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1. QUOTATIONS TO OPEN ON

"A Work Breakdown Structure is not a breakdown of work!"

Robert John Halligan

"The errors of a theory are rarely found in what it asserts explicitly;

they hide in what it ignores or tacitly assumes."

Donald H. McGannon

"The wicked leader is he whom the people despise.

The good leader is he whom the people revere.

The great leader is he of whom the people say, "We did it ourselves."

John Wooden

2. FEATURE ARTICLE

2.1 On the Appropriateness/Inappropriateness of the Keeney-Raiffa Multiplicative Utility Function for Medical Decision Making

by

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Editor's note: Managers who want a structured approach to decision making often turn to Decision Trees, a visual decision support tool that maps out choices and their probable outcomes. Unfortunately, basic decision trees are somewhat limited in their ability to accommodate complex problems with multiple competing decision criteria. For example, a manager deciding between two sustainability projects, say, an energy efficiency enhancement plan and a solar panel installation, would likely first evaluate the electricity savings for the projects. However, there may be other attributes that should also be considered, making the decision more complex. For example, suppose the manager also considers the visibility of the project to be a priority. It then becomes necessary to model both attributes simultaneously in a single decision making model. This would require converting both electricity savings and visibility into a common

metric (so as to "compare apples to apples") and then establishing a tradeoff between the two attributes to arrive at a weighting that reflects the manager's relative preferences. The general process for systematically approaching these types of problems is called multi-attribute decision analysis (MADA).

Abstract

The distinguishing feature of life-critical medical decision making (MDM) is that a preferred treatment should extend years of life and/or improve health-related quality of life. Good performance on other attributes cannot compensate for failure to do so. Additive multicriteria decision analysis (MCDA) models are inadequate for the task. Mutually utility independence (MUI) is a weaker assumption than additive independence; but it is nevertheless a strong assumption. Keeney and Raiffa showed that MUI leads to a multiplicative multiattribute utility function (MAUF). We term it the Keeney-Raiffa multiplicative utility function (KR MUF) to differentiate it from what we term the pure multiplicative utility function (PMUF). The KR MUF consists of 1) the sum of the single attribute utilities, and 2) multiplicative terms that account for interactions between attributes. In this article, we explore the appropriateness/inappropriateness of the KR MUF for modeling joint health-state utilities. We conclude that the KR MUF and PMUF are inappropriate MCDA models for life-critical MDM.

Introduction

There is growing interest in multicriteria decision analysis (MCDA) for medical decision making (MDM). It has been estimated that patients have to choose a preferred treatment in as many as half of all medical cases. MDM is a complex MCDA problem that involves years of life gained, health-related quality of life (HRQL), treatment effectiveness, probability of outcomes, cost, and availability. In 2014, the International Society for Pharmacoeconomics and Outcome Research (ISPOR) established the ISPOR MCDA Emerging Good Practices Task Force. Report 1 [Thokala et al., 2016] identified MCDA as a tool for MDM. Report 2 [Marsh et al., 2016] states:

> *The use of MCDA in health care is in its infancy, and so any good practice guidelines can only be considered "emerging" at this point… Although it is possible to identify good practices that should inform the use of MCDA in health care, inevitably this endeavor would benefit from further research.*

There is a plethora of MCDA methods each of which claims that it has resolved weaknesses of previous methods and that it is best for specific problems [Triantaphyllou, 2000]. The additive MCDA model has been and still is the most widely used MCDA model for all categories of decision making. For *n* additive independent (AI) attributes $X_1,...,X_n$,

$$u^{add}(\boldsymbol{x}) \equiv u^{add}(x_1, \dots, x_n) \qquad (1a)$$

$$= \sum_{i=1}^{n} k_i\, u_i(x_i) \qquad (1b)$$

$$0.0 \le u_i(x_i) \le 1.0, \quad i = 1, \dots, n$$

$$\sum_{i=1}^{n} k_i = 1.0, \quad k_i \ge 0.0 \qquad (1c)$$

where

- $u_i(x_i)$ is the single-attribute utility function (SAUF) for X_i evaluated at the specific value x_i. It is normalized by $u_i(x_i^-) = 0.0$ and $u_i(x_i^+) = 1.0$ where x_i^- and x_i^+ denote respectively the worst and best values of x_i.

- k_i is the weight associated with X_i. It is the utility value of the hypothetical alternative with attribute X_i at its best level and all other attributes at their worst levels: $k_i = u(x_1^-, \ldots, x_{i-1}^-, x_i^+, x_{i+1}^-, \ldots, x_n^-)$, $i = 1, \ldots, n$.

The additive MCDA model is valid if and only if the decision maker's preferences over the various attributes satisfy additive independence (AI). This is a very strong and, in many cases, unrealistic utility independence (UI) assumption because of possible interactions between attributes.

We illustrate the implications of AI for a hypothetical MDM situation.

Example 1 [Kujawski et al., 2019]. Consider the following two health-care lotteries:

- Lottery A: <0.5, (pain-free, 10 years); 0.5, (pain, 1 year)>

- Lottery B: <0.5, (pain, 10 years); 0.5, (pain-free, 1 year)>.

Lottery B outcomes are very bad: 1) 10 years of life in pain or 2) 1 year of pain-free life, each with probability 0.5. Lottery A outcomes are much more attractive: 1) 10 years of pain-free life or 2) 1 year of life in pain, each with probability 0.5. The additive model in (1) predicts the same expected utility (EU) for both lotteries:

$$\begin{aligned}\mathrm{EU}(\text{lottery A}) &= \mathrm{EU}(\text{lottery B}) \\ &= 0.5 \times k \times (u_H(\text{pain-free}) + u_H(\text{pain})) + 0.5 \times (1.0 - k) \times (u_T(10 \text{ years}) \\ &\quad + u_T(1 \text{ year})).\end{aligned}$$

However, most people that we consider rational would prefer lottery A over lottery B. They use reason, including emotions, to make the decision in a systematic and logical manner with due consideration to their personal and social context rather than von Neuman-Morgenstern expected utility theory (vNM EUT) [von Neumann and Morgenstern, 1944]. They simply are not EU maximizers [Kahneman, 2011]. The fact that the additive model in (1) does not provide the obvious answer in such a simple case is a sure indicator that it is inadequate as an aid for MDM when HRQL and years of life are considered attributes.

Keeney and Raiffa [1993, p. 224] advocate assuming some UI assumption when AI is unrealistic:

> *The utility independence assumptions are appropriate in many realistic problems, and they are operationally verifiable in practice.*

They concentrate principally on mutual utility independence (MUI) because it is a sufficient condition for a multiattribute utility function (MAUF) to be either multiplicative or additive. They characterize it as one of the most important results of multiattribute utility theory (MAUT) [Keeney and Raiffa 1993, p. 288].

In this paper we examine the appropriateness/inappropriateness of the Keeney-Raiffa multiplicative utility function (KR MUF)[1] for life-critical MDM. The distinguishing feature is that a preferred treatment should extend years of life and/or improve HRQL, and good performance on other attributes cannot compensate for failure to do so [Morton, 2017]. Additive MCDA models are inadequate for the task. This is equally relevant to systems engineering (SE) and project/program management (PM) where performance, cost, and schedule are critical attributes and risk is ever present [Kirkwood, 1997].

The remainder of the paper is structured as follows:

1. We critically review some fundamental concepts of MAUT with a focus on life-critical MDM.
2. We use several simple real-world examples to test the appropriateness /in appropriateness of MUI and the KR MUF.
3. We summarize the key results and present our conclusion.

Some Fundamental Concepts of Multiattribute Utility Theory

Data Types and Measurement Scales

The single-attribute utilities values (SAUVs) $u_i(\cdot)$ specified in (1) are measured on interval scales (i.e., scales with no absolute or true zero). Thus, $u_X(\cdot)$ and $u_Y(\cdot)$ for different attributes *X* and *Y* cannot be directly compared [Sage, 1992, p. 352]. For example, the least desirable level of health condition H_X may be less desirable than the least desirable level of health condition H_Y. But both health states have the same SAUV on their individual interval scales: $u_X(x^-) = u_Y(y^-) = 0.0$. Direct comparisons require measurements on a ratio scale (i.e., a scale with an absolute zero). The (Dead = 0.0, Full health = 1.0) scale, which is used for health-state utility values (HSUVs), is such a scale. We use an upper-case *U* to denote HSUVs measured on the (Dead = 0.0, Full health = 1.0) and a lower-case *u* for the SAUVs measured on their individual $(u_i(x_i^-) = 0.0, u_i(x_i^+) = 1.0)$ scales. $U_X(x_i)$ and $u_X(x_i)$ are related by a positive linear transformation:

$$U_X(x_i) = c_X \times u_X(x_i) + (1.0 - c_X),$$
$$0.0 < c_X < 1.0. \qquad (2)$$

On the (Dead = 0.0, Full health = 1.0) scale, $H_X(x_i) \preccurlyeq H_Y(y_j) \Leftrightarrow U_X(x_i) \leq U_Y(y_j)$.

A case in point is the Health Utilities Index Mark III (HUI3) classification system which is widely used in population health studies [Feeny et al., 2002]. It consists of eight attributes[2] with five or six levels within each. The HSUVs and SAUVs have a value of 1.0 for level 1 (no impairment) on both scales; but differing values depending on the health condition and level of impairment for the other levels. For example,

- *Dexterity Level 6*[3] (highest degree of impairment) has a HSUV of 0.56 on the (Dead = 0.0, Full health = 1.0) scale and a SAUV of 0.0 on the (Dexterity Level 6 = 0.0, Dexterity Level 1 = 1.0) scale.

[1] We term it such to differentiate it from what we term the pure multiplicative utility function (PMUF).
[2] Vision, Hearing, Speech, Ambulation, Dexterity, Emotion, Cognition, and Pain.
[3] *Limitations in use of hands or fingers requires the help of another person for all tasks (not independent even with the use of special tools).*

- *Emotion Level 5*[4] (highest degree of impairment) has a HSUV of 0.46 on the (Dead = 0.0, Full health = 1.0) scale and a SAUV of 0.0 on the (Emotion Level 5 = 0.0, Emotion Level 1 = 1.0) scale.

Elicitation of Health-State Utilities

The standard gamble (SG), the time trade-off (TTO), and the visual analog scale (VAS) are the most commonly used methods for directly eliciting HSUVs [Schwartz and Bergus, 2008]. Numerous studies have concluded that the VAS, TTO and SG methods can yield significantly different HSUVs for the same individual. Characteristics (e.g., age and risk attitude) may account for some of the differences. Individual preferences are also heavily influenced by the ways the questions are worded. The SG has a sound theoretical foundation within vNM EUT; it is considered the gold standard for directly eliciting HSUVs.

Utility Independence Concepts

UI is a key consideration of MAUT. It provides a necessary and sufficient condition for expressing a MAUF in terms of the constituent SAUFs. The validity of the underlying UI assumptions justifies the use of a specific functional form. AI and MUI and are the two most commonly used UI assumptions [Keeney and Raiffa, 1993].

Definition: Additive Independence [Keeney and Raiffa, 1993, p. 230]. Attribute *X* with values $x_1, \ldots, x_m, m \geq 2$ and attribute *Y* with values $y_1, \ldots, y_n, n \geq 2$ are AI if and only if for an arbitrary outcome (x_i, y_j) and all outcomes (x_k, y_l) the decision maker is indifferent between lottery $\langle 0.5, (x_i, y_j); 0.5, (x_k, y_l)\rangle$ and lottery $\langle 0.5, (x_i, y_l); 0.5, (x_k, y_j)\rangle$.

For Example 1: x_i = pain-free, y_j = 10 years, x_k = pain, and y_l = 1 year. In either lottery A or lottery B, there is 0.5 probability of being in pain or being pain-free and 0.5 probability of being in these health states for 1 or 10 years. The difference is how the health states and durations are combined.

Definition: Utility Independence [Keeney and Raiffa, 1993, p. 226]. Attribute *X* is UI of attribute *Y* if conditional preferences for lotteries over *X* given $Y = y_i$ do not depend on the particular value y_i. More formally, attribute *X* is UI of attribute *Y* if and only if

$$\langle p, (x_i, y_r); (1-p), (x_j, y_r)\rangle \succ \langle p', (x_k, y_r); (1-p'), (x_l, y_r)\rangle \Rightarrow$$
$$\langle p, (x_i, y_s); (1-p), (x_j, y_s)\rangle \succ \langle p', (x_k, y_s); (1-p'), (x_l, y_s)\rangle \ \forall x \text{ of } X, \forall y \text{ of } Y.$$

UI is not a symmetric property. Attribute *X* may be UI of attribute *Y*; but not necessarily vice versa.

Definition: Mutual Utility Independence [Keeney and Raiffa, 1993, p. 289]. Attributes $X_1, \ldots, X_n$ are MUI if every subset of $\{X_1, \ldots, X_n\}$ is UI of its complement.

To illustrate the difference between MUI and AI, consider two health lotteries A and B on *Dexterity* (*D*) and *Emotion* (*E*). Assume the HUI3 data and a PMUF for the JHSUVs:

$U^{PM}(x_i, y_j) = U_X(x_i) \times U_Y(y_j)$. Then

[4] *So unhappy that life is not worthwhile.*

$$EU(A) \equiv E(\langle 0.5, (D_1, E_1); 0.5, (D_6, E_5)\rangle) = E(\langle 0.5{,}1.0; 0.5{,}0.56 \times 0.46\rangle) = 0.66$$

$$EU(B) \equiv E(\langle 0.5, (D_1, E_5); 0.5, (D_6, E_1)\rangle) = E(\langle 0.5{,}0.46; 0.5{,}0.56\rangle) = 0.57.$$

AI does not hold since EU(A) ≠ EU(B); but MUI does. The results are also problematic for MUI. Although$EU(B) < EU(A)$, many people that we consider rational would prefer lottery B because they consider the 50% probability of occurrence of health state (D_6, E_5) to be too high a risk and/or an unacceptable outcome. As previously indicated, they simply are not EU maximizers [Kahneman, 2011]. MUI is a weaker condition than AI. AI implies MUI, but MUI does not imply AI. Nevertheless, MUI is a strong condition that needs to be assessed for each situation [Abbas, 2018, p. 462].

The Keeney-Raiffa Multiplicative Utility Function (KR MUF)

Theorem 6.1 [Keeney and Raiffa, 1993, p. 289]. For *n* MUI attributes $X_1, \ldots, X_n$, the MAUF is given by

$$K \times u^{KRM}(\boldsymbol{x}) + 1.0 = \prod_{i=1}^{n}(K \times k_i \times u_i(x_i) + 1.0) \qquad (3a)$$

where

- $u_i(\cdot)$ is the previously defined SAUF over X_i
- $k_i = u^{KRM}(x_1^-, \ldots, x_{i-1}^-, x_i^+, x_{i+1}^-, \ldots, x_n^-), \;\; i = 1, \ldots, n$
- *K* is a normalization parameter that is a solution of

$$K + 1.0 = \prod_{i=1}^{n}(K \times k_i + 1.0) \qquad (3b)$$

Keeney and Raiffa [(6B.3) and (6B.4), 1993, p. 347] derive the following properties:

$$(1.0 + K \times k_i) > 0.0 \qquad (4a)$$

and

$$K > -1.0. \qquad (4b)$$

- $\sum_{i=1}^{n} k_i < 1.0 \Rightarrow K > 0.0$. Then

$$U_i(x_i) \equiv \frac{K \times k_i \times u_i(x_i) + 1.0}{K \times k_i + 1.0} \qquad (5a)$$

and

$$U^{KRM}(x_1, \ldots, x_n) \equiv \frac{K \times u^{KRM}(x_1, \ldots, x_n) + 1.0}{K + 1.0} \qquad (5b)$$

are positive linear transformations. Thus $U_i(\cdot)$ is a SAUF over X_i and $U^{KRM}(x_1, \ldots, x_n)$ is a MAUF over $(X_1, \ldots, X_n)$.

We divide the right-hand side (RHS) of (3a) by the RHS of (3b) and the left-hand side (LHS) of (3a) by the LHS of (3b). Using (5a) and (5b), (3a) can be rewritten as [Keeney and Raiffa, 1993, p. 290]

$$U^{PM}(x_1, .., x_n) \equiv \prod_{i=1}^{n} U_i(x_i). \quad (6)$$

The linear transformation (5a) has a significant interpretation for HSUVs. Comparing (5a) with (2), we note that $U_i(\cdot)$ is the SAUF defined on the (Dead = 0.0, Full health = 1.0) scale provided $c_i = K \times k_i/(K \times k_i + 1.0)$.

Thus, $U^{PM}(\cdot)$ corresponds to a PMUF defined on the (Dead = 0.0, Full health = 1.0) scale.

- $\sum_{i=1}^{n} k_i > 1.0 \Rightarrow K < 0.0$. Then

$$U_i(x_i) \equiv \frac{-(K \times k_i \times u_i(x_i) + 1.0)}{K \times k_i + 1.0} \quad (7a)$$

$$U^{NM}(x_1, \ldots, x_n) \equiv \frac{-(K \times u^{KRM}(x_1, \ldots, x_n) + 1.0)}{K + 1.0} \quad (7b)$$

are positive linear transformations. Thus $U_i(\cdot)$ is a SAUF over X_i and $U(x_1, \ldots, x_n)$ is a MAUF over $(X_1, \ldots, X_n)$. We can then proceed as above. Using (7a) and (7b), (3a) can be rewritten as

$$-U^{NM}(x_1, \ldots, x_n) = (-1)^n \prod_{i=1}^{n} U_i(x_i). \quad (8)$$

- $\sum_{i=1}^{n} k_i = 1.0 \Rightarrow K = 0.0$. Then (3a) reduces to the additive model (1).

Two-Attribute Case

For the case of two MUI attributes *Y* and *Z*, one can explicitly solve (3b) for *K* and substitute the solution in (3a):

$$K = (1.0 - k_Y - k_Z)/k_Y k_Z \quad (9a)$$

$$u^{KRM}(y_i, z_j) = k_Y \times u_Y(y_i) + k_Y \times u_Y(z_j) + (1.0 - k_Y - k_Z) \times u_Y(y_i) \times u_Z(z_j). \quad (9b)$$

The coefficient $(1.0 - k_Y - k_Z)$ can be interpreted as accounting for interactions between *Y* and *Z*. For $(k_Y + k_Z) < 1.0$, the product term is added to the additive term. There is a positive synergism and the two attributes can be interpreted as preference complements. For $(k_Y + k_Z) > 1.0$, the product term is subtracted from the additive term. There is negative synergism and the two attributes can be interpreted as preference substitutes [Clemen and Reilly, 2001, p. 654).

Life-Critical Medical Decisions

Most people make life-critical medical decisions based on HRQL and years of life.

Quality-Adjusted Life-Years Models

Quality-adjusted life-years (QALYs) combines HRQL and years of life into an intuitively attractive and useful measure for MDM. Numerous QALY models that weigh years of life by HSUV have been developed.

Linear QALY Model

Pliskin et al. [1980] derived the linear QALY model for a chronic disease under the assumptions of (1) MUI, (2) constant proportional trade-off, and (3) risk neutrality over years of life:

$$U^{LQ}(h_i, y) = U_H(h_i) \times y \qquad (10)$$

where $U_H(h_i)$ is the HSUV of health state H_i specified on the (Dead = 0.0, Full health = 1.0) scale and *y* is the number of years.

Bleichrodt et al. [1997] subsequently derived the linear QALY model more directly from the self-evident zero-condition (a dead individual is indifferent to health states) and risk neutrality over years of life. It gave the linear QALY model greater acceptability as a measure for MDM.

Nonlinear QALY Models

There is ample empirical evidence that people violate risk neutrality over life-years [Bleichrodt and Gafni, 1996]. Individual preferences over different health states are affected by how long they last and the sequence over which they occur. Assuming only MUI and constant proportional trade-off leads to QALY models of the general form

$$U^{NLQ}(h_i, y) = U_H(h_i) \times f(y) \qquad (11)$$

where f(·) is the utility function for years of life. The problem with (11) is that it does not specify any specific form for f(·). Power and exponential functions have been proposed [Tsuchiya and Dolan, 2005].

The linear QALY is ubiquitous in medical studies. Based on a recent literature review, Pettitt et al. [2016] conclude:

> *Despite the aforementioned limitations, and, given the lack of robust alternative, the QALY is still regarded as the most rigorous methodological tool available and provides a robust framework to guide healthcare providers.*

Joint Health-State Utilities

Given the increasingly aging population, individuals with multiple co-existing *health conditions* are now the norm rather than the exception. Several simple models have been proposed and used principally because of their simplicity. Numerous studies have shown that they do not give consistently accurate results across the full range of possible HSUVs. Dale [2010] writes:

> *It is remarkable … how little is known about estimating utilities for joint health states (JS)…it would be extremely valuable to have a method for accurately estimating JS utilities based on existing SS[5] utilities.*

Given the complexity of human diseases, we expect joint health-state utility values (JHSUVs) to be complex functions of the constituent single health-state utility values (SHSUVs).

[5] SS: Single health state.

There are significant differences between the KR MUF (3a) and the PMUF (6) when applied to MDM:

- The PMUF (6) is a special case of the KR MUF (3a) for $\sum_{i=1}^{n} k_i < 1.0$.
- The PMUF (6) uses SHSUVs specified on the (Dead = 0.0, Full health = 1.0) scale. These are directly elicited using the methods discussed under "Elicitation of Health-Sate Utilities."
- The use of SHSUVs eliminates the need for the weights k_i. Poor determination of weights is one of the most common mistakes in MCDA [Keeney, 2002].
- Studies indicate that the directly elicited JHSUVs are in better agreement with the predictions produced by the PMUF (6) than the KR MUF (3a) [Feeny et al., 2002].

Interactions in the PMUF

It is often convenient to consider disutility, $\overline{U}(\cdot) = 1.0 - U(\cdot)$, when discussing the loss of HRQL. Consider a joint health state (JHS) (x_i, y_j) and the PMUF (6) with $n = 2$. The associated disutility is

$$\begin{aligned}\overline{U}^{PM}(x_i, y_j) &= 1.0 - U_X(x_i) \times U_Y(y_j) \\ &= 1.0 - \left(1.0 - \overline{U}_X(x_i)\right) \times \left(1.0 - \overline{U}_Y(y_j)\right) \\ &= \overline{U}_X(x_i) + \overline{U}_Y(y_j) - \overline{U}_X(x_i) \times \overline{U}_Y(y_j).\end{aligned}$$

Thus, the PMUF allows only for antagonistic, or negative, interactions in disutility among health states. That is, the disutility of two adverse effects is less than the sum of the constituent disutilities.[6]

Example 2. HUI3 data [Feeny et al., 2002]:

$$\overline{U}(D_6, E_5) = 1.0 - U(D_6, E_5) = 1.0 - 0.56 \times 0.46 = 0.76$$
$$\overline{U}(D_6) + \overline{U}(E_5) = (1.0 - 0.56) + (1.0 - 0.46) = 0.98.$$

But mental conditions (e.g., emotions) and other health conditions (e.g., dexterity) may have a positive synergism [Patten et al., 2014].

Example 3. Basu et al. [2009] directly elicited HSUVs from 207 prostate cancer patients following their biopsies. They report the following interesting data:

- U(impotence) = 0.73, U(watchful waiting) = U(post-prostatectomy) = 0.78
- U(impotence, watchful waiting) = 0.66, U(impotence, post-prostatectomy) = 0.70.

The JHSs consist of identical SHSUVs, but the elicited JHSUVs differ significantly.

Both examples demonstrate that the PMUF is problematic for estimating JHSUVs from SHSUVs.

[6] The medical literature refers the two types of preference interactions among health states. Two health states are said to be (1) *preference complements* if the disutility of both adverse effects is less than the sum of the constituent disutilities or (2) *preference substitutes* if the disutility of both adverse effects is more than the sum of the constituent disutilities [Feeny et al. 2002]. Note the difference between this characterization of interactions in the disutility space versus the characterization of interactions in the utility space provided for the two-attribute KR MUF (9).

Summary and Conclusions

Additive MCDA models are compensatory models. Thus, they are inappropriate for life-critical MDM. A preferred treatment must extend years of life and/or improve HRQL. Good performance on other attributes cannot compensate for failure to do so.

The KR MUF (3) has been proposed and used for decision problems where additive MCDA models are inappropriate. The underlying assumption is MUI. MUI is a weaker condition than AI. AI implies MUI, but MUI does not imply AI. We stress that MUI is a strong condition that needs to be assessed for each situation including life-critical MDM. To choose an appropriate MCDA model, one must understand its limitations, pitfalls, and practical difficulties. This is especially challenging because, as Kahneman [2011, p. 274] cautions us,

> *The errors of a theory are rarely found in what it asserts explicitly; they hide in what it ignores or tacitly assumes.*

For *n* MUI attributes, the KR MUF (3) is defined entirely by the *n* constituent SAUFs, *n* associated weights k_i, and an interaction scaling constant *K*. The determination of the weights is one of the most common mistakes in MCDA. Despite its complex appearance, the KR MUF (3) is either a multiplicative MAUF (6) or (8) or an additive MAUF (9b).

There are important theoretical and practical differences between the KR MUF (3) and the multiplicative MAUF (6) for use in MDM. It is essential to differentiate between the SAUVs and the SHSUVs. The SAUVs $u_i(x_i)$ in (1) and (3) are measured on interval scales $(x_i^- = 0.0, x_i^+ = 1.0)$. These scales have no absolute or true zero. Thus, SAUVs are not commensurable with each other. Zero on one is not the same as 0 on any of the others. The SHSUVs $U_i(x_i)$ in (6) are directly elicited on the (dead = 0.0, full health = 1.0) scale. The latter is a ratio scale; thus, all HSUVs can be directly compared. The SG is considered the gold standard for directly eliciting HSUVs because it has a sound theoretical foundation within vNM EUT.

We presented several simple real-world examples that demonstrate that MUI is a problematic assumption for life-critical MDM. We recognize that model simplicity is desirable. However, based on our results, we conclude that the KR MUF and the PMUF are inappropriate MCDA models for life-critical MDM.[7] Additional research is needed to develop practical MCDA models that reliably reflect the utility of life-critical medical treatments and personal preferences. Otherwise we cannot know that the model provides the right decision.

Epilogue

Many people eventually have to make one or more life-critical medical decisions. This is a complex MCDA problem that involves years of life gained, HRQL, treatment effectiveness, probability of outcomes, cost, and availability. At the Naval Postgraduate School, I taught several of today's most used MCDA methods, including their limitations. I was not satisfied with any of them. When I retired, I proceeded to investigate MCDA methods for life-critical MDM.

[7] Analogous conclusions apply to systems engineering and project management where performance, cost, and schedule are critical attributes and risk is ever present.

A couple of years ago, I received a serendipitous invitation from Evangelos (Van) Triantaphyllou to give a presentation at the 2017 INFORMS conference in the session with the challenging title, “MCDA: Can we always know that we have made the right decision?” My presentation, “How to (and How Not to) Apply MCDA to Medical Shared Decision Making,” was well received. Van and I proceeded to collaborate on this important problem. We wrote a paper, “Additive MCDA Models: Misleading Aids for Life-Critical Shared Decision Making”, which is to be published in the journal *Medical Decision Making*. The following reviewer comment was particularly gratifying:

> *I think it is very valuable to have a critique of MCDA in health contexts…MCDA has weaknesses in medical contexts in life-critical decisions. Some people have really drunk the MCDA Kool-Aid and I think this is worrisome. So good to have a critique.*

This paper is a further step forward in my latest endeavor.

List of Acronyms Used in this Paper

AI	Additive Independence, Additive Independent
EU	Expected Utility
HRQL	Health-Related Quality of Life
HSUV	Health-State Utility Value
HUI3	Health Utilities Index Mark III
ISPOR	International Society for Pharmacoeconomics and Outcome Research
JHS	Joint Health State
JHSUV	Joint Health-State Utility Value
KR MUF	Keeney-Raiffa Multiplicative Utility Function
LHS	Left-Hand Side
MAUF	Multi-Attribute Utility Function
MAUT	Multi-Attribute Utility Theory
MCDA	Multi-Criteria Decision Analysis
MDM	Medical Decision Making
PM	Project/Program Management
PRA	Probability Risk Assessment
MUI	Mutual Utility Independence, Mutually Utility Independent
PMUF	Pure Multiplicative Utility Function
QALY	Quality-adjusted life-year
RAM	reliability/availability/maintainability
RHS	Right-Hand Side
SAUF	Single-Attribute Utility Function
SE	Systems Engineering
SG	Standard Gamble
SHSUV	Single Health-State Utility Value
TTO	Time Trade-Off

UI	Utility Independence, Utility Independent
VAS	Visual Analogue Scale
vNM EUT	von Neuman-Morgenstern Expected Utility Theory

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About the Author

Edouard Kujawski holds a PhD from MIT, where his thesis was in theoretical nuclear physics. He pursued scientific research and taught physics for six years in academia. Following the Three Mile Island (USA) accident, his interests turned to probabilistic risk assessment (PRA). From 2000 to 2005, he was a Staff Engineer with the Lawrence Berkeley National Laboratory where he established an effective system engineering environment and capability. In 2005, he joined the Systems Engineering Department at the Naval Postgraduate School as an Associate Professor. He developed courses in PRA and reliability/availability/maintainability (RAM) and led several capstone projects. He retired to pursue research in MDM. He has authored or coauthored numerous publications including 12 papers in the *Systems Engineering* journal and one in the *Medical Decision Making* journal.

3. ADDITIONAL ARTICLES

3.1 Stop Blaming Top Management

by

Rainer Grau

Article Source

In recent years, I've realized an increasing blaming game toward top management. My urgent appeal to the agile community is: **STOP THIS**!

Why this statement?

I've been working for thirty years. In the last twenty years, I've spent an increasing amount of my time working with middle management, and in the past ten years, with top management. I really have to say,

the vast majority of top managers with whom I've worked are smart, charismatic, engaged, and understand the dark spots around them. Of course, terrible hard-core managers are out there, but hey, terrible employees are as well. Luckily neither is the majority.

I don't like statements such as "A good manager hires people who are smarter than he is". A nice Dilbert tells you where this leads to. A manager or leader requires DIFFERENT and COMPLEMENTING competences, the competencies of a leader and manager. He or she is part of the team(s) complementing with management and leadership competence.

We as the agile community have to ask ourselves uncomfortable questions:

- It seems likely that we as the agile community are part of this view on top management?!
- Probably we do not value the competences of the managers and leaders in our companies?!
- Why are managers where they are?
- Are we, employees and middle management members, lacking influence; and because of that, not part of this status quo?

Here are some of my observations:

- We always talk about failure culture. But, as soon as a manager shows a tiny weakness or made a wrong decision, the blaming starts "What a failure…", "If he has asked me before…" and so on. Where is our feedback culture, openness, and transparency?
- Managers do have the same restrictions as any other employee in the company. It is nonsense to think a CEO just can decide and pull the big lever just as she likes. A CEO is part of the system as we are. There is the supervisory board, the competition, the group CEO, still strange goal definitions (as part of our culture), and so on.
- I recognize: top managers are alone and isolated. They miss colleagues that provide true and open feedback. We all unload our claims and demands on his desk and expect immediate action. Where is our part of the communication and collaboration?
- Our performance-oriented occidental culture interprets stagnation as break down. As soon as one reaches a certain level of responsibility, our culture forces all of us to become better, faster, and more responsible. Otherwise your influence drops, you are marked as a "yesterday model", the competences you own and have a long experience in, are no longer respected. You will be demoted. Managers are forced to go forward as soon as they crossed this social border. There are managers who told me, "You know, actually I was happy with my job as X. We had success with my teams, and me leading and supporting them. We created this product and it was fun. But then the supervisory board asked me to take the responsibility for this large program Y. From my heart, I would rather stay with X, but that would be the end of my life here. They would let me fall. I still must work fifteen years. I like the company. Finally, I agreed to go for Y and I do my best. I got pretty strict constraints, I was better-off before…you know this story, don't you?" And yes, I know.

It is so easy to blame managers. It is so easy to call for leaders instead of managers. It is harder to step back, reflect, and work to improve the situation.

I will not offer a solution in this blog. I do not know if a “solution” to resolve this concern exists at all. The world is complex, and our culture builds up high walls that we have to tear down in order to implement positive and needed change.

What did I decide to do?

I stopped pointing at top management. In my work with top management, I try to find the very rare moments to start an open and safe conversation for both sides. And within the teams I ask for understanding. I try to foster conversation between top management and “all the others”. Conversation is always a way to create mutual understanding. I want barriers to disappear. Top managers and leaders are smart, charismatic, engaged, and it is high value to work closely with them.

Maybe it helps to offer top managers (or top leaders?) support and help instead of only expecting support and help.

Maybe some time in the future a responsible leader of X is allowed to stick with X instead of going for the larger and more demanding Y, still keeping her influence, responsibility, and recognition.

3.2 Roadmaps – Taking the Complexity out of Today’s Complex Systems

by

Taras Alexander Mykytyn

Managing a complex system development being developed is extremely challenging and requires extensive coordination between all stakeholders, technical teams, leadership and decision makers, operational support teams, and the customer/end users. Delivering complex systems capabilities into operations in a timely and efficient manner requires a thorough understanding of each product/service teams planned deliverables, as well as the inter-dependencies for achieving integration, testing, deployment, and support milestones. It sounds like a daunting task, but bringing together streamlined processes, program management tools, and technology can address this challenge, and provide a management capability to plan, track, monitor, and execute their yearly executable and multi-year projected plans.

Understanding baseline management, having disciplined configuration/change control processes, mapping out key inter-dependencies between interfaces, and generating integrated tracking plans for phased deliverables, can breakdown the complexity and bring great efficiencies to the program management of a complex system development effort. Strong systems engineering processes supporting program managers can ensure greater success in a program and buy down risk tremendously for all stakeholders.

Systems engineering discipline brings end-to-end processes incorporated into a product/services life-cycle, covering configuration, change, release, and configuration management through a database (CMDB), knowledge management through the database (KMDB), product/service tracking and

management through a product/service catalogue, workflow management, security operations management, and advanced operational analytics/reporting/visualization for planned baselines and future projected capabilities. Integrated project timelines provide tracking of various swim lanes and present the inter-dependencies for the various teams executing program deliverables.

Figures 1a and 1b depict a project timeline view provided by a commercial tool, in this case – ServiceNow. These views provide direct visibility into what's being planned for delivery into operations.

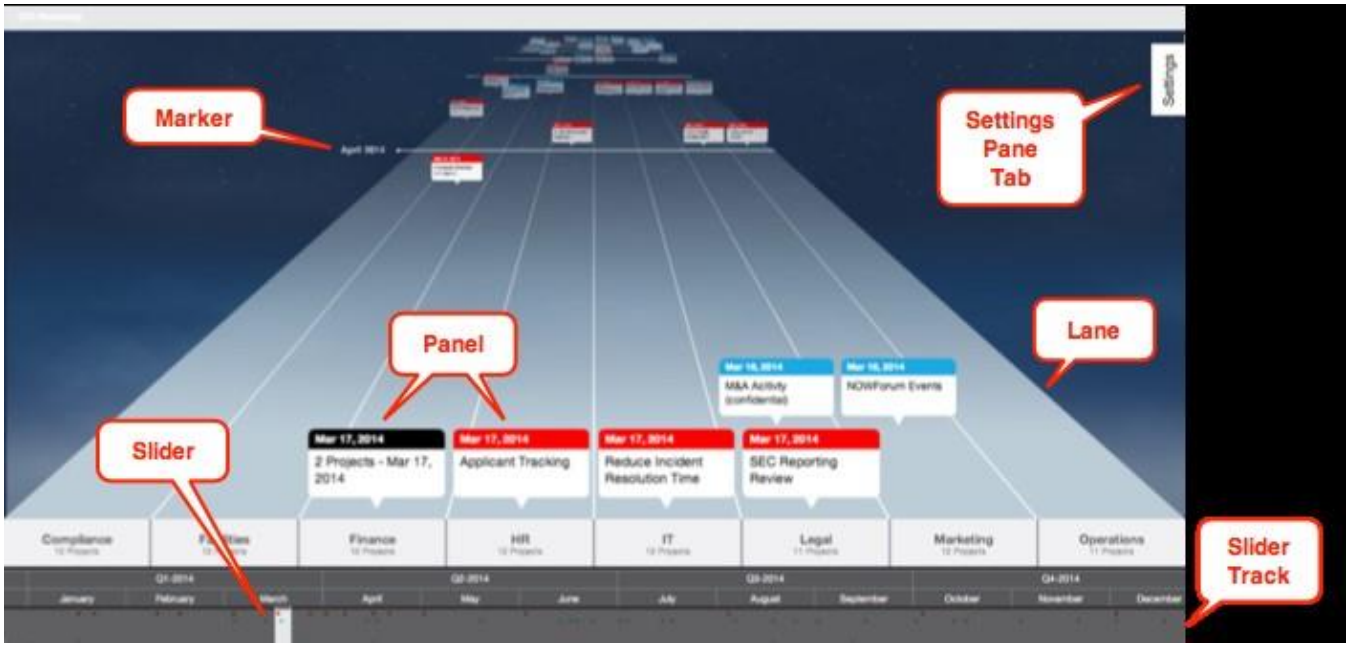

Figure 1a. ServiceNow View of an Integrated Project Timeline across Multiple Swim Lanes

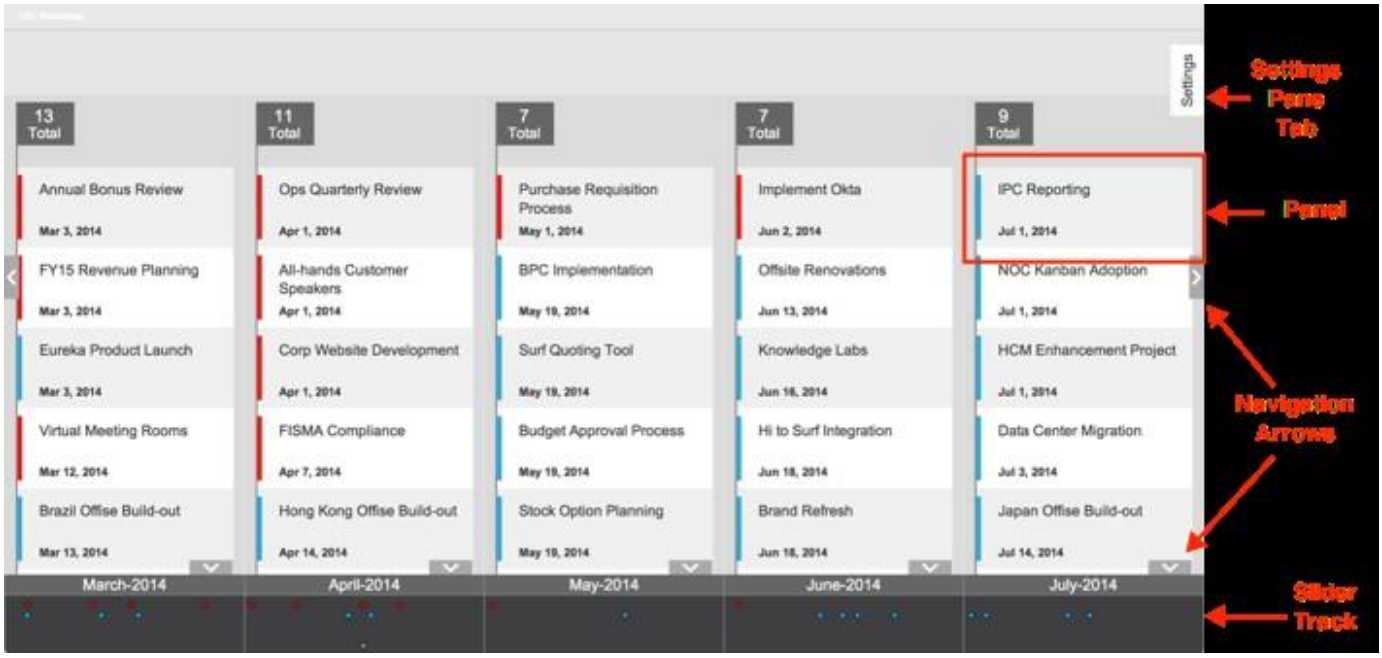

Figure 1b. Timeline View of Project Deliverables

1) Why a Roadmap? Another important tool, beyond an integrated project timeline tool, is a roadmap tool depicting specific milestone deliverables with embedded hot links into more detailed information for specific time periods, noted phased capabilities, and expected deliverables and dependencies for each

milestone. The following information presents the significance of roadmaps, types of roadmaps, and information on managing baselines.

- **Roadmap** *quickly displays specific "swim lanes" that have activities/dependencies tracked and managed. As a program management tool, it helps with communications, planning activities, ensures engineering activities drive out requirements/interfaces/dependencies/integration points/capabilities definitions, etc.). Types of roadmaps that can aid program managers and stakeholders are presented below.*

- **IT Infrastructure (ITI)/Services Technology Roadmap –** *(planned IT upgrades and/or new deployments to support the data centers and end-users; includes servers, storage, network, desktop, laptop/tablets, printers, etc.).*

- **Software/Capabilities Roadmap –** *(planned software updates and/or new functionality related to the ITI assets and interfacing with new services, locations, and integrated capabilities; includes external software support and maintenance contracts).*

- **Acquisition Roadmap –** *(contracts for procurement of and support/maintenance for yearly/new hardware, software licenses, professional services, etc.).*

- **Process/Training Roadmap –** *(planned updates and/or new processes for end users, support personnel, management/decision-makers, and associated training for new processes, software, and/or capabilities).*

- **People/Skills Roadmap –** *(planned new skills and associated addition of new personnel for the support and management staff to keep up with new technology, tools, processes, software tools/capabilities).*

- **Security/Compliance Roadmap –** *(planned software patches, unplanned software patches, updates to business rules for compliance and security operations, etc.).*

- **Technology Roadmap –** *(vendor planned updates/new technology that is part of the technology refresh or obsoleted hardware/software where support, operations, security, and/or compliance are impacted).*

Note: Sample roadmaps are provided in Figures 2a and 2b below.

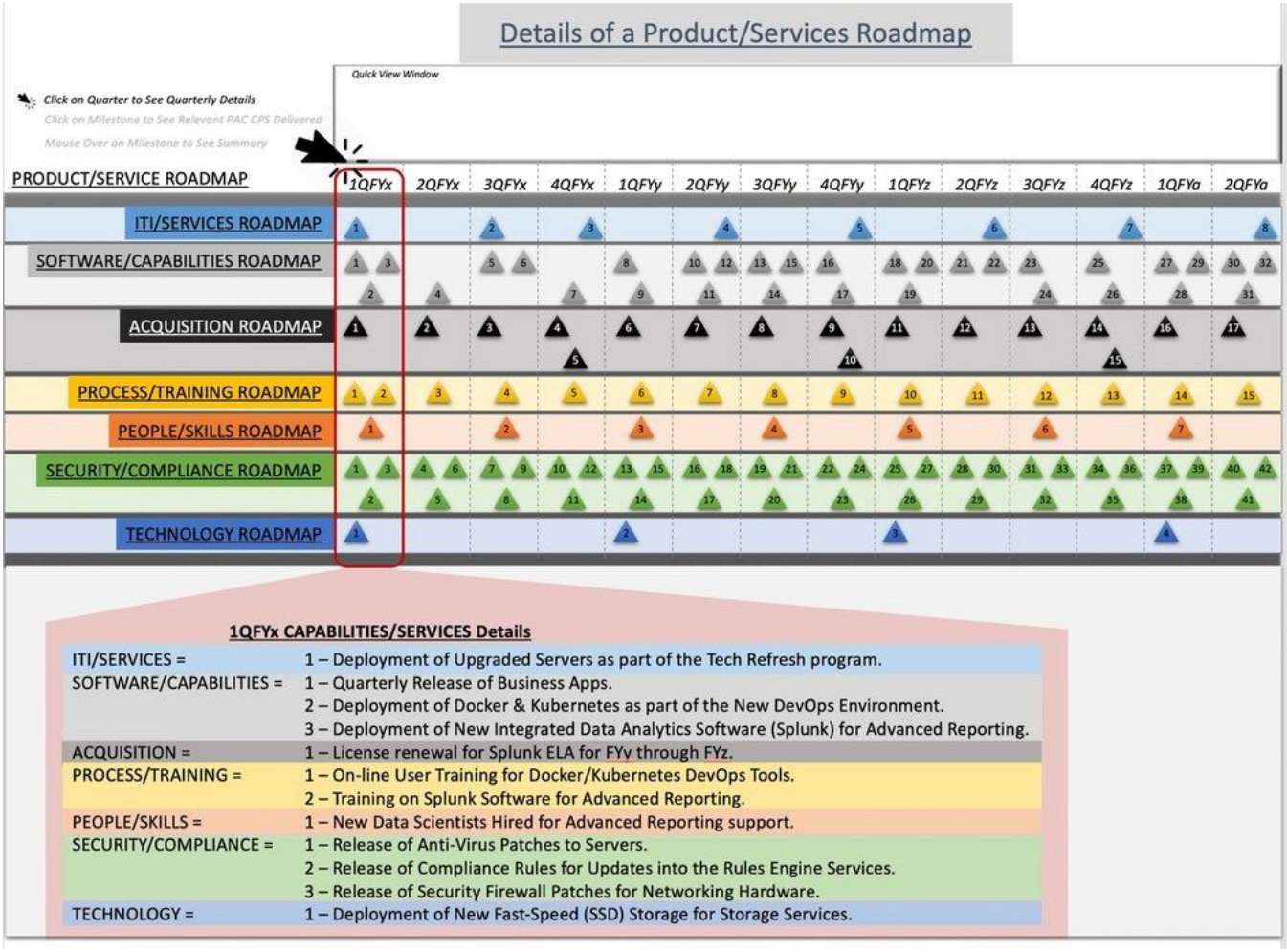

Figure 2a. Product/Services Roadmap with Quarterly Details Denotes

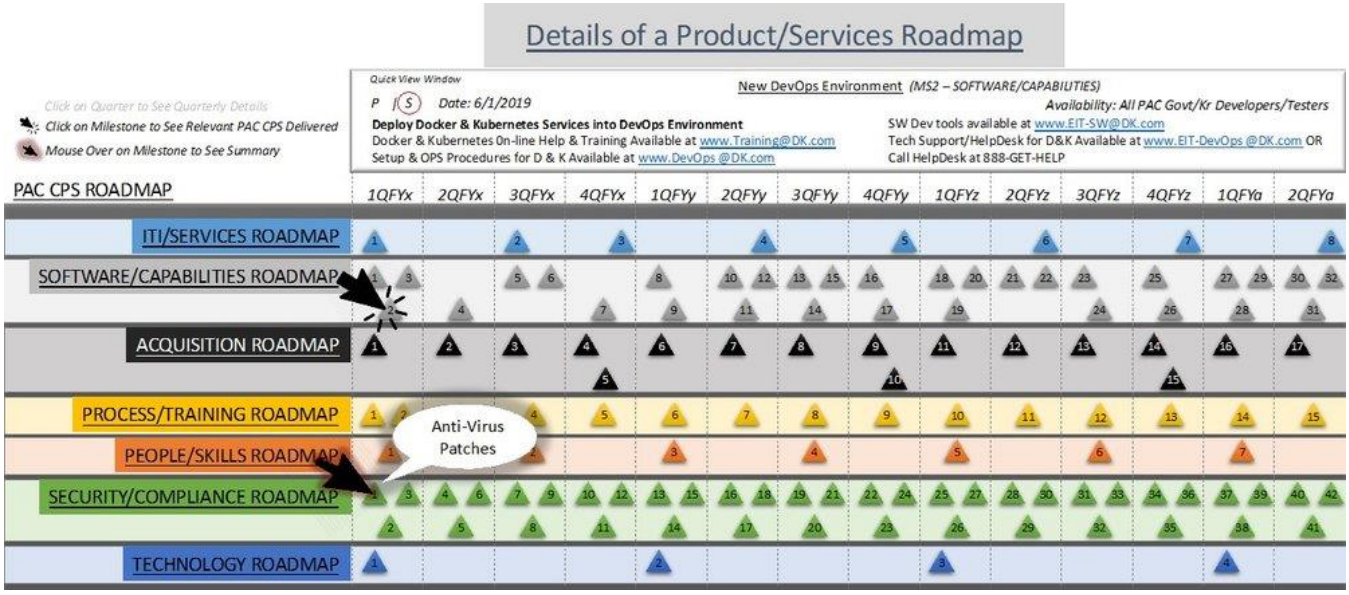

Figure 2b. Product/Services Roadmap with Specific Service Details Provided

2) Configuration & Baseline Management *(understanding what is critical to put under configuration control; who needs this information and what will they use it for; managing baselines to address current capabilities that are supported, transitioning new/upgraded capabilities into operations; foundation for monitoring and managing ITI and services in the enterprise).*

"As-Is" Baseline *(foundation for what needs to be monitored and managed; understanding hardware and software deployed; inventory/asset/license management; and setting baseline for planning future capabilities).*

"To-Be" Baseline *(foundation for where your architecture and services are transitioning to – "end state"; leveraging technology refresh, new (and potentially disruptive) technology; helps with converging services/capabilities planning; sets foundation for all planning activities).*

"Planning" Baseline *(list of services/capabilities to be deployed into operations; continuous feedback on performance and utility of services/capabilities; including patches/minor upgrades, as well as major enhancements and updates; foundation for programmatic and investment plans; capturing all dependencies and impacts for the Roadmap "swim lanes"; business case and operational impacts captured for stakeholders, user base, and decision-makers).*

Tools and technology for Baseline Management *(Configuration Management, Asset Management, Inventory Management, License Management for current and planned future services/capabilities; Capabilities/Service Catalog for current and planned future capabilities/services).*

In summary, Product/Services Roadmaps can provide a very distinct view into what phased capabilities are currently planned for delivery into operations. It provides the program manager, engineering staff, executive leadership, operational support teams, stakeholders, and customers/end users' insight into capabilities being planned for delivery. The roadmap and project timeline tools, underlying processes and technology (i.e., CMDB, KMDB), and advanced visualization tools provide the foundation for managing baselines and coordinating activities between the development, integration, testing, deployment, and operational support teams. There should be no surprises for all of the stakeholders that hold a vested interest in the successful delivery, transition, and operations of planned products and services.

4. SYSTEMS ENGINEERING NEWS

4.1 INCOSE Working Groups Provide a View of the Model Based Systems Engineering Technical Data Package

John Nallon, Chair of INCOSE'S Tool Integration and Life Cycle Management (TIMLM) Working Group, and Mark Williams, Chair, Model Based Systems Engineering for PDES[8] Working Group, have invited colleagues to provide discussion concerning "HOW" to define and exchange a Technical Data Package (TDP). The TDP represents the data that will be exchanged between an Original Equipment Manufacturer (OEM) and a Supplier. International and U.S. examples of data standards representing a TDP include ISO 10303-232 (AP232) and MIL-STD-31000, but neither standard adequately addresses the MBSE elements. The TDP defines "WHAT" to exchange and is a defining factor in HOW to package (assemble/bundle/couple) the MBSE artifacts business objects.

For further information, please see the related article in the Standards section of this issue.

[8] PDES, Inc. is an international industry, government, and university consortium committed to accelerating the development and implementation of standards for product data exchange in the Digital Enterprise. See https://pdesinc.org/.

4.2 International Women in Engineering Day

International Women in Engineering Day (INWED) is an international awareness campaign to raise the profile of women in engineering and focus attention on the amazing career opportunities available to women in this exciting industry. This day of recognition takes place annually on 23 June. This year the celebration was commensurate with the celebration of 100 years of Women's Engineering Society (WES) in the UK. Worldwide activities honoring INWED are under the patronage of the United Nationals Educational, Scientific and Cultural Organization (UNESCO).

Find out more information about IWED here.

4.3 INCOSE India MBSE Local Working Group Kick-off

Figure 1. Photograph taken at the INCOSE India Chapter meeting held on 3rd May 2019

There has been significant interest among INCOSE India members to drive adoption and exploration of Model Based Systems Engineering (MBSE). To channel this interest, the INCOSE India chapter hosted a meeting on 3rd May, 2019, and kicked-off a Local Working Group (LWG) focused on MBSE. The participants represented various industries, such as Aerospace Systems, Embedded electronics, Automotive and Off-highway vehicles, and others.

During the meeting, the participants expressed interest in building training modules, domain specific examples, as well as contribution to standards and guidelines in specific domains. They also reviewed ongoing INCOSE initiatives, such as the SE transformation initiative, and the work done by various challenge/activity teams through the OMG-INCOSE MBSE efforts. It was decided that the members will meet in subsequent months to develop a common understanding of the ongoing efforts and the state-of-the-art. Thereafter, the LWG will choose a couple of challenges to work on, and collaborate with existing teams at INCOSE to deliver technical products, such as domain specific guidelines or examples. To learn more about the India Chapter MBSE Local Working Group or to participate in it, please email Nikhil Joshi (najoshi@gmail.com).

4.4 Korean Society of Systems Engineering Conducts Conference on "Systems Engineering for New Framework of Future Strategy"

by

Dr. Joongyoon Lee

Email: jlee2012@postech.ac.kr

The Korean Society of Systems Engineering (KOSSE) conducted a conference on the topic "Systems Engineering for a New Framework of Future Strategy" on May 30-31, 2019. The conference was held at the Graduate School of Engineering Practice, Seoul National University, Seoul, Korea. Approximately 170 delegates attended the conference. The conference program included:

- Three keynote speakers
- 50 paper presentations
- 7 poster presentations
- A panel discussion moderated by Prof. Joongyoon Lee (POSTECH), presented by Dr. Jaewook Lee (KIDA), Dr. Byongjin Park(ADD), Dr. Changbum Ahn (Chair of KOSSE) and with participation from Gen. Kyongseo Kim (Air Force), Gen. Youngsam Kim (Army), Director Jeongin Seo (KDIA), Dr. Minyong Lee (ADD)
- Six tutorials on the following topics:

    1. Intro of JCIDS
    2. Right OCD
    3. SE-based Concept Design of Ship
    4. Applying M&S for supporting SE of weapon systems
    5. Applying Lean SE & PM
    6. Risk Management using ARM.

4.5 2019 Systems Engineering Inc. Internship Program

by

Blair Colby

Figure 1. The five young engineers selected for the 2019 Systems Engineering Internship Program

Systems Engineering Inc. is an employee-owned company in Portland Maine USA. Each year, the Company sponsors an internship program. The 2019 program includes five members from a variety of schools including the University of Southern Maine, University of Maine, Lehigh University, and the University of Alabama.

While participating in the program, interns receive real-world experience in a technical and professional services environment. The Internship Program offers on-the-job training to help participants' résumés rise to the top of the stack and prepare them to transition relatively seamlessly into full-time careers.

"Finding IT talent is a challenge. We realized that by providing a formal internship program, we could create a unique opportunity to develop a pipeline of talented people. We learn as much from our interns as they learn from us. Their feedback and suggestions are highly valued as we want to ensure we're providing the structure, content, and the tools to deliver a great learning experience during their time with us," said Susan Massey, Systems Engineering's Human Resources Manager.

During the program, interns are assigned a mentor with whom they work to gain knowledge in their development area of choice. They also benefit by learning customer service, troubleshooting, project management, team work skills, and more.

This year, the Systems Engineering Internship Program is running from May 28 through August 23, 2019 and includes the following interns:

Aidan Greenlee, Help Desk
Luke Jillings, Software Services
Matt Mizrahi, Engineering
Nick Lahner, Project Management
Shykeem Canty, Engineering

More Information

4.6 INCOSE Academic Equivalency for Systems Engineering Certification Awarded to University of New South Wales

by

Christine Kowalski

The International Council on Systems Engineering (INCOSE) is excited to announce the award of Academic Equivalency to the University of New South Wales (UNSW) for students to meet the knowledge requirement for the INCOSE Associate Systems Engineering Professional (ASEP) and Certified Systems Engineering Professional (CSEP) certifications. The University of New South Wales is the first university in Australia to be awarded the academic equivalency. INCOSE first awarded this academic equivalency in January 2019.

With this equivalency in place, students who demonstrate knowledge of systems engineering through approved coursework will not have to take the INCOSE Knowledge Exam to get certified. Knowledge demonstration is a mandatory part of the path to becoming an ASEP and CSEP, so this award is a great benefit for New South Wales University students.

“At INCOSE, academic equivalency demonstrates the strength of specific university systems engineering programs in meeting the knowledge requirements for systems engineering certification,” INCOSE President Garry J. Roedler stated. “It also shows the strength of universities working closely with INCOSE to embrace and evolve the requirements in their systems engineering programs toward meeting the accepted competencies for systems engineering. We have seen an increase in certification applications from Australia over the past two years, and this award will help us sustain that growth.”

5. FEATURED ORGANIZATIONS

5.1 Women's Engineering Society (WES)

Image Source

The Women's Engineering Society (WES) is a charity and a professional network of women engineers, scientists and technologists offering inspiration, support and professional development. Working in partnership, WES supports and inspires women to achieve as engineers, scientists and as leaders; WES encourages the education of engineering; and supports companies with gender diversity and inclusion.

Taken from the WES website:

Our Vision

Our vision is a nation in which women are as likely as men to choose to study and work in engineering, and one in which there are enough engineers to meet a growing demand.

Our Mission

Inspiring and supporting girls and women to achieve their potential as engineers, applied scientists and technical leaders. To work collaboratively to assist educators, employers and influencers in creating a diverse engineering community.

Strategic Themes

To achieve our mission, WES has developed strategic themes based upon our role as a supporter, collaborator and challenger:

- **Supporter** – Connecting women engineers, providing the link between WES members and wider networks, providing technical and leadership development opportunities and sharing good practice with members and WES partners
- **Collaborator** – Strengthening engineering, working with partners to plug the leaks along the pipeline from education to leadership, consulting with industry and companies and cooperating with government and policy makers
- **Challenger** – Changing cultures, challenging partners to continue to further the diversity and inclusion agenda within their organizations and more widely across the sector

Our Work

We are a Charity and a Limited Company, and are governed by a Board of Trustees and guided by our Council according to our Memorandum of Articles. We have individual and Partner Members and produce a quarterly printed journal, The Woman Engineer, as well as a monthly e-newsletter. Our programs and projects are focused on our members and on advancing our vision and mission.

Our History, M&As and our Centenary

WES started life after World War I in 1919 when the pioneering women who worked in engineering and technical roles during the War campaigned to retain these roles when the war ended.

In 2019 we are celebrating our centenary. Join us in the celebrations!

More Information

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6. NEWS ON SOFTWARE TOOLS SUPPORTING SYSTEMS ENGINEERING

6.1 PTC Integrates Requirements, Systems and Software Engineering Capabilities

PTC has announced the enhancement of its Windchill® product lifecycle management (PLM) platform with integrated software management and systems engineering capabilities. The addition of these key technologies enables full product traceability and provides stakeholders with key insights throughout the product development and manufacturing cycles.

“Today’s smart, connected products require manufacturers to harmonize mechanical and electrical components with software. Cumbersome, old processes and out-of-date technologies provide poor visibility, and often require duplicate entry and thwart timely business decisions,” writes Jack McAvoy from PTC.

To address these challenges, Windchill now includes built-in linking and tracing between its native product data management capabilities and systems engineering, requirements management, source code management, and testing – powerful capabilities inherent in the current Integrity™ products, which will be rebranded under Windchill. This comprehensive view of PLM enables designers to identify dependencies, view design progress, and understand improvements and exceptions.

More information

6.2 Aras Announces Launch of Requirements Engineering Application within its PLM Platform

Article Source

Aras has announced that its Requirements Engineering application, a next generation solution for managing requirements within a PLM platform, is now available. The rising complexity of products and systems across the industrial landscape and the ever-expanding regulatory environment is driving the

need for transformational technologies to manage requirements in the context of total product configuration at every step of the lifecycle. Many organizations struggle with digital transformation because they rely on a combination of standalone requirements management tools and monolithic documents. These organizations need an aligned technology that will accelerate their time to market by establishing traceability between different requirements types and related design artifacts and manage the related configurations on a single platform.

Aras Requirements Engineering enables end-to-end traceability across complex configurations in various design domains with requirements content representing various types of structured and reusable elements. Its ability to establish and maintain requirement relationships to platform-managed items and structures across all engineering domains is key to enabling a transformational methodology and platform for managing requirements.

Availability
Requirements Engineering is available for 11 SP15 and subscribers can access it through the Aras FTP site and use the Aras update tool to install the solution.

7. SYSTEMS ENGINEERING PUBLICATIONS

7.1 Thirteen Years of SysML: A Systematic Mapping Study

by

Sabine Wolny, Alexandra Mazak, Christine Carpella,

Verena Geist and Manuel Wimmer

Abstract

The OMG standard Systems Modeling Language (SysML) has been on the market for about thirteen years. This standard is an extended subset of UML providing a graphical modeling language for designing complex systems by considering software as well as hardware parts. Over the period of thirteen years, many publications have covered various aspects of SysML in different research fields. The aim of this paper is to conduct a systematic mapping study about SysML to identify the different categories of papers, (i) to get an overview of existing research topics and groups, (ii) to identify whether there are any publication trends, and (iii) to uncover possible missing links. The authors followed the guidelines for conducting a systematic mapping study by Petersen et al. (*Information Software Technology* 64:1–18, 2015) to analyze SysML publications from 2005 to 2017. The analysis revealed the following main findings: (i) there is a growing scientific interest in SysML in the last years particularly in the research field of Software Engineering, (ii) SysML is mostly used in the design or validation phase, rather than in the implementation phase, (iii) the most commonly used diagram types are the SysML-specific requirement diagram, parametric diagram, and block diagram, together with the activity diagram and state machine diagram known from UML, (iv) SysML is a specific UML profile mostly used in systems engineering; however, the language has to be customized to accommodate domain-specific aspects, (v) related to collaborations for SysML research over the world, there are more individual research groups than large international networks. This study provides a solid basis for classifying existing approaches

for SysML. Researchers can use the results (i) for identifying open research issues, (ii) for a better understanding of the state of the art, and (iii) as a reference for finding specific approaches about SysML.

Read the Article

7.2 Guide2Research

Guide2Research is the number one research portal for computer science with free resources to help you progress with your research. If you are a professor, research fellow or studying for a PhD, Guide2Research.com can help you to search for the upcoming conferences around the world. G2R shows conferences indexed by leading and prestigious scientific publishers including IEEE, Springer, and ACM. There is a section dedicated to rank the Top Conferences based on H-index. (The h-index is an author-level metric that attempts to measure both the productivity and citation impact of the publications of a scientist or scholar. The index is based on the set of the scientist's most cited papers and the number of citations that they have received in other publications. Source: Wikipedia)

Guide2Research compiled the list of top journals for the various fields of computer science and electronics based on their research impact factor. One can also browse the list of upcoming special issues for those journals. Lastly, Guide2Research features the list of top scientists in computer science ranked by their Google Scholar h-index. ONe search for scientists, see their ranking, other metrics and the awards they have received.

Guide2Research

7.3 A Systems Approach to Managing the Complexities of Process Industries

by

Fabienne Salimi and Frederic Salimi

Image Source

From the Amazon Website:

A Systems Approach to Managing the Complexities of Process Industries discusses the principles of system engineering, system thinking, complexity thinking and how these apply to the process industry, including benefits and implementation in process safety management systems. The book focuses on the ways system engineering skills, PLM, and IIoT can radically improve effectiveness of implementation of the process safety management system.

Covering lifecycle, megaproject system engineering, and project management issues, this book reviews available tools and software and presents the practical web-based approach of Analysis & Dynamic Evaluation of Project Processes (ADEPP) for system engineering of the process manufacturing development and operation phases. Key solutions proposed include adding complexity management steps in the risk assessment framework of ISO 31000 and utilization of Installation Lifecycle Management. This study of this end-to-end process will help users improve operational excellence and navigate the complexities of managing a chemical or processing plant. Overall, the book:

- Presents a review of Operational Excellence and Process Safety Management Methods, along with solutions to complexity assessment and management
- Provides a comparison of the process manufacturing industry with discrete manufacturing, identifying similarities and areas of customization for process manufacturing
- Discusses key solutions for managing the complexities of process manufacturing development and operational phases

Format: Kindle, Paperback

Publisher: Elsevier; 1 edition (December 12, 2017)

ISBN:

ISBN-10**:** 0128042133

ISBN-13**:** 978-0128042137

7.4 Where's QA in Agile Development?

by

Mike Griffiths

Abstract

For the uninitiated, it can seem as if agile approaches are light on quality assurance. For instance, the Scrum Guide only talks about the development team, not QA roles specifically. There is no testing phase on agile projects, and they are deliberately light on documentation such as specifications and QA plans. These observations, while true, miss the more powerful alternatives in play on correctly executed agile projects.

QAs are part of the development team and engaged from the beginning of the project. They attend planning meetings, have access to the customer, and plan how to validate functionality while developers are creating it. Quality is baked in from the start, not attempted to be tested in later. Likewise, since features are developed in a sequence based on their priority; the most important elements get the most testing and exposure since they are present from the beginning.

Access the Article here.

7.5 Thinking Fast and Slow: A Comprehensive Summary to the Book by Daniel Kahneman

by

Daniel Kahneman

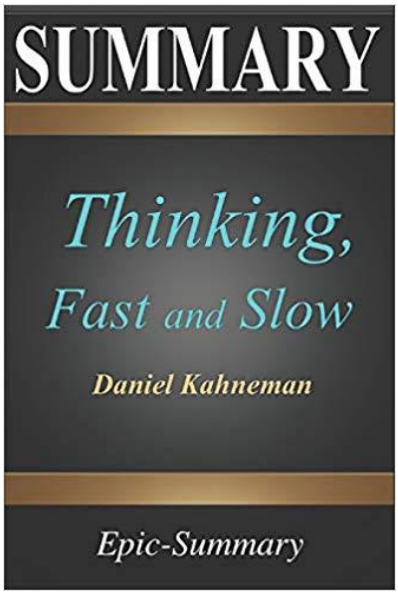


Image Source

From the Amazon.com Website:

If we want to do something in the best possible way, the first thing we need to do is understand what we are dealing with and what we want to do. Thinking, Fast and Slow is a book in which readers can find much useful advice regarding this matter. The way we think plays tremendous role in how we live our lives, how we will react to different situations, how (the way) we communicate with others, how we make decisions, and how we solve our problems – all of this is deeply rooted in the way we think. The author, Daniel Kahneman, writes about the way the human brain works and divides it into two sections, which when combined, create a perfect whole. Thinking, Fast and Slow is written so that its readers can make better decisions.

Format: Kindle, Paperback

Publisher: Independently published (March 25, 2019)

ISBN:

ISBN-10: 109161170X

ISBN-13: 978-1091611702

7.6 The Woman Engineer Journal

The Woman Engineer is the journal of the Women's Engineering Society. Published quarterly, the WES brings you all the news from WES. Women in Engineering Members receive the latest edition on publication. Backdated issues can be viewed/downloaded by following the links below. The Woman Engineer has been published since 1919.

Journals published since 2004

Journals published between 1919 and 2004

Index of women mentioned in The Women Engineer from 1919 to 2014

8. EDUCATION AND ACADEMIA

8.1 Department of Industrial & Systems Engineering

Texas A&M University

The Department of Industrial and Systems Engineering in Texas A&M University College of Engineering was established in 1940. It has consistently ranked in the top 10 departments in the United States over the past 10 years by the Gourman Report, the National Research Council and U.S. News and World Report. The Department provides education and research that contribute to the economic and technological advancement of the state, the nation and the world.

The faculty is nationally and internationally recognized for the quality of their research and teaching, and their leadership in the profession. The Department has programs in manufacturing and production systems, logistics and supply chain management, operations research, data science, applied probability and statistics, systems engineering, quality and reliability, and system simulation (which is especially relevant in the current environment of international trade and global competition).

More information

8.2 Department of Industrial & Systems Engineering

Seoul National University, South Korea

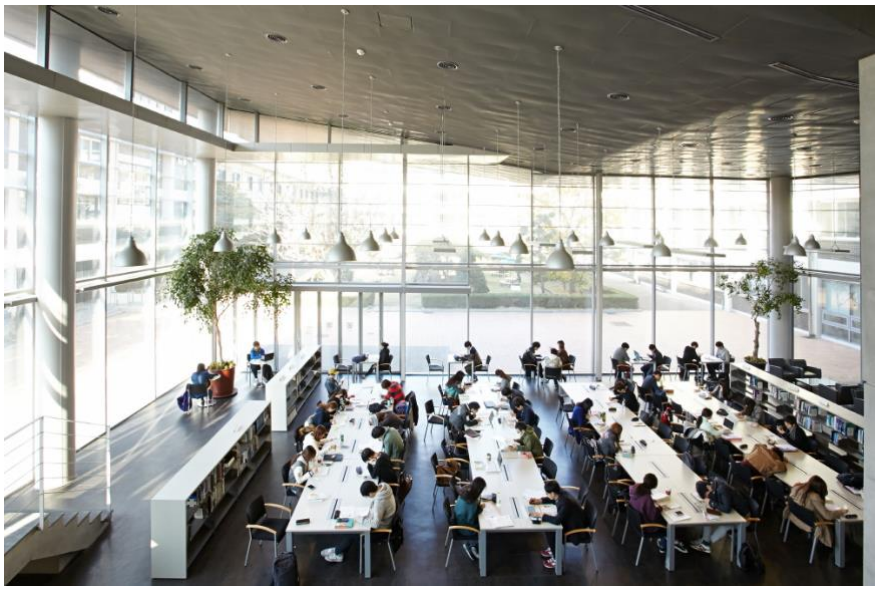


Image Source

Seoul National University (SNU) is a vibrant and intellectual community where students and scholars work together to build a brighter future. SNU is South Korea's first national university, and is already ranked 36th in the world by the prestigious QS World University Rankings, preparing students to live, work and above all prosper, in an increasingly globalized world. Ranked 15th in the world for the quality of its provisions, the College of Engineering at SNU is known across the globe for its technological innovations, and is now widely recognized as one of the world's top engineering faculties. The College comprises multiple engineering departments including architecture, chemical engineering and environmental engineering amongst others.

One of the esteemed departments is the Department of Industrial Engineering which is geared to educate learners to plan and design complicated industrial, public, and service systems using engineering knowledge and scientific tools. The Department enables students to develop and apply various techniques for enhancing the ability to manage, operate, and analyze complex industrial systems efficiently and effectively. The department and its acclaimed programs focus on developing students' creativity, logical thinking abilities and leadership skills. With this training, graduates leave fully equipped to pioneer innovations and improvements in industrial systems.

More Information

8.3 Master's Degree in Systems Engineering

University of New South Wales, Sydney Australia

The Master's of Systems Engineering (MSysEng) is designed for postgraduate scholars with an undergraduate qualification and/or extensive professional experience who wish to develop a high level understanding of the principles and practices of systems engineering and to strengthen their skills in this area.

The Systems Engineering program aims to allow students to develop a high level of understanding of the principles that shape systems engineering and their implementation through the design, development, and application phases.

Students who study their MSysEng will add breadth to their knowledge of engineering in general and expand their skills in engineering management, in addition to developing their technical knowledge and ability to analyze engineering problems. The degree features complex, open-ended enquiry-based projects.

25 specializations are available in studying this degree, these include: Biomedical Engineering; Chemical Process Engineering; Transport Engineering; Project Management; Water Engineering: catchments to coast, Water, Wastewater and Waste Engineering; Environmental Engineering; Geotechnical Engineering and Engineering Geology; Structural Engineering; Civil Engineering; Electrical Engineering; Energy Systems; Satellite Systems Engineering; Systems and Control; Sustainable Systems; Nuclear Engineering; Food Process Engineering; Manufacturing Engineering and Management; Mechanical Engineering; Petroleum Engineering; Petroleum Engineering Open Learn; Geothermal Engineering: Photovoltaics and Solar Energy; Renewable Energy; and Telecommunications.

UNSW offers a range of scholarships for local and international students, find out more here.

9. SOME SYSTEMS ENGINEERING-RELEVANT WEBSITES

Women in Engineering

WomEng is a values-driven organization for women in engineering by predominantly women engineers who have developed a program to address the issues facing women in the engineering sector from school level all the way through to industry.

https://www.womeng.org/about-us

NAE Grand Challenges for Engineering

The website to the National Academy of Engineering (NAE) Grand Challenges for Engineering initiative highlights grand challenges for engineering in the 21st century. The site contains information about each of the challenge as well as news regarding the challenge areas how to work together with people from other sectors to proliferate the attention to these challenges. The 14 Grand Challenges are:

1. Provide access to clean water
2. Advance personal learning
3. Make solar energy economical
4. Enhance virtual reality
5. Reverse-engineer the brain

6. Engineer better medicines
7. Advance health informatics
8. Restore and improve urban infrastructure
9. Secure cyberspace
10. Provide energy from fusion
11. Prevent nuclear terror
12. Manage the nitrogen cycle
13. Develop carbon sequestration methods
14. Engineer the tools of scientific discovery

As well as information on how to work together with people from other sectors to proliferate the attention to these challenges.

http://www.engineeringchallenges.org/

U.S. National Society of Professional Engineers: Code of Ethics

Access to the U.S. NSPE Code of Ethics that highlights the professional duties that engineers should perform, rules of practice and professional obligations.

https://www.nspe.org/resources/ethics/code-ethics

10. STANDARDS AND GUIDES

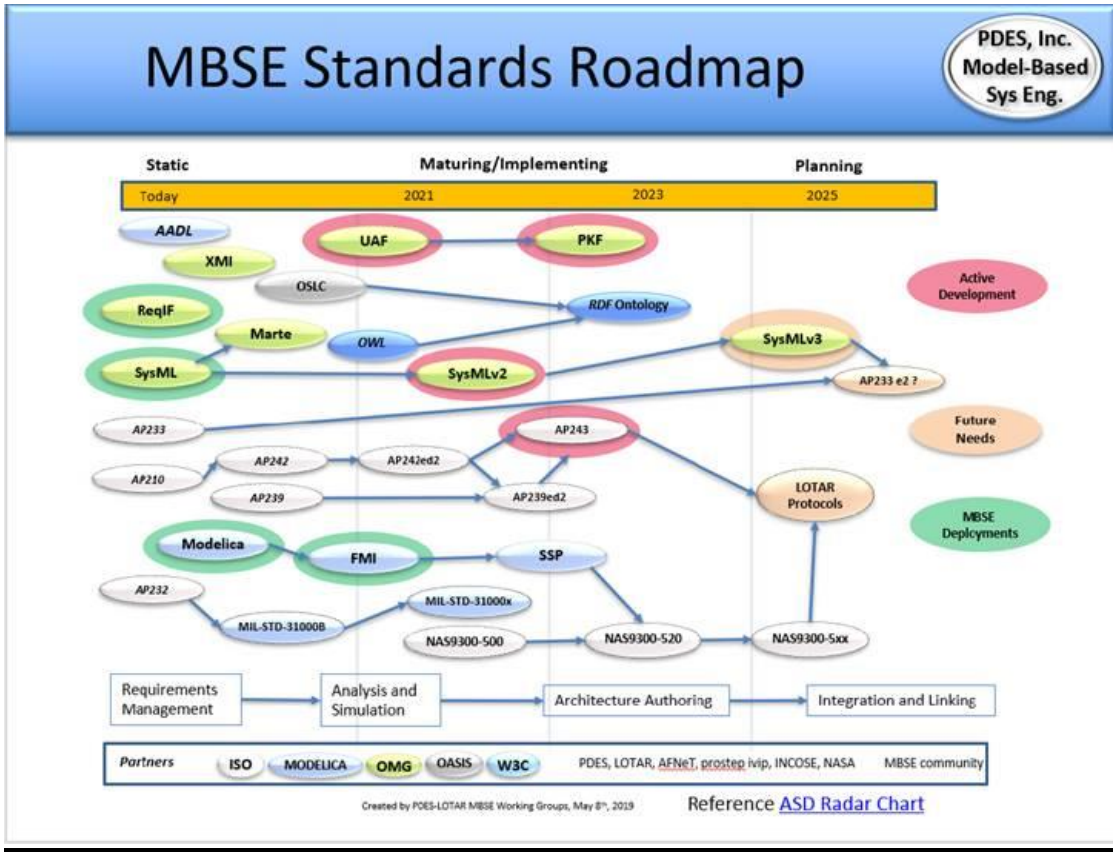
10.1 The MBSE Standards Map

This article provides additional information to that provided in the SE News section of this issue concerning the collaboration that is underway within the INCOSE/PDES[9] Inc. working groups (WG). The collaboration is geared towards unpacking MBSE Standards and the Long Term Archival and Retrieval of digital data.

The current focus of the INCOSE/PDES Working Group is to define **HOW** to package (assemble/bundle/couple) the MBSE business objects, represented by a MBSE Technical Data Package (TDP). Our initial tasks are to look at the *INCOSE Systems Engineering Handbook*, 4th Edition, and the *NASA Systems Engineering Handbook* system lifecycle Concept Stage descriptions and identify the

[9] PDES, Inc. is an international industry, government, and university consortium committed to accelerating the development and implementation of standards for product data exchange in the Digital Enterprise. See https://pdesinc.org/.

process artifacts that could be collected in a TDP to “handoff” to the organizations in the Development Stage.



In the effort to develop a view of the MBSE TDP, the following resources are being used:

- *INCOSE’s Systems Engineering Handbook*, 4th Edition
- Contributions by the DEIX (Digital Engineering Information Exchange) WG
- *NASA’s SE Handbook* and supplemental documents
- ISO 10303-AP232, Technical Data Packaging

MIL-STD-31000, SYSTEMS ENGINEERING STANDARDS AND SPECIFICATIONS, TECHNICAL DATA PACKAGES

INCOSE members or PDES Inc. corporate members are encouraged to participate in this collaboration. Please contact either John Nallon (john.nallon@incose.org), Chair, INCOSE’S Tool Integration and Model Lifecycle Management (TIMLM) Working Group or Mark Williams (mark.williams@boeing.com), Chair, Model Based Systems Engineering (MBSE) for PDES Working Group.

11. SOME DEFINITIONS TO CLOSE ON

11.1 Netcentric

1. (adjective) Pertaining to client/server architecture that is used throughout an enterprise's entire lines of business.

Source: https://www.definitions.net/definition/netcentric

11.2 Effectiveness

1. (noun) The degree to which something is successful in producing a desired result; success.

Source: Oxford English Dictionary

11.3 Proficiency

1. (noun) Advancement in knowledge or skill.

Source: Merriam Webster

2. (noun) A high degree of skill; expertise.

Source: Oxford English Dictionary

11.4 Emergence

1. (noun) The act or an instance of emerging.

Source: Merriam Webster

2. (noun) The process of coming into existence or prominence.

Source: Oxford English Dictionary

11.5 Capability

1. (noun) The facility or potential for an indicated use or deployment.

Source: Merriam Webster

2. (noun) The power or ability to do something.

Source: Oxford English Dictionary

11.6 Collaborate

1. (verb) To work jointly with others or together especially in an intellectual endeavor.

Source: Merriam Webster

2. (verb) Work jointly on an activity or project.

Source: Oxford English Dictionary

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12. CONFERENCES AND MEETINGS

For more information on systems engineering related conferences and meetings, please go to our website.

The featured event for this edition is:

Portland International Conference on Management of Engineering and Technology (PICMET)

25 - 29 August 2019 – Oregon, USA

PICMET (Portland International Conference on Management of Engineering and Technology) was established in 1989 as a non-profit organization to disseminate information on technology management through an international conference. It is governed by a Board of Directors and an Executive Committee. The Advisory Council provides advice and counsel on the global issues and critical dimensions of technology management and assists the president in the selection of key speakers. Advisory Council members deliver plenary speeches at the Conference.

The first PICMET was held as PICMET'91 in Portland, Oregon in October 1991. The theme was "*Technology Management: The New International Language*". Approximately 400 attendees from about 30 countries attended PICMET'91. Initially there was no plan to make PICMET a continuous conference but the success of PICMET' 91 and requests from researchers and practitioners of technology management from around the world prompted the Board of Directors to repeat it as a biennial conference to be held in Portland during the last week of July in odd-numbered years. Since 2004, PICMET has become an annual conference held at different locations in the world.

The theme of this conference is "Technology Management in the World of Intelligent Systems".

More Information

13. PPI AND CTI NEWS

13.1 The PPI Vision, Mission and Strategy

Having just passed the halfway mark through the year, it is a good time to pause and reflect on where we've come from and where we're going – personally and professionally. This month the team has taken time to reflect on its vision, mission and strategy and we wanted to share this with our readership too.

Our Vision

A world in which the need for our services has disappeared, because every engineer graduates, not only as a competent technologist, but with an understanding of how to go about successfully applying that technology expertise. A world in which every CEO expects and requires systems engineering to be practiced at every level of the enterprise. A world in which engineering academics without exception see systems engineering as an integral part of the discipline of engineering. And then we can sit on the beach in Rio de Janeiro and count the stars.

Our Mission

To improve the performance of our clients and the lives of their people by improving the practice of engineering, based on systems thinking, and using the principles and methods of systems engineering.

Our Strategy

To grow agents of change in enterprises worldwide, at every level of the enterprise, by delivering demonstrably outstanding, evidence-based consulting and training services that win hearts and minds. To do so using a team of outstanding professionals who gain satisfaction from empowering others.

This and additional information regarding our capabilities and clientele is available on our website.

13.2 PPI and CTI are Expanding the Team

PPI is proud to welcome a few new members to its family. The latest members of our team are: John O'Kelly as Business Development Assistant and Nick Linn as Print Operator and Courseware Coordinator. Welcome to the team gentlemen! We know that the application of your expertise will substantially benefit the company and the engineering profession.

13.3 Meet Us in Orlando at the INCOSE IS 2019

PPI is excited to announce that it will be exhibiting at the INCOSE Annual International Symposium in Orlando, Florida between July 20th and 25th at the Hyatt Regency Grand Cypress Hotel. INCOSE IS 2019 is the largest 4-day annual worldwide gathering of people associated with the value - adding discipline systems engineering for four with various presentations, case studies, workshops, tutorials and panel discussions.

The INCOSE IS is a great opportunity for people to share ideas, network, build competency, pursue certification, contribute to the advancement of the discipline through collaboration on tools, processes and methodologies, learn about new offerings in training and education, and establish new partnerships.

PPI's Managing Director Robert Halligan, together with Randall Iliff, René King and Kimberley Taylor will be present at INCOSE IS and would love the opportunity to meet with you. Look for us at Booth 4 and pick up a gift from Australia!

In addition, Robert Halligan, will be giving a presentation on *How Systems Engineering Could Have Prevented The Aral Sea Human Disaster* on Wednesday 24th July 2019 at Regency 6 – Ground Level from 10:45am to 11:15am.

We hope to see you there!

13.4 The SEG Upgrade is Complete

Over the last few months, the PPI Systems Engineering Goldmine has undergone major changes to enhance its performance and user experience. For those who are not familiar, the SEG is an online database of SE and SE-related content including over 4GB of downloadable templates, standards, papers and guides as well as 7,800+ definitions; all available in an easily searchable format. Lifetime access to the SEG is available for all PPI and CTI course delegates. If you would like to apply for access to the SEG but have not attended one of our courses, you may do so here.

Do explore the SEG site and email any feedback you may have on the performance and content of the SEG to SEG Assistant Kim Taylor at ktaylor@ppi-int.com.

13.5 Robert Halligan Appointed to AOSEC 2019 Advisory Board

PPI Managing Director Robert Halligan has been appointed to AOSEC 2019 Conference Advisory Board. AOSEC is the Asia Oceania Systems Engineering Conference 2019, to be held in Bangalore, India over

17-18 October. AOSEC 2019 is organized by INCOSE Asia Oceania Sector - INCOSE India Chapter in collaboration with SAEINDIA - Bengaluru Section, and ISSE (isseindia.co.in) Bangalore Chapter. Visit https://aosec2019.org/ for more information on the conference.

14. PPI AND CTI EVENTS

On-site systems engineering training is being delivered worldwide throughout the year. Below is an overview of public courses. For a full public training course schedule, please visit https://www.ppi-int.com/course-schedule/

Systems Engineering 5-Day Courses

Upcoming locations include:

- Washington, D.C. United States of America (P006-792)

  12 Aug – 16 Aug 2019

Requirements Analysis and Specification Writing 5-Day Courses

Upcoming locations include:

- Melbourne, Australia (P007-484)

  14 Oct – 18 Oct 2019

Systems Engineering Management 5-Day Courses

Upcoming locations include:

- Stellenbosch, South Africa (P1135-163)

  16 Sep – 20 Sep 2019

Systems Engineering Overview 3-Day Courses

Upcoming locations include:

- Chantilly, Virginia, United States of America (P884-15)

  09 Dec – 11 Dec 2019

Requirements, OCD and CONOPS in Military Capability Development 5-Day Courses

Upcoming locations include:

- Pretoria, South Africa (P958-58)

  21 Oct – 25 Oct 2019

Engineering Successful Infrastructure Systems (ESIS5D)

Upcoming locations include:

- Las Vegas, Nevada, United States of America (P2005-3)

  02 Dec – 06 Dec 2019

Architectural Design 5-Day Course

Upcoming locations include:

- London, United Kingdom (P1768-23)

  11 Nov – 15 Nov 2019

CSEP Preparation 5-Day Courses (Presented by Certification Training International, a PPI company)

Upcoming locations include:

- Utrecht, the Netherlands (C002-85)

  02 Sep – 06 Sep 2019

Medical Device Risk Management 3-Day Course

Upcoming locations include:

- San Francisco, California, United States of America (P1848-4)

  26 Aug – 28 Aug 2019

Other training courses available **on-site** only include:

- Project Risk and Opportunity Management 3-Day
- Managing Technical Projects 2-Day
- Integrated Product Teams 2-Day
- Software Engineering 5-Day

15. UPCOMING PPI PARTICIPATION IN PROFESSIONAL CONFERENCES

PPI will be participating in the following upcoming events. We support the events that we are sponsoring and look forward to meeting old friends and making new friends at the events at which we will be exhibiting.

The INCOSE International Symposium 2019

(Exhibiting)

Date: 20 – 25 July, 2019

Location: Orlando, Florida, USA

Asia Oceania Systems Engineering Conference 2019

(Exhibiting)

Date: 17 – 18 October, 2019

Location: Bangalore, India

EnergyTech Conference 2019

(Exhibiting)

Date: 21 – 25 October, 2019

Location: Cleveland, Ohio, USA

The INCOSE International Symposium 2020

(Exhibiting)

Date: 18 – 23 July, 2020

Location: Cape Town, South Africa

Kind regards from the PPI SyEN team:

Robert Halligan, Editor-in-Chief, email: rhalligan@ppi-int.com

Ralph Young, Editor, email: ryoung@ppi-int.com

René King, Managing Editor, email: rking@ppi-int.com

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Tell us what you think of PPI SyEN. Email us at syen@ppi-int.info.