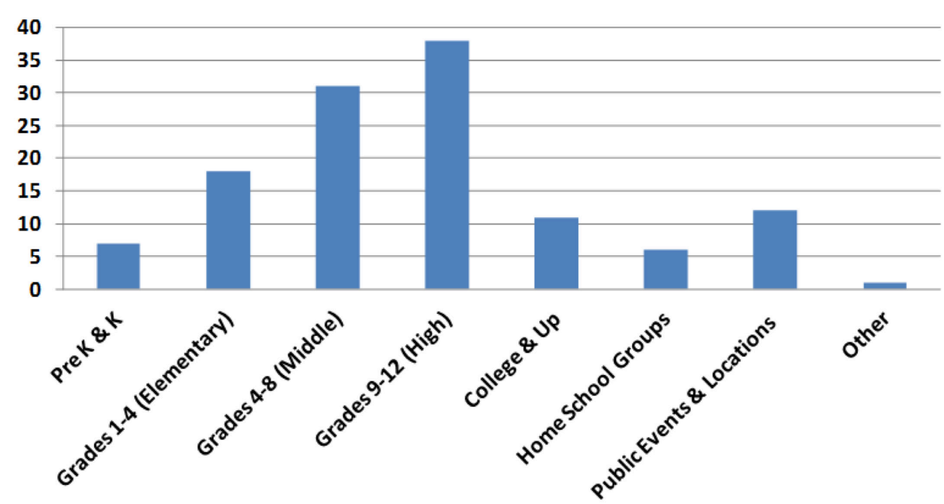

Figure 4 — Age Demographics for Outreach Support

traditional methods, such as active, Inductive and problem based learning.[19,20,21] This ensures that they can optimally support the teachers. This understanding needs to be part of the educational maintenance plan, both reviewing the methods being used but educating the personnel on how to use and interact with it. All of this requires a clear method and process to ensure that the outreach providers are continuously being trained and educated as mentioned in Part II.

Conclusions

Based on the discussion presented throughout this paper it is clear that RMS has a very important role in STEM outreach organizations and other social systems. The three attributes, Organization, Personnel and STEM Material, are all required to ensure the organizational system operates properly. Each of these areas could be further broken down and discussed in greater detail but would still highlight the overall importance of RMS. Not highlighted previously is the importance to ensure RMS principles are considered early on when developing a STEM organization. Further it is even more critical to review and update the RMS philosophies within the STEM organization regularly to ensure they adapt to any changes and that the system is being optimized to deliver its desired performance goals. As for any system the RMS tasks and concepts are never completed and must be worked on to optimize any system. Utilizing these RMS tools will enable better STEM outreach organizations to impact young minds, which hopefully aid in their ability to solve the complex and difficult problems of the future. Overall RMS has a large role in any social system and can positively impact existing, or the creation of a new, STEM outreach organizations. ●

References

1. (2011), "The Federal Science, Technology, Engineering and Mathematics (STEM Education Portfolio", Federal Inventory of STEM Education Fast-Track Action Committee, National Science and Technology Council
2. Kuenzi, J. J. (2008). "Science, technology, engineering, and mathematics (stem) education: Background, federal policy, and legislative action", Congressional Research Service, RL33434, www.crs.gov, last viewed May 2016
3. (2015) "Progress Report on Coordinating Federal Science, Technology, Engineering, and Mathematics (STEM) Education", National Science and Technology Council
4. R. Tillinghast & M. Mansouri, (2016), "Influencing Factors in Identifying the Optimal Age for Conducting STEM Outreach", Integrated STEM Education Conference, IEEE, Princeton NJ
5. K. Unertl, et all, (2016), "Developing new pathways into the biomedical informatics field: the AMIA High School Scholars Program." Journal of the American Medical Informatics Association: ocw036.
6. A. Kney et all, (2016), "Transforming STEM to STEAM: How a Traditionally Run STEM Camp Successfully Incorporated the Arts into Its Framework", Integrated STEM Education Conference, IEEE, Princeton NJ
7. R. Tillinghast & E. Petersen, (2016) "Establishing a Balanced Organizational Structure for Large STEM Outreach Programs: Adopting the 10, 20, 30, 40 Rule", Spring 2016 Mid-Atlantic ASEE Conference, George Washington University, DC, April
8. Duschl, R. et all (2007) "Taking Science to School: Learning and Teaching Science in Grades K-8" ISBN: 0-309-10205-7, National Academy of Sciences, National Academy of Sciences, Washington D.C.
9. Tillinghast, R. et all, (2016) Learning Methods to Construct K-12 STEM Outreach: Invention and Innovation Workshop Case", Integrated STEM Education Conference, IEEE, 2016, Princeton NJ
10. J. Burtner, (2001), "The Use of Quantitative and Qualitative Measures to Evaluate a Summer Camp for Elementary School Girls" American Society for Engineering Education Annual Conference
11. A. Sala, et all, (2014), "Stimulating an Interest in Engineering Through an 'Explore Engineering and Technology' Summer Camp for High School Students", American Society for Engineering Education Annual Conference
12. O. Knill, E. Slavkovsky, (2013), "Think Like Archimedes with a 3D Printer," Department of Mathematics, Harvard University.
13. Tillinghast, R. et all (2014) "Integrating Three Dimensional Visualization and Additive Manufacturing into K-12 Classrooms", IEEE Integrated STEM Education Conference.
14. Flynn, Eric P., (2012) "Design to Manufacture – Integrating STEM Principles for Advanced Manufacturing Education", IEEE Integrated STEM Education Conference.
15. L. Baxter & F. Harche, (1991), "On assembly of series-pararellel systems", Operations Research Letters, Vol 11, Issue 3, pp.153
16. M. Csikszentmihalyi, & I.S. Csikzsentmihalyi, (1988). Optimal Experience: Psychological studies of flow in consciousness. Cambridge, United Kingdom: Cambridge University Press.
17. Tillinghast R. et all (2015), Utilizing Science and Engineering Professionals in the Classroom: How Your Workforce Can Positively Impact STEM and our Company's Bottom Line", IEEE Integrated STEM Education Conference.
18. C. Christensen, (1997), "The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail", Boston, Massachusetts, USA: Harvard Business School Press
19. Anderson, Richard, et al. (2007), "Supporting active learning and example based instruction with classroom technology." ACM SIGCSE Bulletin 39.1: 69-73.
20. M. Prince, and R. Felder, (2006), "Inductive teaching and learning methods: Definitions, comparisons, and research bases." JOURNAL OF ENGINEERING EDUCATION-WASHINGTON- 95.2 (2006): 123.
21. W. Hung, et all, (2008), "Problem-based learning." Handbook of research on educational communications and technology 3: 485-506.

A Simple Procedure for Grouping and Optimizing Preventive Replacement Times

SHARON HONECKER

Abstract

When purchasing a piece of equipment, it is necessary to consider both the cost to acquire the equipment, or the capital cost, and the cost to maintain the equipment, or the recurrent cost[1]. The recurrent cost can vary greatly depending on the type of maintenance strategy that is employed. The optimum replacement time calculation is an important consideration when deciding on the best maintenance strategy to keep recurrent costs in check. This paper introduces corrective and preventive maintenance strategies and then examines how to optimize replacement times for individual components and groups of components.

Introduction

Corrective maintenance, or run to failure, is a strategy where a component is repaired or replaced only when a failure occurs. There are several scenarios where this type of maintenance strategy makes sense. One example is when a component exhibits infant mortality (i.e., has a Weibull shape parameter less than one). In this case, a new component is more likely to fail than one that has survived for some time. Therefore, replacing such a component with a new one will make the system less reliable. A second example is when a component exhibits a constant failure rate behavior (i.e., has a Weibull shape parameter equal to one). In this case, the probability of failure is not dependent on the age of the component. Therefore, replacing such a component with a new one will have no effect on system reliability while having a cost associated with procuring a new component and possible cost associated with downtime due to performing the replacement. For numerical examples of this case, see.[2] A third example is when a component exhibits a wear out behavior (i.e., has a Weibull shape parameter greater than one) and the risk, or cost, associated with preventive replacement is greater than the risk associated with allowing the component to fail before replacing it.

Preventive maintenance is a strategy where a component is repaired or replaced at a specified age before the component fails. This type of strategy makes sense only when both of the following conditions are met:

1. The component exhibits an increasing failure rate behavior (i.e., has a Weibull shape parameter greater than one).
2. The risk, or cost, of waiting until a component fails to repair or replace it is higher than the cost of repairing or replacing the component before it fails.

Using the failure distribution of the component, an optimum replacement time can be computed by finding the time, t, that minimizes the cost per unit time (CPUT). The CPUT for a single component is given by Equation 1:

$$CPUT = \frac{C_{PM} \cdot R(t) + C_{CM} \cdot [1 - R(t)]}{\int_0^t R(s)ds}$$

Equation 1

where,

C_{PM} is the cost to preventively maintain (replace) the component,

$R(t)$ is the component reliability at time, and

C_{CM} is the cost to correctively maintain the component.

Optimum Replacement Time for Individual Components

Consider a system where a preventive maintenance strategy is being developed. The following six components in the system exhibit an increasing failure rate behavior and would be less costly to preventively replace than to run to failure: oil and oil filter, water pump, timing belt, air filter, spark plugs, and fuel filter. One could compute optimum replacement times for the components by applying the CPUT equation separately to each component, as shown in Table 1. By summing the CPUT column, one can calculate that the cost per unit time to maintain these six components at their individual optimum replacement times is $0.11719/mi.

A plot of the CPUT curves for each component is shown in Figure 1, where the diamond markers represent the optimum replacement times. From the plot, it can be seen that some of the components have optimum replacement times that are close to those of other components. When taking into account personnel costs in addition to the non-personnel costs considered in the optimum replacement time calculation, it might make sense to perform preventive maintenance on groups of items at a common time at the expense of a slight increase in CPUT for each component in the group. For example, it would make sense to replace the oil and oil filter (optimum time = 3263 miles) and the air filter (optimum time = 3059 miles) at some time that would be between the optimum times for each component individually.

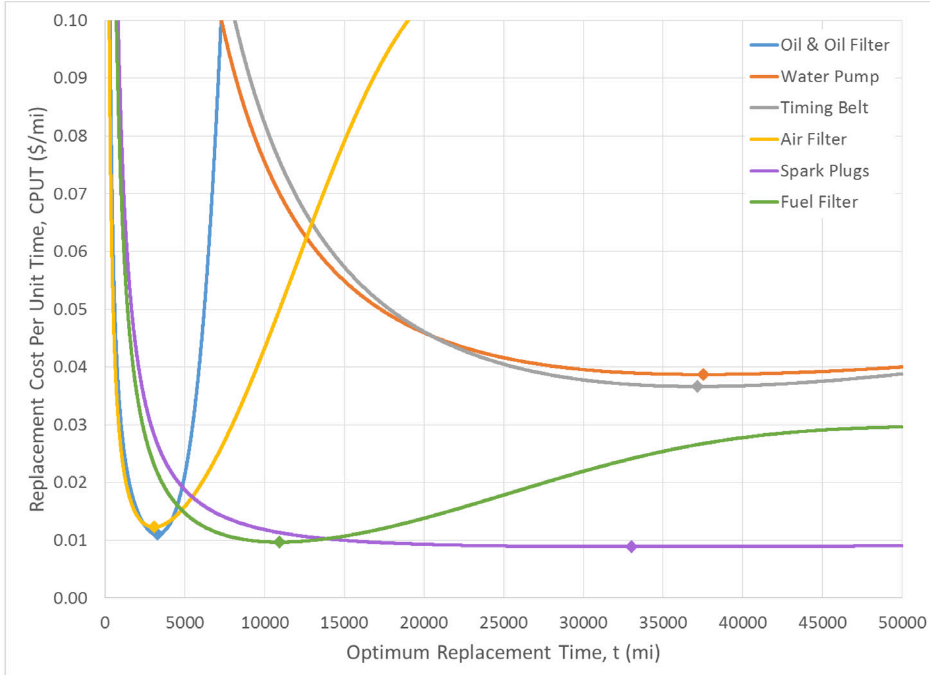

Figure 1 – Cost Per Unit Time Curves for Each Component

Assigning Components to Maintenance Groups

There are many algorithms that can be used to group, or cluster, the replacement times.[3] For this paper, we will consider a simple algorithm that groups items based on minimum Euclidian distance. Initially, each replacement time is assigned to a separate group. In other words, there will be an equal number of groups and maintenance times. Each pass through the algorithm reduces the number of groups by one by combining the closest two groups. (Note that the remaining groups are not renumbered after a group is absorbed.)

Component	Weibull Shape	Weibull Scale (mi)	PM Cost ($)	CM Cost ($)	Optimum Replacement Time (mi)	CPUT ($/mi)
Oil & Oil Filter	6.0	10,000	30	5,000	3,263	0.01103
Water Pump	2.0	80,000	700	4,000	37,509	0.03868
Timing Belt	2.5	80,000	800	4,500	37,170	0.03662
Air Filter	3.0	15,000	25	1,500	3,059	0.01227
Spark Plugs	1.5	30,000	80	250	33,029	0.00892
Fuel Filter	3.0	30,000	70	800	10,920	0.00967

Table 1 – Component Failure Properties, Maintenance Costs, and Optimum Replacement Time and Cost

Suppose that it is desired to have three groups of replacement times for the data given above. The algorithm will group the items in the following manner:

1. Initially, group 1 is the oil and oil filter, group 2 is the water pump, group 3 is the timing belt, group 4 is the air filter, group 5 is the spark plugs, and group 6 is the fuel filter.
2. During the first pass, groups 1 and 4 are the closest groups so they are combined. Then, group 1 is the oil and oil filter and the air filter, group 2 is the water pump, group 3 is the timing belt, group 5 is the spark plugs, and group 6 is the fuel filter.
3. During the second pass, groups 2 and 3 are the closest groups so they are

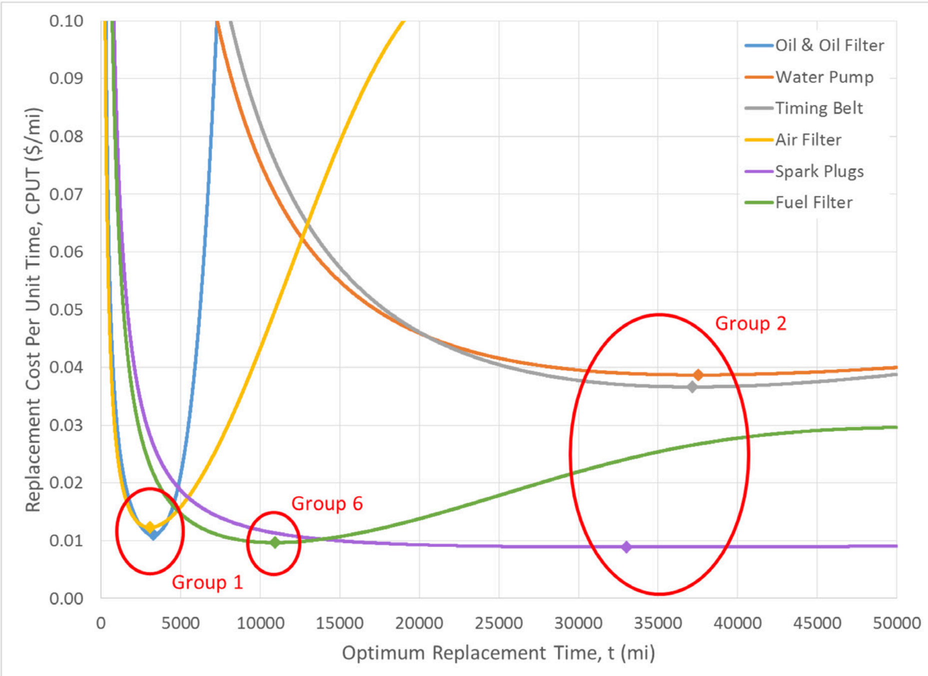

Figure 2 – Groups of Maintenance Times

combined. Then, group 1 is the oil and oil filter and the air filter, group 2 is the water pump and the timing belt, group 5 is the spark plugs, and group 6 is the fuel filter.

4. During the third pass, groups 2 and 5 are the closest groups so they are combined. Then, group 1 is the oil and oil filter and the air filter, group 2 is the water pump, the timing belt, and the spark plugs, and group 6 is the fuel filter.

The resulting groups are shown in Figure 2.

Optimum Replacement Time for Groups of Components

In order to determine the best time to perform the preventive maintenance for the group, the sum of the CPUT for the group of components is minimized. Thus, for a group containing N components, the optimum replacement time for the group minimizes the CPUT for components given by Equation 2:

$$CPUT_{group} = \sum_{i=1}^{N} \frac{C_{PM_i} \cdot R_i(t) + C_{CM_i} \cdot [1 - R_i(t)]}{\int_0^t R_i(s)ds}$$

Equation 2

where,

C_{PM} is the cost to preventively maintain (replace) the component,

R(t) is the component reliability at time, and

C_{CM} is the cost to correctively maintain the component.

Figure 3 shows the CPUT curves for each item in group 1 and the group CPUT as well as the optimum replacement times. The group optimum replacement time is closer to the oil and oil filter optimum time than to the air filter optimum time. This is because the oil and oil filter curve is more convex (i.e., its second derivative is larger) around the optimum. In other words, for a small change in replacement time the oil and oil filter curve has a greater increase in CPUT than the air filter curve. Therefore, the common optimum replacement time is more heavily influenced by the oil and oil filter CPUT than that of the air filter.

Figure 4 (following page) shows the CPUT curves for each item in group 2 and the group CPUT as well as the optimum preventive maintenance times. In this case, the CPUT time for the spark plugs is almost flat while the CPUT curves for the water pump and timing belt have a slight curvature. (Note that this difference in curvature is seen more easily in Figure 2.) Therefore the spark plugs CPUT curve has less influence on the optimum maintenance time of group 2 than the water

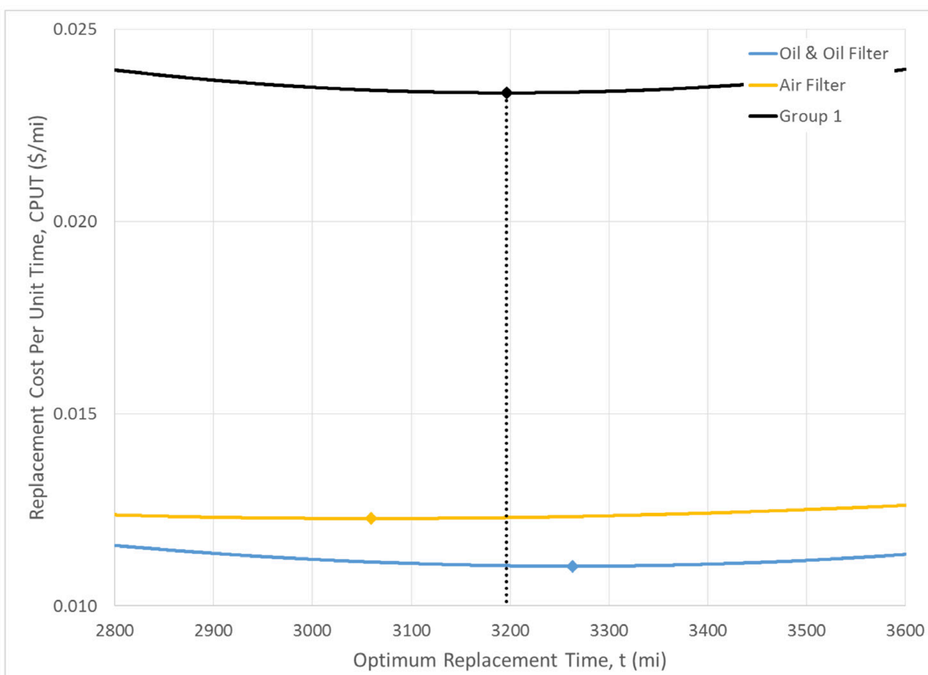

Figure 3 – Optimum Replacement Times for Group 1 and Each Component in Group 1

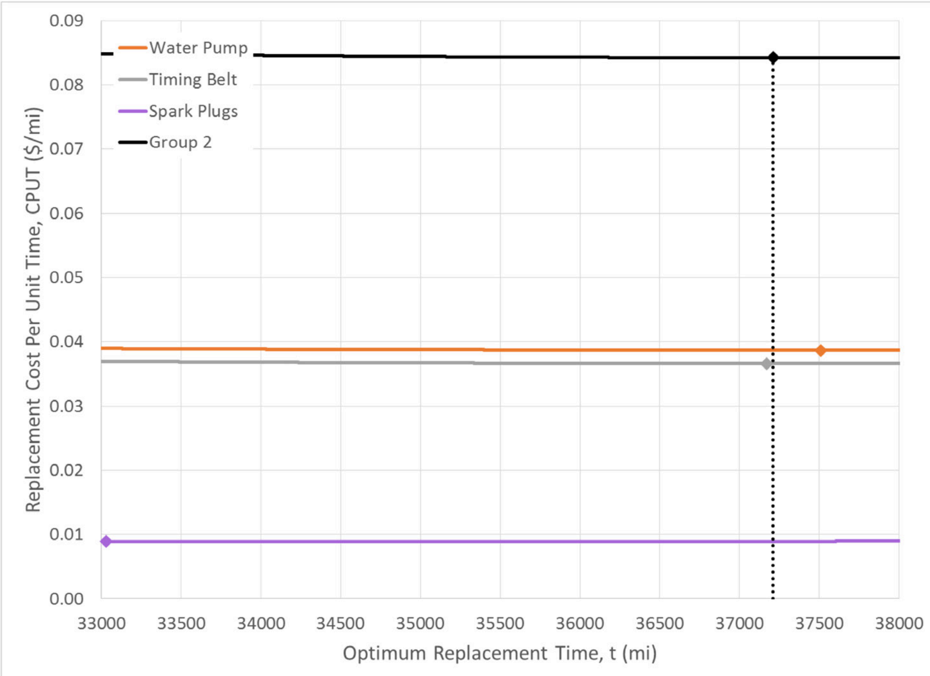

Figure 4 – Optimum Replacement Times for Group 2 and Each Component in Group 2

Group	Component	Individual Optimum Replacement Time (mi)	Individual CPUT ($/mi)	Group Optimum Replacement Time (mi)	Group CPUT ($/mi)
1	Oil & Oil Filter	3,263	0.01103	3,196	0.02339
	Air Filter	3,059	0.01227		
2	Water Pump	37,509	0.03868	37,210	0.08423
	Timing Belt	37,170	0.03662		
	Spark Plugs	33,029	0.00892		
6	Fuel Filter	10,920	0.00967	10,920	0.00967

Table 2 – Individual and Group Optimum Replacement Times and Costs

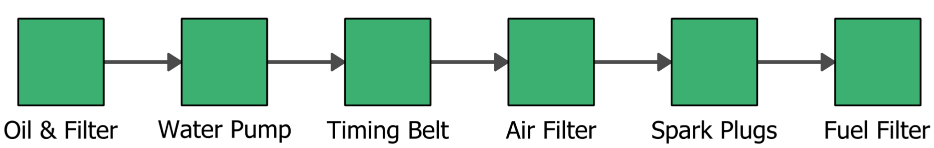

Table 5 – Reliability Block Diagram Representing the Six Components in the System for which Preventive Maintenance will be Performed

pump and timing belt CPUT curves and the resulting group maintenance time is close to the individual optima for the water pump and timing belt.

Table 2 (following page) shows the individual and group optimum replacement times. Summing the group CPUT values yields a cost per unit time to maintain the three groups of $0.11724/mi, compared to $0.11719/mi to maintain the six components individually. When the personnel costs are considered, it is likely that this small increase in cost per unit time for three preventive maintenances (one for each group) will be offset by the personnel cost savings due to having half the number of preventive maintenance times.

Finally, consider grouping all of the items into a single replacement time. ReliaSoft's BlockSim software can be used to perform this calculation, or any of the ones described above, to allow the different groupings of component maintenance times to be compared quickly and easily. The procedure is as follows. First, a reliability block diagram is created as shown in Figure 5 and each block is assigned the failure distribution parameters of one component.

Then, the Optimum Replacement tool is opened and the corrective and preventive replacement costs are entered as shown in Figure 6 (following page).

When the optimum is calculated, the software prompts the user to select if individual, common, or clustered (grouped) replacement times should be calculated, as shown in Figure 7 (following page). If the user chooses the clustered option, then the user specifies the number of groups. The results of the common replacement time calculation are shown in Figure 8 (following page). For this case, the replacement cost per unit time is $0.34472/mi. This common maintenance time yields a CPUT that is triple the cost

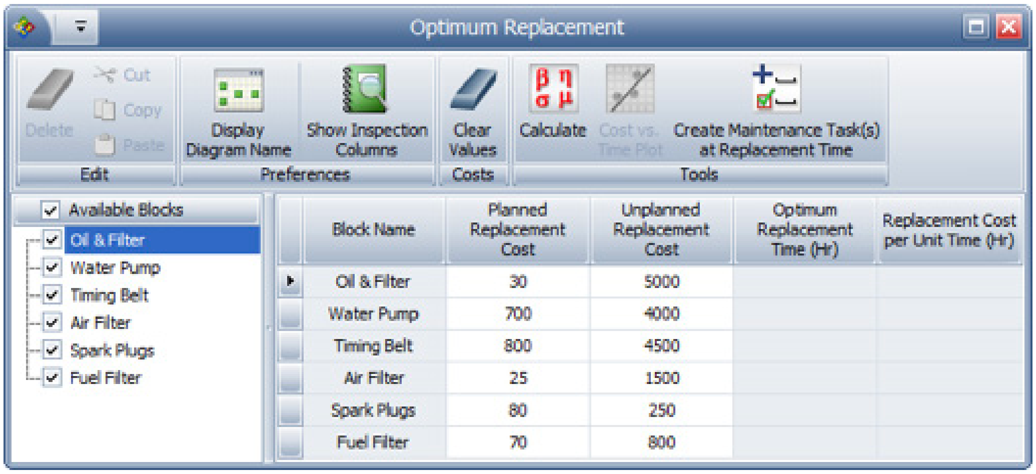

FIGURE 6 – BLOCKSIM'S OPTIMUM REPLACEMENT TOOL

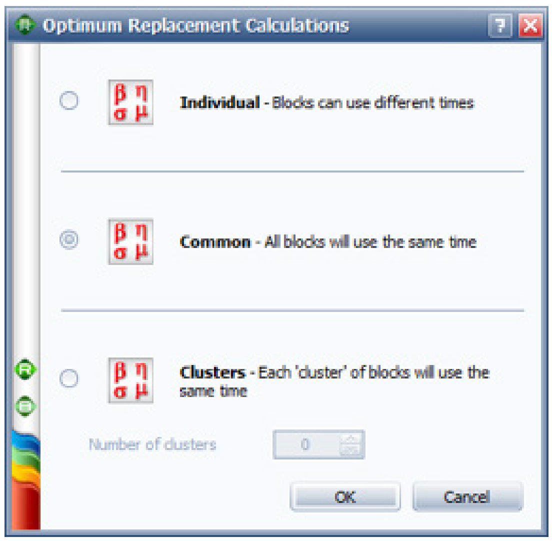

FIGURE 7 – BLOCKSIM'S OPTIMUM REPLACEMENT CALCULATION OPTIONS

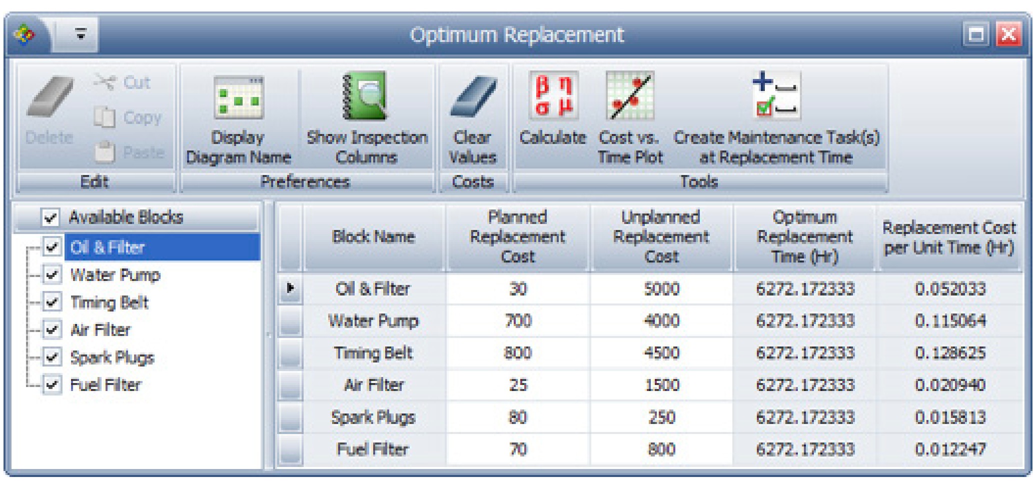

FIGURE 8 – COMMON OPTIMUM REPLACEMENT TIME AND COSTS FOR EACH COMPONENT

of grouping the maintenance time into three groups. For this case, the increased cost per unit time to maintain all the components may not offset the decreased personnel costs associated with having a single replacement time.

Conclusion

The cost per unit time equation provides a way to calculate the optimum replacement time for a component based on the failure distribution parameters of the component and the costs to correctively and preventively maintain the component. This paper shows how to group components and how to find the optimum replacement time for the group(s). Three different preventive replacement strategies were compared for a set of six components: individual, grouped, and common. For the failure distribution parameters and maintenance costs presented it was seen that the individual preventive maintenance times yielded the lowest cost per unit time to maintain the components. Grouping the items into three maintenance groups provided an alternate maintenance strategy with a very small increase in cost per unit time to maintain the components. In contrast, using a common preventive maintenance time for all components resulted in a significant increase in cost per unit time to maintain the components. The preventive maintenance strategy that would be chosen in practice would depend on both the cost per unit time calculations presented here and other practical constraints, such as personnel costs. ●

References

1. http://fmlink.com/articles/operating-budgets-vs-capital-budgets-for-fms/
2. http://reliawiki.org/index.php/Introduction_to_Repairable_Systems#Preventive_Maintenance_2
3. https://en.wikipedia.org/wiki/Cluster_analysis

Global Supply Chain Management (GSCM)

KATHERINE PRATT

Abstract

Over the past forty-five years, the traditional logistics and purchasing functions have evolved into a wider strategic approach to material and distribution management known as Supply Chain Management (SCM). Post World War II, through the 1960's, the primary operations strategy was for manufacturers to give priority to mass production in order to minimize the unit production cost. E-commerce has altered the practice, timing and technology of business-to-business (B2B) and business-to-consumer (B2C) commerce. It affected pricing, product availability, transportation patterns, and consumer behavior in developed economies worldwide. B2B electronic commerce (e-commerce) accounts for the vast majority of total e-commence sales and plays a leading role in GSCM networks. One reason why B2B e-commerce is more sophisticated and larger in size than direct-to-consumer commerce is that B2B transactions developed out of the electronic data interchange (EDI) networks of the 1970 and 1980s.[1]

During the 1970's the introduction of Manufacturing Resource Planning (MRP) concept changed to increasing production by spreading fixed cost to bigger output (economies of scale), as well as by increasing performance, too. By the 1990's, the drive for improved logistical services resulted in outsourcing logistics activities through cooperative chain-relationships and a re-focus on core competencies instead. This new supplier-buyer relationships increased global competitiveness, leading to Enterprise Resource Planning (ERP) for intra-organization support planning, while Electronic Data Interchange (EDI) used by manufacturers, supported inter-organizational integration. By the 21st century, IT Internet—based solutions systems supplanted both the inter- and intra-organizational integrations. The buyer-supplier relationship also evolved from partnerships to long-term strategic alliances, exploiting supplier strengths and technology in support of new product development, cost reductions, and new distribution channels. Trending now are Global Systems of Supplier Relations (GSCM), which achieve economies of scale by sourcing lowest cost sources and growing markets, even for selling their obsolete, or outdated inventories.[2]

Organizing Logistics via SCM

SCM Logistics is defined as the process of planning, implementing, and controlling the efficient, effective flow and storage of goods, services, and related information from point of origin to point of consumption for the purpose of conforming to customer requirements. The core activities are customer service standards, transportation, inventory management and supply plus information flow, order processing and transmittal. Goods damaged in transit may be disposed, refurbished, or reused as scrap value. The logistics strategy is described as the right time, the right place, and in a cost efficient manner. The logistics strategy has three objectives: cost reduction, capital reduction and service improvement. Optimally, logistics aims to achieve maximum customer service level; to ensure high product quality; to achieve minimum (possible) cost; and to be flexible even with the constant market changes.

SCM is defined as the integration of activities of optimal core and the supporting cost sources of material, transportation, manufacturing and inventory from suppliers, manufactures, wholesale and distribution centers, retailers and customers through improved supply chain relationships, to achieve a sustainable competitive advantage. Support activities vary from company to company, however, a comprehensive list may include organizing the variables by using a logistics decision hierarchy, such as strategic, tactical/planning or operations:

Warehousing (space determination, number and size of distribution depots, type of storage, (*strategic*), stock layout, configuration, stock placement (*tactical /planning*) and personnel, working hours, shifts, overtime (*operations*)).

Storage-materials handling (raw materials policy, ready materials policy (*strategic*), size of pallets, equipment selection, quantities purchased, timing (*tactical/planning*), and (replacement policies, order-picking procedures, specify aggregate quantities, sequence & time production output, schedule supplies stock storage & retrieval (*operations*)).

Transportation (warehouse replenishment/transportation; distribution to clients) (*strategic*), Buy or rent vehicles, fleet, mix, size, load planning, type of delivery operation, delivery vehicles, size, (*tactical/planning*), type of vehicle used, mode of transport, service region for each vehicle, vehicle routes schedules, vehicle maintenance (*operations*)).

Information maintenance (data analysis and control (includes design of systems, control procedures and forecasting) (*strategic*) and storage and manipulation, (*tactical/planning*) and includes information collection (*operations*)).

Inventory (what to stock (*strategic*), when to stock (*tactical/planning*), and how much to stock (*operations*)). Packaging and utilization includes the unit load, protective packaging (designed for handling, storage, protection from loss/ damage), and the handling systems.[3]

Customer service performance (supply chain management budget forecasting (*strategic*), customer service performance monitoring (*tactical/ planning*), order processing/ customer service, (*operations*)).

Supply chain management (sales forecasting (*strategic*), master production planning (*tactical/planning*), third-party invoice payment/audit (*operations*)).

Global Supply Chain Management (GSCM) Pipeline Practices

Global-based supply chain management pipelines have undergone major changes as deregulation has spread to all modes of transport, resulting in the decline of overall number of companies. Shippers move cargo now over whatever mode provides the best service. Parcel containers are increasing their maximum shipment weight and accept partial trailer loads as small as 10,000 pounds. Customer's needs have changed as well, because of Just-In-Time, Quick-Response inventory management, and third-party SCM requiring all participants in the SCM chain to consider shorter cycle time a 'competitive advantage.

Information Technology

Manufacturers, distributors and some carriers effectively use 'information technology' (IT) to reduce cycle times and improve the quality of the freight handling. Even package handlers now use technology to a great competitive advantage. Less-than-truckload (LTL) carriers are now adapting their IT systems to provide real-time, on-line data on the movement of freight through their systems. Bar code and radio frequency identification (RFID) technologies provide the tools for LTL carriers to speed cargo through every phase of LTL operations, including systems for both Dock Management and Yard Management. The results are positive control of all moving stock, optimization of personnel and rolling stock and shortened stripping and loading at the doors.

Consistent application of appropriate IT throughout the SCM pipeline is resulting in shortened cycle(s) times and lowered effort, assuring each phase earns immediate economic benefit and improves the carrier's strategic position. The city terminals and break bulk consolidation and other cargo transfer techniques allow LTL carriers to sell economies of scale to shippers with small cargo consignments. This same process allows for greater handling, which increases the potential for more frequent opportunities for delays, miss-shipments, and cargo damage. Effective use of IT can mitigate this by allowing positive tracking of every package as well as other automatic optimization techniques that can be employed.

Dockside data collection allows operators to enter all data about an inbound truck's cargo at the dock even as operators strip cargo for consolidation. This becomes even more efficient when shippers produce scan-able bills of lading using a two-dimensional bar code. Effective SCM may be the best way to achieve reduced order-to-delivery cycle time. Instead of treating each function as consisting of discrete activities, SCM considers all functions to be linked and interdependent. As a result, SCM can reveal the cumulative effect of problems anywhere in the chain, not just within the SCM' areas of responsibility.

GSCM Objectives

The objectives of SCM, when perceived as a tool to help accomplish strategic objectives are:

- Reducing working capital
- Taking assets off the balance sheet
- Accelerating cash-to-cash cycles
- Increasing inventory turns, etc.

For example, the average cycle times of a product, such as fish fingers is 150-days. Products such as corn flakes or the pharmaceutical industry average 465 days, which is considered an "extended enterprise." By reducing these extended enterprises to 30-days, this would provide more inventory turns, also a fresher product, as well as an ability to customize better, and increased customer responsiveness.

Supply chain inefficiencies can waste as much as 25% of a company's operating costs. With a profit margin of only 3 to 4 percent, even 5-percent reductions in supply chain waste can double a companies' profitability. However, achieving maximum value is not dependent upon efficient operation alone. It demands executive-management-level commitment and superb execution at the operational level. IT is not a functional adjunct to SCM, rather it is the linkage that connects the various components and partners, of SCM into an integrated whole and enables or facilitates the following:

- Short-term systems that handle routine day-to-day transactions such as order-processing and shipment scheduling
- Longer-term perspective that technology must facilitate planning and decision making, supporting activities such as demand planning and master production scheduling to optimally allocate resources
- Longer-range information systems which enable strategic analysis by modeling and other tools that synthesize data for use in high-level "what-if" scenario planning, and thus help managers evaluate distribution centers, suppliers, and third-party service options.[4]

SCM Uses New Tools, Resources and Methods: Data Base Projects: Big Data, Data Science and Predictive Analysis

"Big Data" is a growing combination of tools, resources, and applications. There are more data because, among other reasons, the data are captured in more detail. For instance, previously just recording that a unit sold at a particular location was sufficient information. Now, the time it was sold, as well as the amount of inventory at the time of the sale, is also captured. As another example, many companies that formerly did not record daily sales by location and by stock-keeping unit to make inventory decisions now are able to do so.

However, because these data sets are larger than can reasonably be managed, new techniques such as data science are now used.

"Data science" is the application of quantitative and qualitative methods used to solve relevant problems and predict outcomes. This confluence of data science, predictive analytics and big data, known as DBP (data base projects) uses analytical skills and an understanding of business and management. Because there is an exponential increase of false positives when using Big Data to investigate new variables, this method requires using appropriate logic and or theory to build models prior to running predictive analytics.[5]

The Internet of things: IOT

The Internet of things is the Internet workings of physical devices such as consumer objects and industrial equipment onto the network. This collection of ideas and information become interconnected, and enables information gathering and management of these devices using software to increase efficiency, enable new services or achieve health, safety or environmental benefits. As an example, consider connecting homes through the use of Smart Technologies applied to thermostats, appliances, HVAC systems, security, lighting, and entertainment systems. Or another example could be connecting cities through the use of Smart technologies applied to meter technology such as traffic lights, parking meter, electronic vehicle charging, and real-time analysis. Examples of Industrial applications include real-time analytics, factory automation, robotics, and supply chain efficiency. These Smart technologies can even be applied to Cabs affecting their safety, vehicle diagnostics, information and diagnostics, and fleet management. Smart technology is also used in fitness bands, watches, glasses, and action cameras. The use of this technology has become this diverse because it enables the product costs to reduce over time. For instance, over the past ten years, the cost of bandwidth has been reduced 40 times, and sensor cost has gone from $1.30 to $0.60 in that same period of time. Smart technologies are being developed for mobile medicine and retail, next.[6]

New Worldwide SCM Safety Labeling Provisions Imposed

Different countries have different systems for labeling and classification of products, such as chemicals. What may be considered a hazardous chemical to use in some countries may be classified as safe for use in another. [7] There are now calculations available to predict no-effect concentrations (PNEC) of various substances.[8] The United Nations Economic Commission for Europe, (UNECE) has created a new system, called "Globally Harmonized System of Classification and Labeling of Chemicals (GHS) which addresses classification of chemicals by types of hazard and proposes using standardized labels and safety data sheets. While governments, regional institutions and international organizations are the primary audiences for the GHS; their information contains sufficient context and guidance for those in industry, who will ultimately be implementing these requirements.[9] Canada offers a free online webinar on this topic.[10]

SCM Environmental Management Systems

Green logistics is gaining recognition throughout logistics and GSCM, as the cost of not factoring in the humanitarian quotient, which is increasingly becoming unacceptable to most. The main objective of green or sustainable logistics is to coordinate supply chain activities so that needs are met at "least cost" to the environment. It is a principle component of reverse logistics. In the past "cost" has been defined in purely monetary terms, whereas "cost" can now also be understood as the external costs of logistics associated with: climate change, air pollution, dumping waste (including packaging waste), soil degradation, noise, vibration and accidents. Green or sustainable logistics is concerned with reducing environmental and other negative impacts associated with the movement of supplies. Green supply chains are designed to reduce negative environmental impact through the redesign of sourcing/distribution systems and to manage reverse logistics to eliminate inefficiencies. By designing your shipping and storage packaging for reuse (subject to sanitation and or disease vector suppression requirements), and providing your suppliers and or buyers with the option for you to recover and reuse, to recycle or at least dispose the material properly, is the long-term best practices method for managing your GSCM. Logistics and transport activities have been identified as having major impact on the environment. Environmental issues are often complex, and they have the ability to generate public interest and therefore product support. Consequently, logistics and transport have attracted significant attention both at the national and international level. Targets for improving environmental management systems (EMS) performance have already been set by the international community at Rio, Kyoto and the Copenhagen summit meetings.

By pro-actively establishing your EMS requirements for adhering to systems of continuous improvement in environmental management, you're safeguarding your organization from being exposed by failing to meet legal and moral obligations.

Performance measures can include monitoring measurements of:

- Miles per gallon of fuel;
- Average life of tires (in miles);
- Amount of waste lubrication oil generated by the operation;
- Utilization of vehicle load space (expressed as a percentage);
- Percentage of miles run by vehicle empty; and
- Targets for reducing waste packaging.

By creating an environmental checklist, you can assess your impact as an organization in areas of waste, material selection, assessing your costs and types of waste, risk of pollution, possible opportunity to be gleaned from your waste distribution systems, ensuring you have a complete and up-to-date set of environmental standards, current systems in place for environmental monitoring, plan-of-action for improving and highlighting your environmental image to donors and employees and customers.

Minimization of environmental impacts can entail:

Methods of improving the sustainability of logistics work:

- Avoid wasting water by using simple water recycling methods;
- Use interceptor tanks to avoid the run-off pollution from fuel dispensing areas.
- Careful management and monitoring of other hazardous chemicals on site;
- Keep pallet stacks tidy; and
- Take steps to better manage the production, collection and disposal of waste.

For vehicles, consider the following:

- Driver training reduces accidents and improves fuel consumption;
- Monitor fuel consumption;
- Monitor vehicle utilization in terms of both payload and empty running;
- Follow preventative maintenance programs as a poorly serviced vehicles use more fuel; and
- Dispose of used tire rim casings responsibly.[11]

Total Asset Visibility Applied to Military Logistics

There is a "revolution in military logistics" that uses acronyms such as ATAV (Army Total Asset Visibility), and it is also an Army Force XXI initiative. ATAV is an automated capability that is designed to dramatically improve the ability of soldiers, logisticians and managers to obtain information on the location, quality, condition and movement of assets throughout the logistics pipelines. It is as fully automated, near-real-time, open architecture capability that provides complete, integrated visibility over Army assets and other logistics data. Basically, this is designed as a distributed system of multiple databases, from which users gain telecommunications access to existing personal computers located at Army commands and activities by means of logon scripts.

In 1995, this program was selected as one of the winners of the Federal Technology Leadership awards, as it demonstrated extraordinary leadership in using information technology to improve service to the public, lower costs to the Government, and to improve their ability to meet their mission requirements. Currently, the Army Logistics Integration Agency (LIA), headquartered in Alexandria, VA, is responsible for the Army-wide implementation of the ATAV capability. The ATAV capability relies on systems in Huntsville, AL, such as the Standard Army Management Information Systems (STAMIS) and other sources, for obtaining wholesale and retail data on all classes of supply, including Standard Army Retail Supply System (SARSS), Worldwide Ammunition Reporting System, Army War Reserve Deployment System, Standard Property Book System-Redesign, Commodity Command Standard System, AMC Installation Supply System, Standards Army Maintenance System-Installation/Table of Distribution and Allowance, Materiel Returns Data Base, and Logistics Intelligence File. The ATAV capability provides timely information from the strategic level through the tactical level that is totally transparent to the user and in a format that is readily used by soldiers, logistician and managers to support routine operations. It is designed to support managers making materiel management decisions, such as redistributing excess items or diverting materiel in transit. ATAV-related business rules and policy are currently being developed at the DA level. ATAV data sources provide unit authorization data, basis-of-issue plans, procurement plans, procurement information, distribution priorities, and catalog data.

The ATAV provides visibility on Army-owned and Defense Logistics Agency (DLA) wholesale assets and shares that information with logisticians throughout the Army and the Department of Defense (DOD). In support of the Office of the Secretary of Defense directed Lateral Redistribution and Procurement Offset Initiative, ATAV also provides asset data to all the armed services and the DLA, enabling all to redistribute critical assets to meet user requirements. Managers supporting Paladin production under the Program Manager-Paladin use ATAV to determine potential production-line stoppers and the availability of assets that can be redistributed to prevent work stoppages. ATAV-enhanced (ATAV-E), is an application using ATAV data, providing users visibility of redistributed materiel, in formats supporting reporting DA and MACON requirements, such as authorized stockage lists (ASL), requisitioning objective dollar-value reports, ASL zero balance Reports, and percent fill of Army pre-positioned stocks reports. The ATAV capability is supported by automatic identification technologies (AIT(s)), such as memory cards, bar coding, and radio frequency (RF) tags and readers that provide rapid, accurate data capture, retrieval and transmissions. For instance, an RF tag can identify the contents of trucks; sea vans air pallets and their locations. These RF tags are read automatically when queried by RF interrogators at air and seaports of embarkation and debarkation, and other transportation nodes and choke points, and other receiving activities. This information is transmitted via satellite or landline to a regional server, thereby providing in-transit visibility. Optical memory cards, applied to multipacks at the source of supply, provide total content visibility and assist in error –free receipt processing and forward movement of required supplies. AIT-related technologies are being implemented within the army.

LIA has the lead in preparing ammunition logistics for operations in the next century. In partnership with the Military Traffic Management Command, (MTMC); the Army Materiel Command, the Army Combined Arms Support Command, U.S. Army, Europe as well as industry, the groundwork has been laid in applying this to the ammunition business process, as is basically described in the fore-going AIT information, subject to funding constraints.[12]

The Naval Air Systems Command (NAVAIR) Depot Cherry Point now uses the Contact Memory Button instead of record cards and paperwork. By integrating AIT into logistical business practices, they are able to facilitate the collection of initial source data, reduce processing times, improve accuracy and enhance asset visibility. This has led to their being able to manage configurations, identify latent defects, manage warranties, better determine reliability, reduce misidentification and losses and achieve total asset visibility. In conjunction with AIT, using existing automated information systems to provide asset visibility tracking through maintenance and supply chains is termed Serial Number Tracking (SNT). SNT provide more accurate, timely information on which to make better decisions.[13]

SCM Technology Solutions

Sense the 2008 recession that created a trucking capacity crisis, from which the US is still recovering, there has been a growth of using third-party logistics (3PL) and another crisis is expected in 2017. US transportation infrastructure remains underfunded and the driver shortage remains. We are not alone, the United Kingdom's markets also have been plummeting, and China appears headed for a recession. These economic factors are what is driving the increased use of 3PL. Historically, during and after the Great Recession, which lasted from December 2007 through June 2009, shippers and manufacturers used 3PLs to improve SC visibility, streamline the processes, reduce costs, drive growth, basically to survive. Because of current economic stabilization, there is a slight decrease in using 3PLs to shield the GSCM from SC interruptions and market fluctuations.

Years ago, it might have taken two years for events in one country to affect another's economy. Now, thanks to technology, and instant communication, the impact can be almost immediate.

So, what do all of these examples of Global Supply Chain Management have in common? Each of these above described examples of GSCM practices relies on each country that participates, even if it is vicariously, to be assuming it's full legal responsibility for their management and participation in each segment of each chain and for complying with all the world safety, and health provisions, such as those mandated by the Globally Harmonized System of Classification and Labeling of Chemicals (GHS) created by the United Nations, which became effective as of June 2016. Before this standard was created and implemented, there were many different regulations and classification systems on hazard classifications in use if different countries. Given the extent of the international trade in chemicals, and the potential impact on neighboring countries when controls are not implemented, the countries determined that a worldwide approach was needed. Although the GHS was designed as one universal standard for all countries to follow, it is not compulsory under U.N. law.

In the U.S., the current lack of US-based industry has had negative consequences, particularly on the middle and lower classes who have lost their economic standing, and leading to increasing numbers of citizens requiring economic support at a time when our industries are unable to compete with the price-models imposed on the poorest societies in the world today. Yet, when you compare the recent June 2016 deadline for signing the GHS building blocks in EU', the USA', China' and Japan's compliance, there are not even unilateral agreements upon which documentation revision to subscribe to, much less what category of GHS Hazard Classes each country are implementing and incorporating into their respective national regulations.

For instance, for the pyrophoric gases categories, Europe, China and Japan has all declined at this time participate in the regulation of this particular hazard class, yet the U.S. is willing. For Skin irritation/corrosion category 3, neither Europe nor the US are willing to support this Hazard Class at this time, however, China and Japan both are. Further complicating this GHS classification criteria are that additional hazard categories exist for simple asphyxiants and combustible dust, but only in the US. In Europe, there are also some supplementary hazard classes, which are not even included yet in the GHS.[15]

Clearly, there are advantages of time, money, and increased efficiencies to be realized from using these nested, contiguous Systems of Systems (SoS) for organizing information, assets and people. This means that any given country supplying labor, product or resource, within a GSCM SoS, may not have the ability or laws requiring them to comply with the full body of laws of the receiving country. However, unless there are unilateral agreement and compliance on the full spectrum of global safety measures, without which it may adversely affect peoples, environments, livestock, and even the basic elements of our planet, such as water, and air—how can we condone the global business practice of GSCM, particularly when there are no agreed upon and applied measures for safety and remediation, should an accident occur.

In theory, during peacetime, great opportunities for integrating disparate services can be realized. However, when world relations are becoming more estranged, and inner-centered, one cannot help wondering if these SoS efficiencies can be afforded by societies, regardless of the system of evaluation you choose to use. As in all things, you get back what you put out. If the current business raison d'être has become squeezing humanity for a buck irrespective of the damages you may impose along the way, then it was true in the past, and it remains true: Caveat emptor! ●

This concludes Part One of a two-part article. The second article addresses GSCM vulnerabilities.

References

1. “The Economic Impact of e-commerce,” by Chris G. Christopher, Jr. Money Matters, Quarter 2, 2011 http://www.supplychainquarterly.com/columns/scq201102monetarymatters/
2. “Explaining the Evolution of Supply Chain Management”, by UK Essays, Nov. 2013 1 https://www.ukessays.com/essays/business/explaining-the-evolution-f-supply-chain-management-business-essay.php
3. “Chapter 2 Logistics – Basic Concepts & Characteristics Courier Routing through Innovative Emulation Learning Program” http://www.adam-europe.eu/prj/7095/prj/CourieL_WP2_Chapter2_final.pdf
4. “Supply Chain Management” by Sotiris Zigiaris MSc, BPR engineer, BPr Hellas SA Jan 2000, http://www.adi.pt/docs/innoregio_supp_management.pdf
5. “Data Science, Predictive Analytics, and Big Data: A Revolution That Will Transform Supply Chain Design and Management”, by Matthew A. Waller, Stanley E. Fawcett, June 2013 ResearchGate
6. “Internet of Things Meets... What Is The internet of Things?” Goldman Sachs http://www.goldmansachs.com/our-thinking/pages/iot-infographic.html
7. “Globally Harmonized System (GHS)” Canadian Centre for Occupational Health and Safety, http://www.ccohs.ca/oshanswers/chemicals/ghs.html
8. “ChemSafetyPro”, http://www.chemsafetypro.com/
9. “UNECE”, http://www.unece.org/trans/danger/publi/ghs/implementation_e.html
10. “Green Logistics Operational Guide” by Justin White http://dlca.logcluster.org/display/LOG/Green+Logistics?sortBy=createddate
11. “Green Logistics Operational Guide” by Justin White http://dlca.logcluster.org/display/LOG/Green+Logistics?sortBy=createddate
12. “Army Total Asset Visibility” by Cecilia Butler and Sandra Latsko
13. “Memory Button Tracks Aviation Components” by FRCE Public Affairs http://www.navair.navy.mil/index.cfm?fuseaction=home.NAVAIRNewsStory&id=2481
14. “3PL Perspectives 2016”, by Jason McDowell July 2016 http://www.inboundlogistics.com/cms/article/3pl-perspectives-2016/
15. “What are the GHS Building blocks?” http://www.chemsafetypro.com/Topics/Review/comparison_GHS_building_blocks_EU_USA_China.html

Reliability-Centered Maintenance (RCM)

JOHN BLYLER

Introduction

Reliability-centered maintenance (RCM) is a systematic approach to develop a focused, effective, and cost-efficient preventive maintenance program and control plan for a system or product. This technique is best initiated during the early system design process and evolves as the system is developed, produced, and deployed. However, the technique can also be used to evaluate preventive maintenance programs for existing systems, with the objective of continuous product/process improvement.

The RCM technique was developed in the 1960s primarily through the efforts of the commercial airline industry.* The approach uses a structured decision tree that leads the analyst through a "tailored" logic in order to delineate the most applicable preventive maintenance tasks (their nature and frequency). The overall process involved in implementing the RCM technique is illustrated in Figure C.11 (following page). Note that the functional analysis and the FMECA are necessary inputs to the RCM, and that there are trade-offs resulting in a balance between preventive maintenance and the accomplishment of corrective maintenance. Figure C.12 (page 26) presents a simplified RCM decision logic, where system safety is a prime consideration along with performance and cost.

The Analysis Process

Three major steps in accomplishing an RCM analysis are as follows:

1. **Identify the critical system functions and/or components.** For example, these might be airplane wings, car engine, printer head, video head, and so on. Criticality in terms of this analysis is a function of the failure frequency, the failure effect severity, and the probability of detection of the relevant failure modes. The concept of criticality is discussed in more detail in Section A3.1. This step is facilitated through outputs from the system functional analysis (see Section 2.7) and the failure mode, effects, and criticality analysis (FMECA). This is also depicted in Figure C.11, Blocks 1.0 to 4.0.
2. **Apply the RCM decision logic and preventive maintenance (PM) program development approach.** The critical system elements are subjected to the tailored RCM decision logic. The objective here is to better understand the nature of failures associated with the critical system functions or components. In each case, and whenever feasible, this knowledge is translated into a set of preventive maintenance tasks, or a set of redesign requirements. A simplified illustrative RCM decision logic is depicted in Figure C.12. Numerous decision logics, with slight variations to the original MSG-3 logic and tailored to better address certain types of systems, have been developed and are currently being utilized.†

* A maintenance steering group (MSG) was formed in the 1960s that undertook the development of this technique. The result was a document titled *747 Maintenance Steering Group Handbook: Maintenance Evaluation and Program Development (MSG-1)*, published in 1968. This effort, focused on a particular aircraft, was next generalized and published in 1970 as *Airline/Manufacturer Maintenance Program Planning Document-MSG2*. The MSG-2 approach was further developed and published in 1978 as *Reliability Centered Maintenance*, Report Number A066-579, prepared by United Airlines, and in 1980 as *Airline/Manufacturer Maintenance Program Planning Document-MSG3*. The MSG-3 report has been revised and is currently available as *Airline/Manufacturer Maintenance Program Development Document (MSG-3), 1993*. MSG3 activity continues with the results of analyses from the C-5 program. These reports are available from the Air Transport Association.

† RCM decision logics, with some variations, have also been proposed in (1) MIL-STD-2173(AS), *Reliability-Centered Maintenance Requirements for Naval Aircraft. Weapons Systems, and Support Equipment*; (2) AMC-P-750-2, *Guide to Reliability-Centered Maintenance*; (3) John Moubray, *Reliability-Centered Maintenance*, 2d ed. (New York: Industrial Press, 1997); and (4) A. M. Smith, *Reliability-Centered Maintenance* (New York, McGraw-Hill, Inc., 1993).

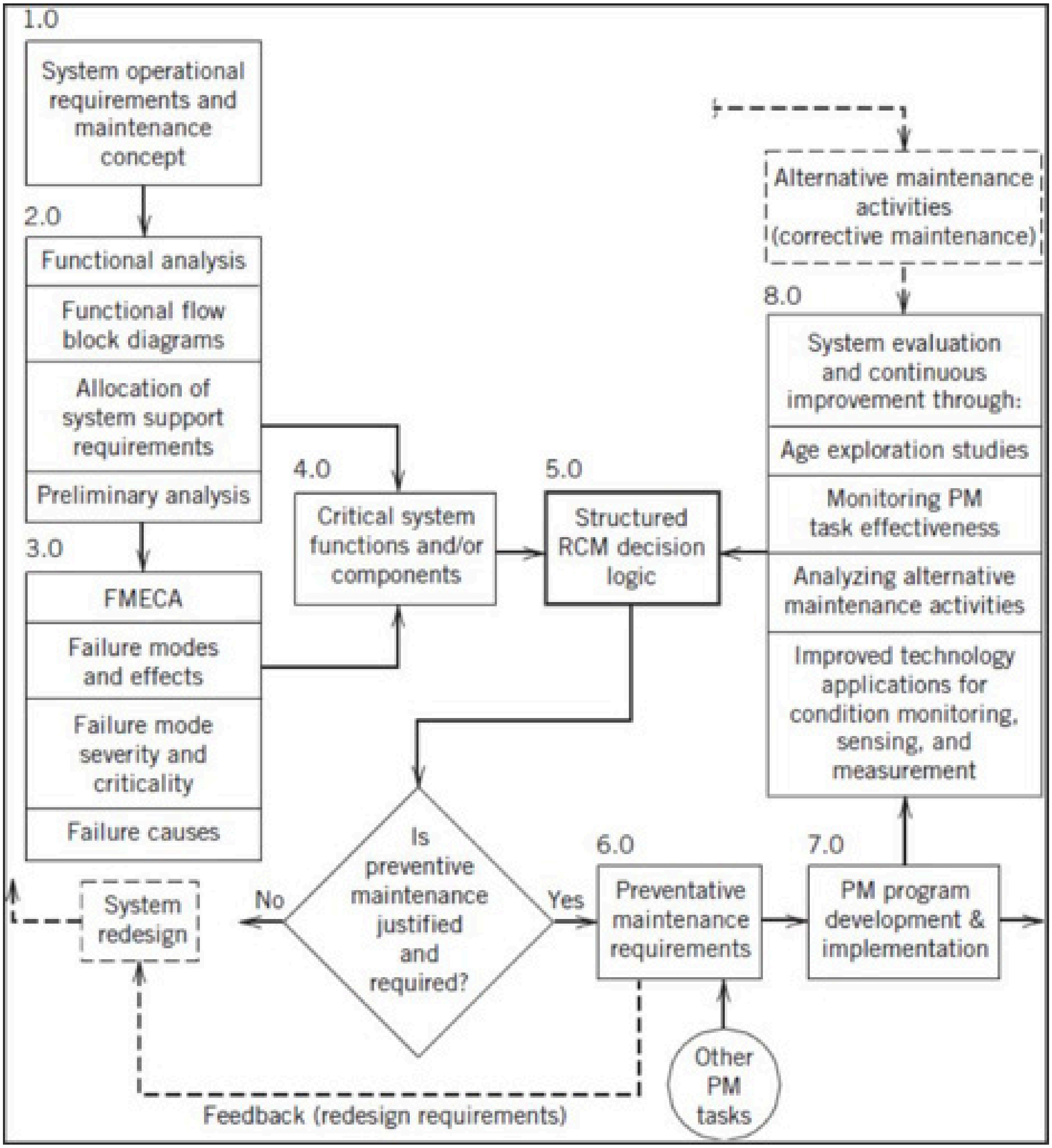

Figure C.11 – Reliability-Centered Maintenance Analysis Process

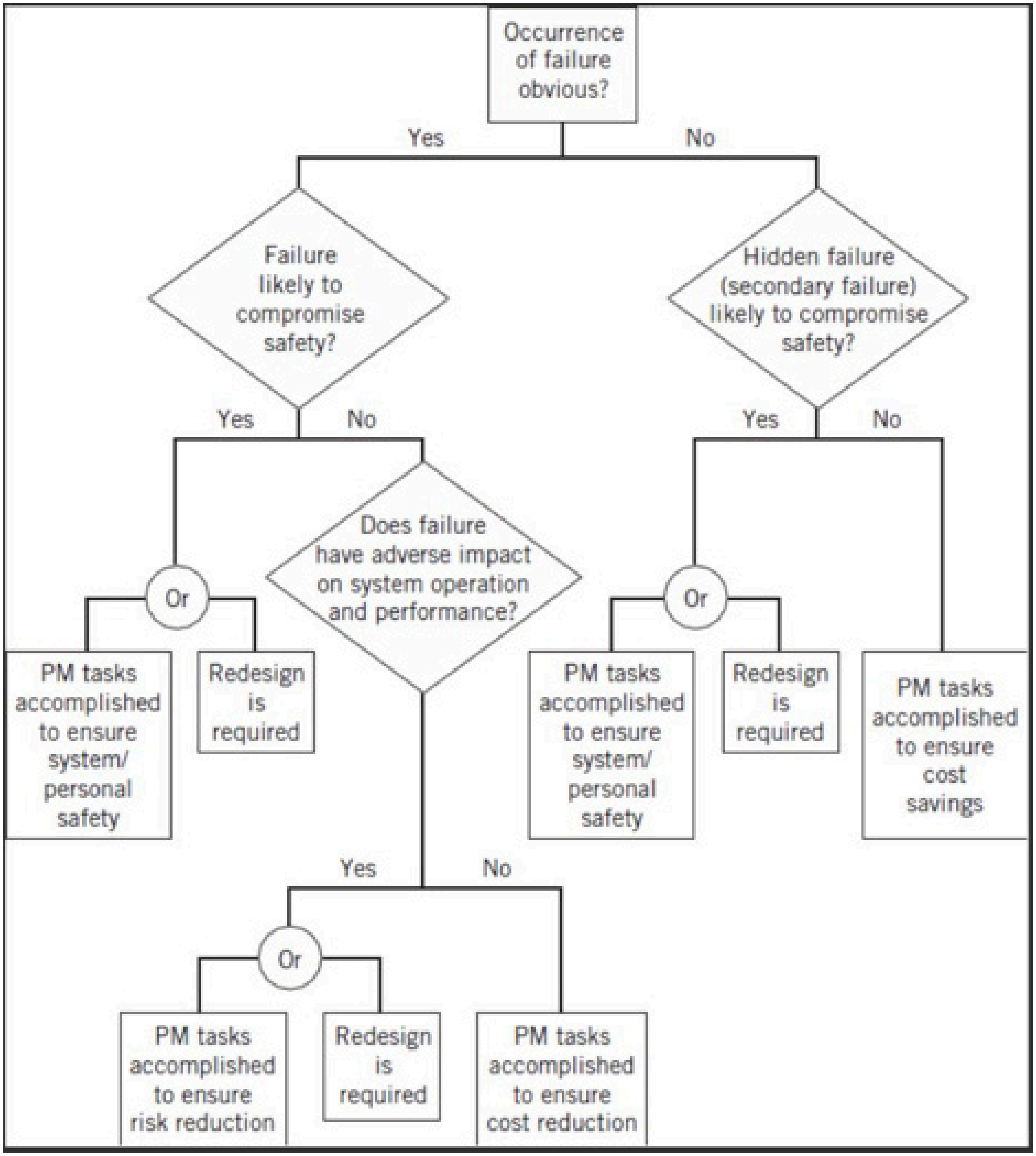

Figure C.12 – Simplified RCM Decision Logic

These slight variations notwithstanding (as illustrated in Figure C.12), the first concern is whether a *failure is evident or hidden*. A failure can become evident through the aid of certain color-coded visual gauges and/or alarms. It may also become evident if it has a perceptible impact on system operation and performance. On the other hand, a failure may not be evident (i.e., hidden) in the absence of an appropriate alarm, and even less so if it does not have an immediate or direct impact on system performance. For example, a leaking engine gasket is not likely to reflect an immediate and evident change in an automobile's operation, but it may in time and, after most of the engine oil has leaked, cause engine seizure. In the event that a failure is not immediately evident, it may be necessary to either initiate a specific fault-finding task as part of the overall PM program or design in an alarm that signals a failure (or pending failure).

The next concern is whether the failure is likely to compromise personal safety or system functionality. Queries exist in the decision logic to clarify this and other likely impacts of failures. This step in the overall process can be facilitated by the results of the FMECA (Section A3.1). The objective is to better understand the basic nature of the failure being studied. Is the failure likely to compromise the system or personnel safety? Does it have an operational or economic impact? For example, a failure of an aircraft wing may be safety-related, whereas a certain failure in the case of an automobile engine may result in increased oil consumption without any operational degradation and will therefore have an economic impact. In another case, a failed printer head may result in a complete loss of printing capability and may be said to have an operational impact, and so on.

Once the failure has been identified as a certain type, it is then subjected to another set of questions. However, in order to answer this next set of questions adequately, the analyst must thoroughly understand the nature of the failure from a *physics-of-failure* perspective. For example, in the event of a crack in an airplane wing, how fast is this crack likely to propagate? How long before such a crack causes a functional failure?

These questions have an underlying objective of delineating a feasible set of compensatory provisions or preventive maintenance tasks. Is a lubrication or servicing task applicable and effective, and, if so, what is the most cost-effective and efficient frequency? Will a periodic check help preclude a failure, and at what frequency? Periodic inspections or checkouts are likely to be most applicable in situations where a failure is unlikely to occur immediately, but is likely to develop at a certain rate over a period of time. The frequency of inspections can vary from very infrequently to continuously, as in the case of condition monitoring. Some of the more specific queries are presented in Figure C.12. In each case, the analyst must not only respond with a yes or no, but should also give specific reasons for each response. Why would lubrication either make, or not make, any difference? Why would periodic inspection be a *value-added* task? It may be that the component's wear-out characteristics have a predictable trend, in which case inspections at predetermined intervals could preclude corrective maintenance. Would it be effective to discard and replace certain system elements in order to upgrade the overall inherent reliability? And, if so, at what intervals or after how many hours of system operation (e.g., changing the engine oil after 3000 miles of driving)? Further, in each case a trade-off study, in terms of the benefit/cost and overall impact on the system, needs to be accomplished to determine the trade-offs between performing a task and not performing it.

In the event that a set of applicable and effective preventive maintenance requirements are delineated, they are input to the preventive maintenance program development process and subsequently implemented, as shown in Figure C.11, blocks 5.0 to 7.0. If no feasible and cost-effective provisions or preventive maintenance tasks can be identified, a redesign effort may have to be initiated.

3. Accomplish PM program implementation and evaluation. Very often, the PM program initially delineated and implemented is likely to have failed to consider certain aspects of the system, delineated a very conservative set of PM tasks, or both. Continuous monitoring and evaluation of preventive maintenance tasks along with all other (corrective) maintenance actions is imperative in order to realize a cost-effective preventive maintenance program. This is depicted in Figure C.11, block 8.0. Further, given the continuously improving technology applications in the field of condition monitoring, sensing, and measurement, PM tasks need to be reevaluated and modified whenever necessary.

Often, when the RCM technique is conducted in the early phases of the system design and development process, decisions are made in the absence of ample data. These decisions may have to be verified and modified, whenever justified, as part of the overall PM evaluation and continuous improvement program. Age exploration studies are often conducted to facilitate this process. Tests are conducted on samples of unique system elements or components with the objective of better understanding their reliability and wear-out characteristics under actual operating conditions. Such studies can aid the evaluation of applicable PM tasks and help delineate any dominant failure modes associated with the component being monitored and/or any correlation between component age and reliability characteristics. If any significant correlation between age and reliability is noticed and verified, the associated PM tasks and their frequency may be modified and adapted for greater effectiveness. In addition, redesign efforts may be initiated to account for some, if any, of the dominant component failure modes.

The Analysis Results

Quite often in the early design process, as system components are being selected, the issue of maintenance is ignored altogether. If maintenance is addressed, however, the designer may tend to specify components requiring some preventive maintenance (usually recommended by the manufacturer). If this is done, the perception is that such PM recommendations are based on actual knowledge of the component in terms of its physical characteristics, expected modes of failure, and so on. It is also believed that the more preventive maintenance required, the better the reliability. In any event, there is often a tendency to overspecify the need for PM because of the reliability issue, particularly if the component *physics-of-failure* characteristics are not known and the designer assumes a conservative approach, just in case.

Experience indicates that although the accomplishment of some selective preventive maintenance is essential, the overspecification of PM activities can actually cause a degradation of system reliability and can be quite costly. The objective is to specify the correct amount of PM, to the depth required, and at the proper frequency; that is, *not too much* or *too little*. Further, as systems age, the required amount of PM may shift from one level to another. The application of RCM methods on a continuing basis is highly recommended, particularly in evaluating systems from a life-cycle cost perspective. ●

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Ed.: John's article emphasizes the need for RMS professionals "at the table" as early as concept development. With today's U.S. Navy destroyers manned with 50% or less of crew sizes 20 years ago, for example, the notion that PM shouldn't be "too little or too much" couldn't be a more important constraint in system design. Equally important, the introduction of a Systems of Systems approach to delivering "capabilities" is rife with "opportunities" to expect the purchased items to "just work" with little thought devoted to the "what if it all isn't/doesn't integrate well?

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