PPI SyEN

SYSTEMS ENGINEERING NEWSJOURNAL

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Empowering Decision-Making with Quality Data

DECISION PATTERNS
Turning problems into solutions

TOOLS OF DATA ANALYTICS
Applying analytics to complex systems

SYSTEM DYNAMICS ANALYSES
Avoiding stock-flow failure

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WELCOME

Hello friends of PPI. Welcome to the final edition of PPI SyEN for 2021. Just like that, we're into December – what a whirlwind.

In this edition we'll equip you with tools to answer questions such as: how do you find the right person for the job? What thinking mode should I apply when approaching this decision? To answer each of these questions you will of course need data - good quality data. This publication of PPI SyEN offers multiple perspectives on how we may use data to equip us to make decisions more effectively, to engineer better designs and even to hire the right person for the role! As we evolve to a more digitized way of life, we ought to remember that AI will be capable of doing what we do in a more 'manual' fasion but more effectively, with greater accuracy or at a faster rate (in most cases). AI cannot replace or correct what is inherently flawed logic in decision-making. Thus the need exists now more than ever to establish protocols and methods within our organizations that are based on sound decision-making principles. Data dictatess those decisions and the quality, accuracy, frequency of retrieval, ease of interpretation and relevance of that data is increasingly important in supporting our decisions.

We'll open and close this edition of PPI SyEN which contains the usual updates in the systems engineering world including news, conferences, meetings and webinars, interesting articles about SE in society and more. However, the fearure articles are the highlight of PPI SyEN and with this month we will end on a high.

In Feature Articles, we kick off with a substantial article from John Fitch titled 'Introduction to Decision Patterns'. In this piece, John shares his wisdom on defining decision patterns, identifying various scenarios for applying each type of decision pattern and understanding why we would want to consciously apply a decision pattern in the first place. Rick Hefner provides an insightful article on data analytics as a powerful enabler for systems engineering, covering various data analytics methods that, when applied with a systems thinking mindset, will assist engineers to address challenges and opportunities with future systems. Finally, I provide a short reflection on how analytical thinking skills relate to system dynamics skills and how this discovery may be applied in our organizations.

Not a bad way to end the year, huh? I hope you enjoy this edition while we wish you a relaxing and safe holiday break with your friends and family! See you in 2022!

Regards

René

Managing Editor, PPI SyEN

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Views expressed in externally authored articles are not necessarily the views of PPI nor of its professional staff.

PPI Systems Engineering Newsjournal (PPI SyEN) seeks:	**PPI defines systems engineering as:**
➢ To advance the practice and perceived value of systems engineering across a broad range of activities, responsibilities, and job-descriptions ➢ To influence the field of systems engineering from an independent perspective ➢ To provide information, tools, techniques, and other value to a wide spectrum of practitioners, from the experienced, to the newcomer, to the curious ➢ To emphasize that systems engineering exists within the context of (and should be contributory toward) larger social/enterprise systems, not just an end within itself ➢ To give back to the Systems Engineering community	*an approach to the engineering of systems, based on systems thinking, that aims to transform a need for a solution into an actual solution that meets imperatives and maximizes effectiveness on a whole-of-life basis, in accordance with the values of the stakeholders whom the solution is to serve. Systems engineering embraces both technical and management dimensions of problem definition and problem solving.*

SYSTEMS ENGINEERING NEWS

Recent events and updates in the field of systems engineering

Call for Proposals: PDMA Handbook of New Product Development

The Product Development & Management Association (PDMA) has announced the development of the 4th edition of the popular Handbook of New Product Development published by John Wiley & Sons, Inc. The handbook is an essential guide for managers and scholars interested in the latest insights on successful new product development and related topics. PDMA seeks contributions from skilled practitioners and leading scholars who can advance this topic and also provide a primer for those new to the field.

The Handbook is organized around six topics:

- Getting Started — New Product Development and Innovation
- Organizing for New Product Development
- Idea Generation and Opportunity Identification
- Idea Screening/Analysis
- Design Issues
- New Product Launch

The target audience for this book is both experienced new product development (NPD) practitioners who are grounded in the basics of new product development and are seeking new, practical knowledge to improve their NPD processes, and also academic researchers interested in a broad coverage of the area with deep dives into emerging, impactful topics.

A sampling of suggested chapter topics include:

- Factors driving successful new products
- Frameworks for innovation management
- Sustainable/responsible new product development and innovation
- Success factors for new product development in emerging markets
- Influence of customer needs on product development
- New product concept generation and testing
- Design and design thinking
- User innovation and co-creation
- Influences of artificial intelligence, big data, etc., on new product development
- Product platform development
- Standardization versus customization in NPD

Chapter proposals should be no longer than 2 pages (single-spaced), not including supplemental material, and should include:

- 1 paragraph definition of the objective and target audience for the chapter
- 1-2 paragraph description of the intended contribution
- an outline for the chapter that covers its basic content
- any central figures or other graphics which will be focus of your chapter

The projected Handbook timeline in 2022:

- 3 January: Chapter proposals due
- 17 January: Decisions and feedback to authors
- 15 April: Full chapters due
- 15 May: Feedback to authors
- 30 June: Revisions due back to editors
- 15 July: Feedback to authors on revisions
- 5 August: Final changes due
- Fall 2022: Publication

Download the Call for Proposals

Submit proposals via email to Charles Noble at: cnoble@utk.edu

Project Management Institute and Product Development Management Association Joint Initiative and Survey

The Project Management Institute (PMI) and Product Development Management Association (PDMA) have launched an initiative to find ways to improve how project managers and product managers can collaborate successfully. The goal of this initiative is to identify and recommend possible solutions that PMI and PDMA can offer to their members and practitioners, allowing project managers and product managers to work together and align.

To inform these recommendations, PMI/PDMA are conducting a survey to gather first-hand insights from practitioners. To share your expertise and insights, take the survey here.

Learn more here.

System Dynamics Society releases updated SDM-DOC tools

The System Dynamics Society announces the release of version 1.4.7 of the System Dynamics Modeling - Documentation (SDM-Doc) tool. SDM-Doc provides analysis and validation support for system dynamics models in Vensim and XMILE format.

Developed by the Decision and Infrastructure Sciences Division at the Argonne National Laboratory, SDM-Doc 1.4.7 analyzes and reports on model characteristics, potential omissions, causal links and causal loops information, variables information and warnings, graphical functions, and many other model elements. SDM-Doc 1.4.7 provides an enhanced ability to:

- Extract and Replace Comments
- Extract and Replace Variables Names
- Adjacency Matrix to Map Conversion
- Run Loop Length Analysis

SDM-Doc 1.4.7 provides a free suite of tools that can be applied to System Dynamics models in Vensim.mdl format and, in a limited capacity, in XMILE format. SDM-Doc now can be directly launched from Vensim 9.0.

Download SDM-Doc.

Provide feedback on SDM-Doc to: martinez-moyano@anl.gov

Arcadia-Capella Online Training Sessions in 2022

Obeo organizes two professional Arcadia and Capella training sessions on 24-31 January, 2022, and on 21-28 March, 2022. Each course will be delivered by a Thales MBSE expert, in English, through 6 sessions of 3.5 hours each.

This is a great opportunity to get the best-in-class courses on how to use effectively the open-source tool Capella and the Arcadia MBSE method.

Please contact sales@obeosoft.ca for pricing and registration!

Two new records for PPI and CTI to End the Year with a Bang

Last year PPI/CTI set a new record of five PPI/CTI courses running simultaneously in one week! In the last week of November, the record was broken, with six concurrent courses! Like everything we do, this is a result of a team effort of the presenter team, production, marketing, business development, and administration.

In addition, this was the first week ever that CTI had three concurrent CTI ISEP courses being delivered. Congratulations to the CTI team and its PPI support team that together have made this possible.

Energy Systems Interest Group Receives Outstanding Service Award from INCOSE UK

At the INCOSE ASEC UK, The Energy Systems Interest Group received the INCOSE UK award for Outstanding Service. The Outstanding Service recognizes members who have contributed substantial volunteering time and made a difference to the INCOSE UK. The award was presented to the ESIG for "remaining active throughout the COVID-19 pandemic and subsequent lockdowns and producing Z-guide 14 and organizing a COP 26 Panel Session: "A Systems Approach to the Energy Transition to Net Zero." Michael Gainford, presenter for PPI and CTI is chair of the Energy Systems Interest Group (ESIG). PPI/CTI are very proud of Michael's achievements with the ESIG.

Read more about the ESIG Drivers, Challenges, Objectives, Core Values and Activities here.

CONFERENCES, MEETINGS & WEBINARS

Upcoming events of relevance to systems engineering

Registration Opens for INCOSE International Workshop 2022 (IW2022)

INCOSE's IW2022 will be held on 29 January – 2 February, 2022 as a hybrid event allowing for in-person attendance and remote participation. The Torrance (California, USA) Marriott Redondo Beach Hotel will host the in-person sessions. The workshop enables INCOSE members of more than 50 Working Groups and Initiatives, the Chapters, Leadership, and Administrative Committees to come together to advance the progress on the products and activities of INCOSE.

Highlights of IW2022 include:

- Opening Plenary and Town Hall Meetings: Updates on INCOSE Projects and Initiatives.
- SE Vision 2035: Strategic direction and challenges of systems engineering.
- Working Group Meetings: Working and outreach sessions.
- Model-Based Systems Engineering Initiative.
- Closing Plenary and Market Place: Short reports by Working Groups on the key outcomes from IW2022, plus important announcements about IS2022.

More information. Register for IW2022.

Call for Papers - Complex Systems Design and Management Conference

The Complex Systems Design and Management (CSD&M) Conference has issued a Call for Papers. The conference, to be held in Paris, France on 15-16 December, 2022, serves as an international meeting point for academic researchers, industrial and governmental players working on complex industrial systems architecture & engineering. Sponsored by the French Center of Excellence on Systems Architecture, Management, Economy & Strategy (CESAMES), this thirteenth CSD&M event will provide opportunities to present and learn about innovative methods, practices and case studies that span diverse industries, sciences and systems types.

Suggested topics and system types include:

TOPICS	SYSTEM TYPES
Systems fundamentals	Product-Service Systems Engineering
Requirements engineering	Embedded systems
Systems architecture / design definition	Transportation systems
Model-Based Systems Engineering (MBSE)	Software systems
Human-Systems Integration	Information systems
Information Management	Systems of systems
Project planning / assessment	Artificial eco-systems
Systems metrics	
Systems properties	
Systems analysis tools	

Important dates:

- Paper submission: 13 May, 2022
- Results announcement: 1 July, 2022
- Final version: 22 July, 2022

See submission procedures here

Direct submission link through EasyChair. See Conference website for more details.

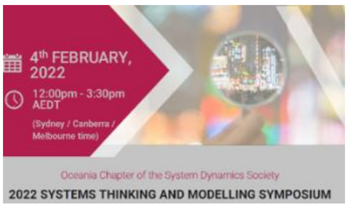
Systems Engineering approach to Technology Maturation for risk reduction using TRL, IRL, and MRL Standards

On 9 November, the INCOSE Los Angeles monthly chapter meeting hosted Andrew Murrell's presentation on the application of a systems engineering approach to technology maturation.

Elaborating on the introduction of carbon fiber technology into aerospace systems, Andrew, a Principal Systems Engineer at Northrop-Grumman, CSEP and INCOSE LA Chapter Secretary, quantified technology risk in the form of Technology, Integration, and Manufacturing Readiness levels. He also discussed acceptable levels of risk for business unit adoption of new technologies and the organizational constructs that are needed to bridge the "Technology Valley of Death" and successfully transition maturing technologies to business unit customers.

INCOSE members may access both the presentation and video through INCOSE Connect.

Call for Abstracts - 2022 Systems Thinking & Modelling Symposium



The Oceania Chapter of the System Dynamics Society is hosting a free online Systems Thinking and Modelling Symposium on 4 February, 2022. The Society invites practitioners, researchers and students to submit an abstract for the Oceania Chapter Online Symposium concerning their work in applying systems thinking and/or system dynamics modelling within industry, government, or academia.

The deadline for abstract submission is 7 January 2022 at 5:00 PM AEDT.

See more details and links for registration and abstract submission here.

Healthcare Systems Process Improvement Conference 2022

The Society for Health Systems of the Institute of Industrial & Systems Engineers (IISE) is sponsoring the Healthcare Systems Process Improvement (HSPI) Conference, to be held in Orlando, Florida, USA on 19-21 January, 2022. The conference will provide new insights into the application to healthcare systems of operational and quality improvement tools, methods and concepts such as lean, Six Sigma, productivity, benchmarking, simulation and project management.

Conference presentation topics include:

- Strategy and Care Transformation
- Analytics and Technology
- Clinical Quality and Patient Safety

- Operational Excellence
- Care Redesign, including facilities, layout and patient flow.

An optional pre-conference workshop, Introduction to Design Thinking, will be offered.

More details. Register here.

Applied Ergonomics Conference 2022

The Applied Ergonomics Society (AES) of the Institute of Industrial & Systems Engineers (IISE) is sponsoring the 25th Annual Applied Ergonomics Conference and Expo, to be held in Orlando, Florida, USA on 21-24 March, 2022.

Conference presentation topics include:

- Ergonomics in Action
- Ergonomics in Health, Safety and the Environment (HSE) and the Multi-skilled
- Ergonomics Programs
- Master Track & Round Tables
- Office Ergonomics Programs and Applications
- Research to Reality
- Technology in Ergonomics

The conference will include presentations by the finalists of the Ergo Cup® Competition that highlights successful innovations in ergonomics.

More details. Register here.

IEEE Aerospace Conference – Systems Engineering Offerings

The IEEE Aerospace Conference will be held in Big Sky, Montana, USA on 5-12 March, 2022. This 43rd conference, co-sponsored by the American Institute of Aeronautics and Astronautics (AIAA) and the Prognostics and Health Management (PHM) Society, is organized to promote interdisciplinary understanding of aerospace systems, their underlying science and technology, and their applications to government and commercial endeavors.

In addition to more than a dozen tracks of peer-reviewed papers and presentations that address various conceptual and technology aspects of aerospace system design (Missions, Communications, Remote Sensing, Diagnostics/Prognostics, Launch Vehicle Systems, Ground & Space Operations, etc.), Track 13 will focus on Systems Engineering, Management and Cost and reports on new approaches for development and operation of aerospace systems.

Topics in Track 13 include:

1. **Systems Architecture, Engineering and System of Systems:** Fundamental challenges associated with architecting and high level systems engineering of large-scale systems and systems-of-systems, including development and application of tools and techniques that support both architecting and system engineering processes (e.g., Architecture Descriptions, Model Based Systems Engineering, Architecture Decision Support), maintaining the integrity of "the architecture" across the project lifecycle, and discussions of successful (and not so successful) architecting and systems engineering endeavors with an emphasis on the lessons learned.

2. **Management and Risk Tools, Methods and Processes:** Tools, methods, and processes for managing aerospace system development programs/projects, mission operations, technology development programs, and systems engineering organizations. Risk management in aerospace endeavors, including new insights from the successful application of risk management, and lessons learned when risk management did not prevent realization of consequences. Applications include commercial, military and civil space systems, and commercial and military aircraft systems.
3. **Cost and Schedule Tools, Methods, and Processes**: Cost and schedule analysis tools, methods, processes, and results including design trades for design concepts and technologies throughout a project's life cycle. Topics addressed include cost or schedule model development, regression analysis and other tools, historical studies addressing trends, databases, government policies, industry training, mission cost analysis, operations and supporting/infrastructure cost, mission portfolio analysis, case histories, lessons learned, process control, and economic and affordability analysis that assesses program/project viability.
4. **Operationally Driven Design, Development, and Testing of Space Systems:** Examples include robotic and human surface assets, ISRU and in-space manufacturing and assembly, tele-operational methods, EVA tools and methods, human space vehicles, unique approaches to deep space missions, and NASA's Moon to Mars Campaign.
5. **Advances in Conceptual Design Methods and Applications:** Current state of practice and future advances in the application of conceptual design methods and applications. The goal of the session is to foster the application of MBSE and MBE in conceptual design, advances in concurrent engineering and collaborative engineering practices and approaches across the lifecycle, advances in methods that support team based systems engineering, and novel applications of concept design methods. Examples are optimization techniques, results visualization, and trade space exploration.
6. **System Simulation and Verification:** Design, implementation, and use of system-level simulations to measure or verify the performance and utility of space, ground, and related systems.
7. **System Verification & Validation and Integration & Test:** Verification & Validation and Integration & Test processes and case studies for Projects/Flight/Sub systems, and systems of systems.
8. **Strategic Technology Planning, Management & Infusion:** Strategic planning, research, development, and infusion of innovative technology to meet the future needs of civil space, commercial space, and national security space users. Includes technology strategy and roadmaps, technology maturation, and mission infusion to overcome the valley of death. This session also focuses on opportunities as well as legal and operational challenges as associated with partnerships, technology transfer, commercialization, and recent developments in aerospace startup accelerators for public and private sectors.
9. **Promote (and Provoke!) Cultural Change:** "Culture Eats Strategy for Breakfast!" Culture is a byproduct of habits, and this session explores how to create habits, environments, and nutrients that help great things grow.

See conference details here.

FEATURED ARTICLES

Introduction to Decision Patterns

by John Fitch

Email: jfitch@ppi-int.com

Abstract

Decision-making is one of four fundamental human thinking (aka analysis) processes. Decisions comprise the essential thinking content, the integrative mechanism of any design process, and as such effect the transformation of a problem definition into a solution.

The author's 35 years of experience in teaching and facilitating decision-making has led to the conclusion that there is a pattern of decisions behind every strategy, solution design or life. A wide variety of decision patterns have been created and refined through use in 150+ projects across 40+ organizations. Multiple generations of software tools have been created or adapted to deliver decision patterns to project teams.

This paper summarizes the conceptual basis for decision patterns and how they were "discovered", defines a decision-centric information model of the engineering process, explains key principles behind how decision patterns create value, shares how a pattern-based decision model fits into a broader engineering process and identifies a range of use cases in which decision patterns have been employed.

Decision patterns examples will be shared to help the reader map this engineering construct to their experience. A more thorough coverage of the techniques, benefits and challenges of using decision patterns will be the subject of a follow-on article.

Introduction

First, I beg your indulgence as I tell the story of decision patterns from a first-person perspective. By using a story format, I hope that, you, the reader, can better appreciate the twists and turns, the serendipitous events and roadblocks that have shaped the evolution of my understanding of decision patterns. Perhaps you will see yourself in this story and thereby build a better bridge to the application of decision patterns to the engineering challenges that you face.

Background

My foray into the discipline known as systems engineering came through the side door of Systematic Thinking or Rational Process. About five years into my career (and 40 years ago) while working as a substation design engineer at an electric utility company, I attended a Problem-Solving & Decision-Making workshop [1] during which the instructor asserted that the resolution of any organization's or individual's job concerns (aka issues) could be mapped to four human thinking (aka rational) processes:

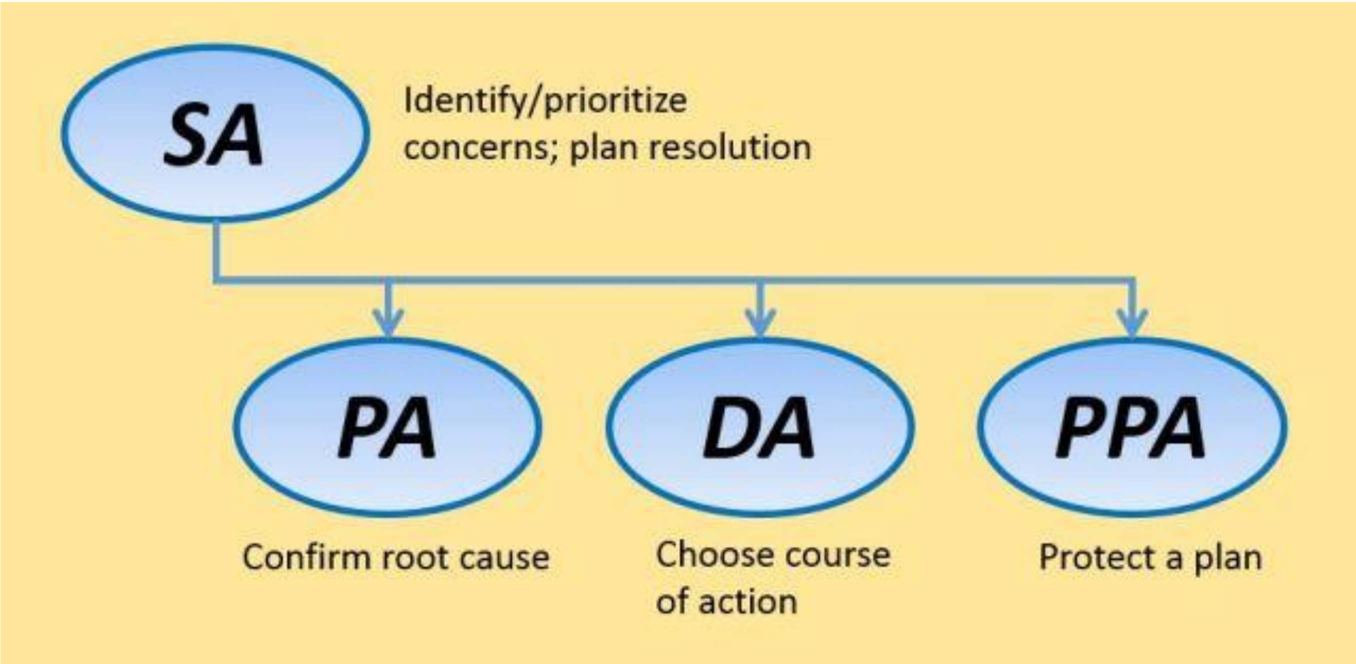


Figure 1: Systematic Thinking / Rational Processes [2]

Situation Appraisal (SA) is the recurring process through which we scan our situation to identify and prioritize issues/concerns and plan how we will resolve these concerns (by thinking, i.e. the use of the other 3 rational processes). SA separates concerns, but doesn't resolve them.

Problem Analysis (PA) is the thinking process used when something has gone wrong and we don't know ***why*** and we need to identify and confirm ***root cause*** before we can take an effective action to resolve the concern.

Decision Analysis (DA) is the thinking pattern used to design the future, i.e. conceive possible solutions to a set of stakeholder needs/requirements, evaluate these solution alternatives and select the course of action that is believed to deliver maximum value. Decision Analysis answers the "Which one?" or "How?" question.

At this point, engineers should note that this use of the term "Problem Analysis" is much narrower than "Problem Analysis/Definition" phase of a typical engineering project. An engineering project may be initiated because something has gone wrong, failed in operations, thereby demanding Problem, i.e. Root Cause Analysis prior to choosing a fix. But more often engineering projects are triggered simply by the desire to do something new or to offer an improved capability, e.g. send humans to Mars and back. There's no reason to perform a Problem (Root Cause) Analysis in these situations; nothing has failed. We are simply trying to achieve outcomes that have never before been achieved. In such cases, Decision Analysis shows us the way ahead. The Problem Analysis/Definition, aka Requirements Analysis phase of such projects provides an efficient means to model and understand the totality of the stakeholders' priorities to inform our design decision-making.

Potential Problem Analysis (PPA) is a future-focused cause-effect thinking pattern that takes the results of design decision-making (whether a technology, an architecture or project plan to realize this design), anticipates ways that the solution/plan may fail and proactively mitigates those potential problems. The PPA thinking pattern forms the common core of engineering process such as Risk Management, Failure Modes and Effects Analysis (FMEA) and Safety/Hazard Analysis.

The implications of the instructor's assertions, that all human thinking could be mapped to just four process patterns, were staggering. The patterns gave me a set of questions that I could ask to make progress in any situation where clear thinking skills were the determinant of success or failure. If I could master these four skills, the sky was the limit. So I set out to "trust, but verify" by diligently mapping my work assignments and life concerns to this model. Over the next five years, I found that these rational process patterns were both true and very, very useful.

I was exposed to a second type of pattern during my utility engineering experience. In those days before the Internet of Things (IoT) was even a dream, we were deploying Supervisory Control and Data Acquisition (SCADA) capabilities to all of our transmission and distribution substations. As an engineer assigned five substations, I quickly concluded that sketching or marking up five sets of drawings as if each substation required a unique design would be both boring and inefficient. So I worked with my favorite draftsman to develop a set of standard drawings that provided a common pattern for the substation electrical and control schematics and the SCADA terminal wiring diagrams. Armed with this pattern and a drafting group that saw its benefits, I completed my five substations in the same time that it took my peers to complete their first.

From Systematic Thinking to Decision-centric Systems Engineering

Five years later I moved to my next job at a mid-sized, Midwestern U.S. defense contractor. I introduced the Systematic Thinking / Rational Processes to the management team and was sent off to a 12-day certification bootcamp. Afterwards I trained hundreds of engineers and managers in these skills. That led to a multi-year role as a champion/coach/facilitator (internal consultant) across many organizations and product lines.

I was initially surprised that eighty percent of my coaching engagements were focused on Decision Analysis. And in those engagements, I began to see the same types of decisions being made whether the team was designing a manufacturing process or work center, a Command-Control software system, a military radio or selecting critical technologies or algorithms for Anti-Submarine Warfare (ASW) or Electronic Warfare (EW) solutions. Satisfied customers in these engineering-focused projects led to coaching at the broader business unit level where the focus of decisions was business strategies, product portfolios and capability/process improvement initiatives.

When asked to lead the development of a set of systems engineering standards and guides for the organization, I jumped at the chance, recognizing that the Systematic Thinking patterns could form the foundation for such processes. Rather than focusing systems engineering on a myriad of fill-in-a-template document artifacts and tangible activities, I could shift the emphasis toward thinking quality, i.e. the ability ask the right question at the right time and capture the essential knowledge created by each task into a holistic model that included the answer (system model) and the rationale behind it.

Authoring the bulk of these standards and guides inevitably led to the opportunity to develop a systems engineering course in which teams of engineers identified and worked through real engineering decisions, managed risks, etc. That put me in a position to jump-start numerous new product development projects or help teams work through high-level solution concept decisions that drove bids and proposals.

As the SE process "owner", I was responsible for delivering a systems engineering capability to the organization, including an integrated set of processes, training and tools. Our tool sets were in their infancy, mostly documents and spreadsheets or manual drawings. Our first target was a basic requirements management/traceability capability, realized through DOORS™ V2.1. While missing most of the features expected by today's MBSE tool suites, this early version of DOORS enabled (forced?) us

to create our own information model (schema) that could account for not only requirements (for traceability) and system architecture elements (for decomposition and allocation), but also decisions and associated criteria, alternatives, performance estimates and risks. I didn't realize this at the time, but this was the first database that explicitly captured in one repository the:

- Problem definition in the form of requirements
- Solution definition in the form of rudimentary system models
- Thinking (decision analysis/tradeoffs and risk management logic) that transformed the problem into a committed solution
- Traceability relationships among these three models.

In the twenty-five years that followed (mostly working as an independent consultant), I've had the privilege of refining a decision-centric information architecture [3] through the development of multiple built-for-purpose engineering tools and extensions to commercial requirements and model-based systems engineering software. In every case, treating a decision as a first-class object of interest has the provided the integrative mechanism that more fully captures the thinking that translates requirements into solutions and solutions into the next level of derived requirements.

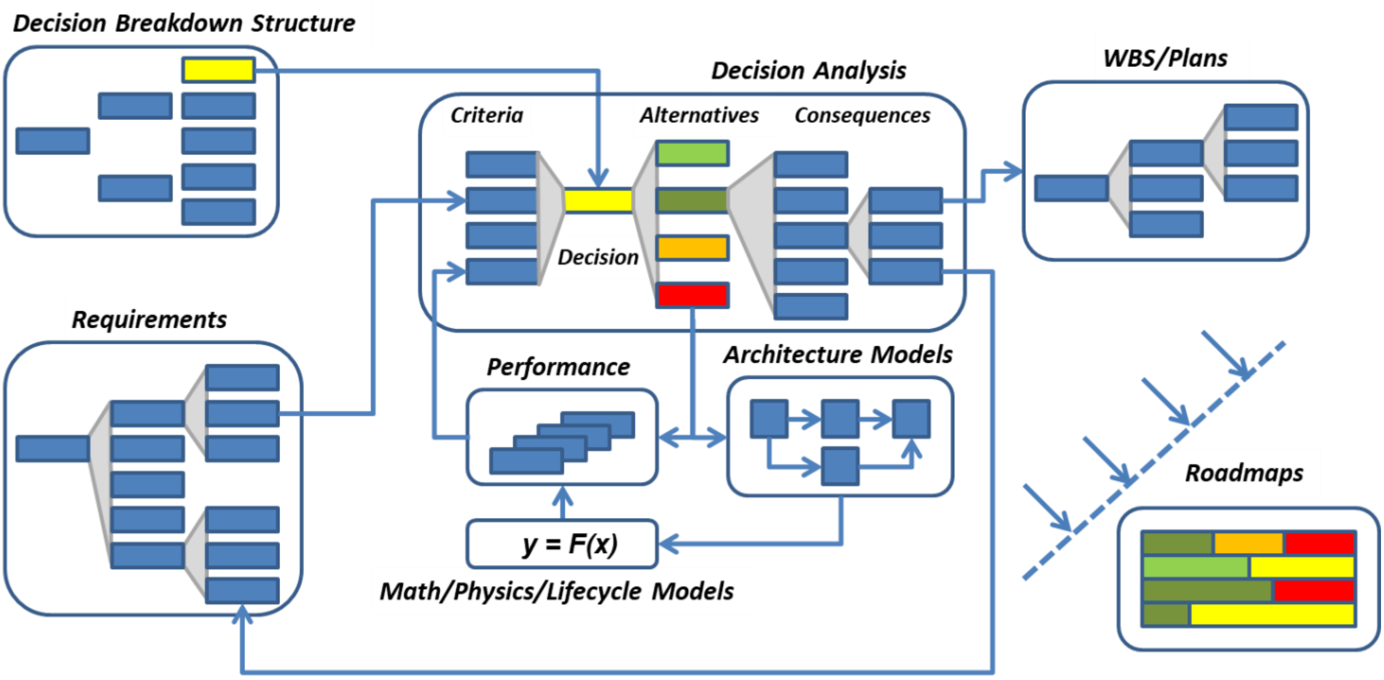


Figure 2: Simplified Decision-centric Information Architecture (ca 2013)

As with all models, this information architecture is intentionally incomplete (e.g. no stakeholder needs, requirements allocation to architecture elements or verification/validation information is shown) in order to focus on the novel constructs and associated capabilities that each of these constructs brings to an engineering project:

Information Architecture Construct	SE Capability Provided
Decision Breakdown Structure [4]	Proactive decomposition of a complex problem into discrete, loosely-coupled decision "questions" that create a knowledge pull from other SE processes. Reuse of decision models as patterns across projects and domains.
Essential information "within" each decision, e.g. criteria, alternatives, performance estimates and consequences (risks/mitigations, opportunities/growth actions, derived requirements, implementation tasks) [4]	Explicit, traceable and consistently-structured rationale for each decision that improves decision quality, stakeholder buy-in and impact/change analysis. Avoid decision rationale that is expressed as hard-to-interpret paragraph blobs.
Requirements to decision traceability acting through the criteria [5]	Explicit tie between requirements/goals and each design decision. Ability to detect requirements that haven't been used to influence the design. Ability to manage budget allocation tradeoffs and roll-ups between decisions, i.e. multi-decision tradeoffs.
Decision-to-requirements derivation traceability flowing through the alternative chosen [5]	Explicit visualization of the inherent consequences of each decision's chosen alternative; constraints imposed on the rest of the system design. Proactive and efficient change management.
Decision-to-plan traceability flowing through the alternative chosen [5]	Explicit visualization of the inherent consequences of each decision's chosen alternative on the project plan. New tasks required to realize the alternative.
Architecture models representing the structure and behavior of decision alternatives [3]	Lean set of logical and physical architecture models that represent solution alternatives; only to the level of fidelity and decomposition needed to inform design decisions. No modeling for modeling's sake. Avoid tunnel vision when the first model "drawn" limits solution creativity.
Math/physics and lifecycle models of alternatives informing performance estimates [3]	Lean set of system performance models that represent solution alternatives; only to the level of fidelity needed to inform design decisions. No modeling for modeling's sake.
Decision-to-roadmap traceability [4]	Roadmaps are "decisions put to time". The Decision Breakdown Structure provides the framework for modeling strategy, capability, platform, product or technology roadmaps to show the evolution of alternatives and their performance. Strategic decisions and roadmaps visualized from a single source of truth.

Packaged together, these constructs have been delivered as part of a comprehensive Decision Management methodology:

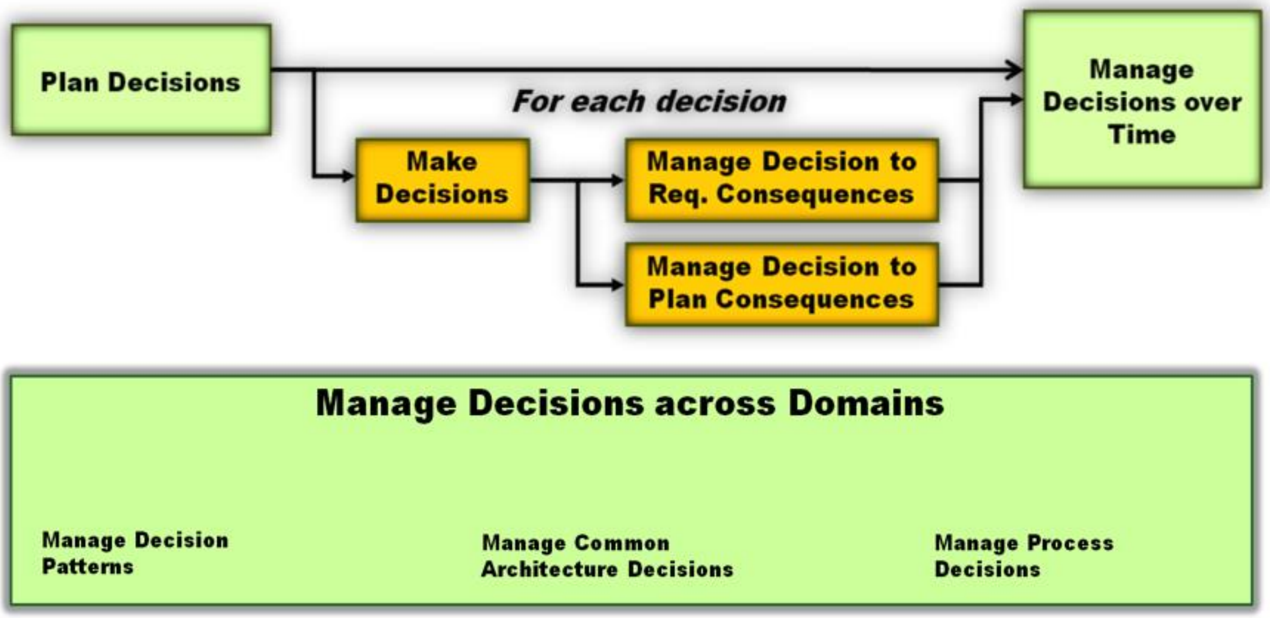


Figure 3: Decision Management Methodology

This methodology and its associated constructs and capabilities have been delivered via workshop-based training to ~2500 professionals and exercised in support of ~150 different engineering projects and strategic initiatives, spanning 40+ different client organizations. [6] The methodology and information architecture have been remarkably robust, working across numerous industries (defense/aerospace, telecommunications, energy, transportation, medical devices, software/IT, facilities/infrastructure, consumer devices, agriculture, manufacturing, education, business processes, services, non-profits, etc.).

These engagements represent a variety of use cases:

- New product development
- Technical proposals
- Technology insertion projects
- Portfolio management
- Strategic capability design initiatives, e.g. transformational or continuous improvement
- Common/reference architecture development (platform & product line engineering)
- Innovation framework
- Feasibility analyses
- Research and Development (R&D) and Science and Technology (S&T) project management
- New business/technology incubation
- Capability, product, technology and platform roadmapping
- Business ecosystem modeling and design (looking for opportunities)
- Life coaching

Two processes within the Decision Management methodology are particularly relevant to focus of this paper. The Plan Decisions process is where a decision pattern is used to rapidly frame the critical thinking within the project as a Decision Breakdown Structure, prioritize and sequence the decisions to be made and plan the analyses and resources that will inform each decision, i.e. build a Trade Study Plan.

The Plan Decisions process can be applied to guide the forward engineering of a solution to a defined problem, but also in reverse engineering (typically from requirements or other source documents) the decisions of the upstream stakeholders in order to clarify requirements, the system boundary and other "givens". The majority of client engagements have begun with this reverse engineering step. This Decision Blitz complements other requirements analysis techniques and stimulates early stakeholder involvement. Often this process yields surprises by:

- Exposing disagreements among stakeholders about what has been previously decided (committed alternatives) and the requirements that flow from such decisions
- Highlighting upstream decisions that, if re-opened, could create more value for stakeholders than delivering what has been specified

The reverse engineering process is a bit like playing the Jeopardy™ game. Source documents are reviewed for stated solutions or solutions embedded in or implied by a requirement. A decision pattern provides the framework for asking, "If X is the answer, what was the question (decision)? A few days of reverse engineering effort will typically yield a Decision Breakdown Structure of ~ 50 decisions. That model is then reviewed with stakeholders to gain their concurrence, to identify where their decisions are firm (Closed vs Open) and to update system requirements and boundary accordingly.

Beyond the upfront use of a decision pattern, the Manage Decisions Across Domains process includes a Manage Decision Patterns sub-process in which the lessons learned from a project's decisions are "harvested" by the enterprise at project completion in order to improve the decision pattern for future use.

Important Definitions and Fundamental Concepts

I would not have conceived the idea of a decision pattern if I had adopted the conventional, most frequently used definitions of a decision.

- a determination arrived at after consideration (Webster)
- a choice or judgement that you make after thinking (Oxford)
- a conclusion or resolution reached after consideration (Google)

Each of these definitions focus on the ***answer*** that results from the decision-making process, i.e. the alternative or course of action that has been chosen as best and worthy of committing resources to implement.

However, Systematic Thinking (my roots) assigns a scoping title to each issue/concern that emerges from the Situation Appraisal process. Issues classified as decisions (rather than problems or potential problems) are titled with a Decision Statement such as "Choose which university to attend", "Choose automotive braking technology", or "Choose use cases to support". In this context the term "decision" assumes a very different definition.

Decision = a fundamental question/issue that demands an answer/solution.

From this perspective a decision is part of the decomposition of the problem that exists independent of the solution chosen. The entire problem domain may be represented by 1-N decisions, typically arranged in a hierarchy as a Decision Breakdown Structure (DBS).

This approach, mirrors and extends one of Project Performance International's key systems engineering principles:

Maintain a distinction between the statement of the problem and the description of the solution to that problem, for the system of interest, and for each subsystem/component/system element of that system.

The decision-centric information model not only maintains the problem/solution distinction, but interposes an explicit object, the decision, in the middle to maintain that distinction. At the simplest level, I like to visualize each decision as wormhole through which the problem description and potential solutions or solution building blocks pass. Out of the wormhole emerges a committed solution (the chosen alternative) which then typically leads to other problem definitions that call for subsequent decisions.

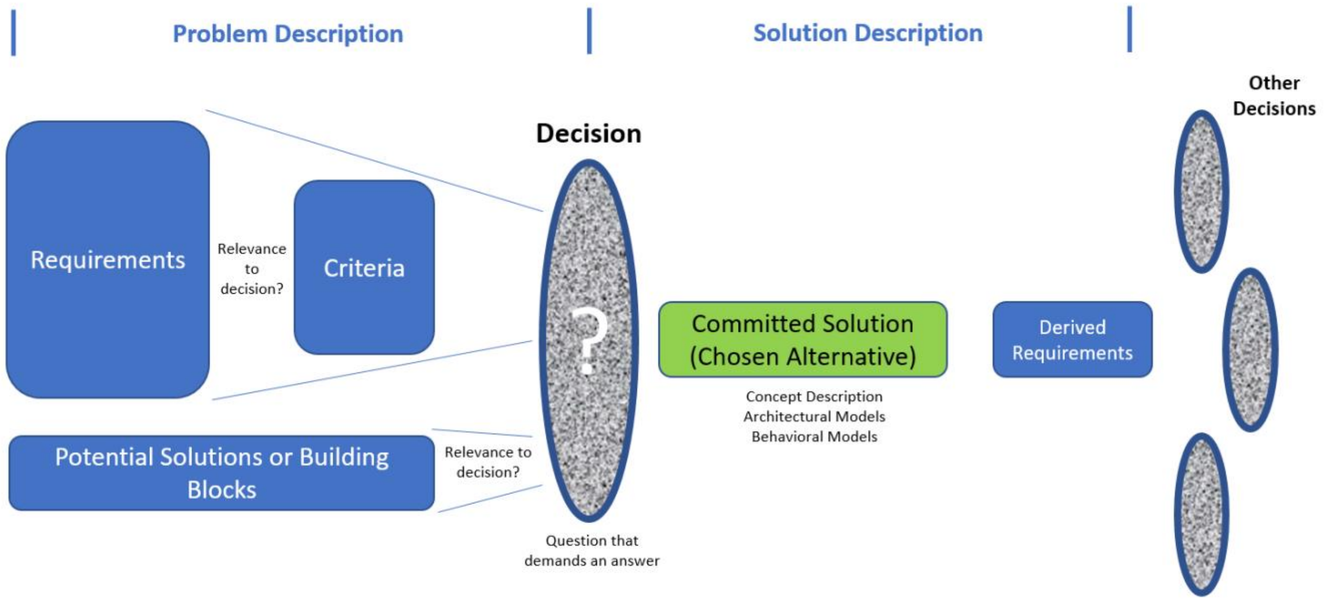


Figure 4: Decisions Maintain Problem-Solution Distinction

Elements of a Decision Pattern

In a sense, any previously-made decision, whether successful or unsuccessful, can serve as a pattern/template to jump-start the analysis for a current decision. And any information object associated with the decision may also be used to inform a current choice – criteria, alternatives, performance estimates, risks, derived requirements, analysis tasks or implementation tasks.

However, experience has shown that the greatest value generated by use of a decision pattern lies in the decisions (questions to be answered), the relationship among decisions (DBS structure) and the criteria pattern for each decision.

A decision pattern enables timely, proactive identification of important project decisions and reduces the risk that a critical decision will be overlooked or discovered late in the project. Overlooked decisions will get the “leftovers” of resource and performance budgets that have been consumed by other choices and often lead to loss of stakeholder value (and good will) through dropped features or non-compliant performance.

Each decision in the pattern is typically given a short title (often dropping the implied term “Choose” for sake of brevity) and a more complete scope description expressed as a question. The decision pattern for Process Capability Design is shown in the table below.

Number	Decision Name	Decision Description	Decision Class
1	Capability Concept	What is the top-level architecture, design or implementation concept for this capability?	Single Answer
1.1	Usage Scenarios	Where (in which situation, scenarios) will we apply this capability?	Multiple Answer
1.1.1	Value Proposition	How will this capability offer unique value in this usage scenario?	Single Answer
1.2	Core Methods	What methods or combination of methods provide the engine for this capability?	Single Answer
1.3	Process Architecture	What process architecture, framework or flow will we use to deploy this capability?	Multi-part Answer
1.3.1	Process Design	How will this part of our process operate?	Single Answer
1.3.1.1	Tools	What set of tools will we use to enable this part of our process?	Single Answer
1.3.1.2	Work Products	What work products will this process create? How will these be delivered to downstream processes?	Multiple Answer
1.4	Capability Interfaces	With what processes or other capabilities will this capability interact?	Multiple Answer
1.4.1	Interface Concept	How will these capabilities interact with each other? How will their interface be implemented?	Single Answer
1.5	Organization Design	How will we organize ourselves to effectively deliver this capability? Who will staff our team? What role will each member play?	Multi-part Answer
1.6	Platform	What infrastructure (facilities, work centers, equipment, tools) combine to provide the platform for this capability?	Multi-part Answer
1.7	Metrics	What metrics will be monitored for this capability? How will each metric be captured?	Multiple Answer
1.8	Growth Plan	How will we acquire or grow this capability?	Single Answer

Note that each decision is assigned a Decision Class attribute value, one of:

- Single Answer: Typically used for “How?” questions, evaluating concepts or technologies and “down-selecting” to a single best solution (unless solution redundancy is demanded).
- Multiple Answer: Portfolio choices, “Which N out of M alternatives?” where two or more alternatives may be selected to create value concurrently.
- Multi-part Answer: Architectural choices, in which the alternatives are best represented by an architectural model comprised on boxes and arrows, i.e. architectural elements interacting with one another to create value.

These classes are important to the understanding of the overall topology of the DBS. Multiple Answer and Multi-Part Answer decision are the fan-out points in the model where the alternatives chosen determine the number and naming of the subsequent branches. For example, if three (out of perhaps eight possible) alternatives are chosen for implementation for the decision, *Usage Scenarios to Support*, then we would expect a separate *Scenario X Value Proposition* decision for each of the three scenarios chosen. If the decision, *Capability Interfaces*, yielded interfaces with four external capabilities (of perhaps six considered), we would expect an *Interface Z Concept* decision for each external capability.

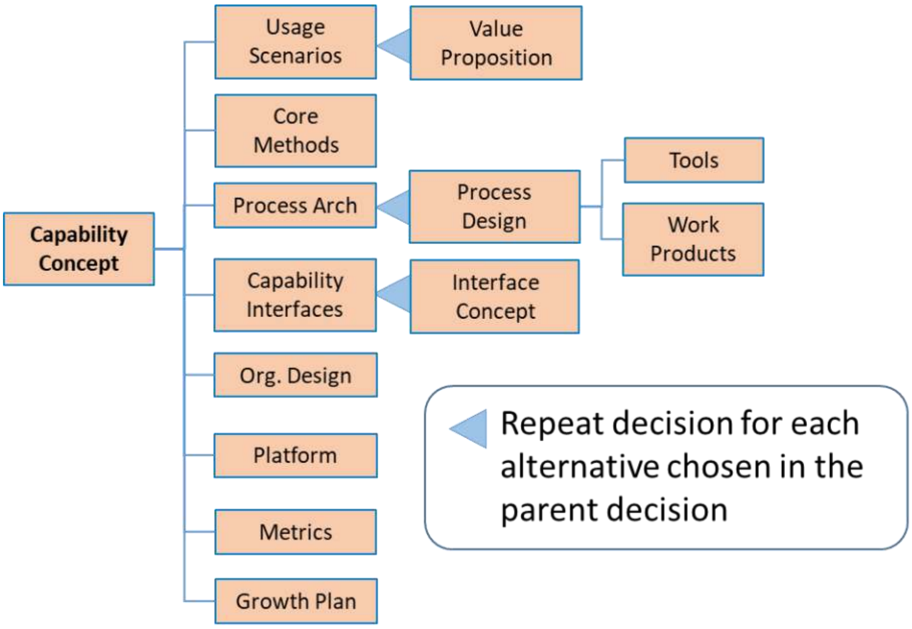


Figure 5: Decision Pattern for Process Capability Design

If the *Process Architecture* decision results in an architecture comprised of five processes, we would expect five *Process Y Design* branches. Similar logic would apply to the Organization Design, Platform and Metrics decisions.

From this discussion, it should be obvious that a decision pattern can’t identify on Day 1 every decision to be made in an engineering project, but does provide a mechanism for rolling-wave decision planning. Branches of the pattern are added and named as decisions are made. In addition, decision patterns may be used to model both high-level and detailed design. Experience should guide the leaf-level decision granularity that is appropriate for any project. We don’t normally formalize decisions for the lowest level “piece-parts” of a solution for which standards and best practices govern the selection. However, if the nuts, bolts and screws are mission-critical, then a *Fastener System* selection decision is appropriate. As with all engineering tasks, process skills are insufficient; knowledge of the problem domain and solution technologies is essential.

Although the DBS provides a logical decomposition of the problem domain, it doesn't specify the order in which decisions should be made. Although the general flow is top-down, it is also common to make critical technology choices early to identify a set of solution building blocks and then consider a parent *Solution Architecture* decision that evaluates various ways to combine these building blocks to create the greatest stakeholder value. Such "middle-out" decision-making is often used in projects with high complexity, mission-criticality and solution novelty. Be prepared to iterate and revisit decisions as needed when initial estimates of the effectiveness of solutions has a high level of uncertainty.

Note the difference between the DBS in which each "node" is a decision/question to be answered, compared with the more widely known Decision Tree, a branching structure in which each node represents a solution alternative with associated probability and utility.

Beyond the individual decisions (questions) and the overall structure, a decision pattern typically include a criteria pattern for each decision. The criteria pattern identifies the most common evaluation factors that should be considered when making a specific decision. The criteria pattern for the *Usage Scenarios* decision in the Process Capability Design pattern is show in the table below.

Criterion Name	**Criterion Description**
Compliance	The capability should support the use cases that comply with customer specifications, regulatory requirements and relevant standards
Number of users	The capability should support use cases with many potential users
Urgency	The capability should support use cases that meet urgent needs expressed by customers
Differentiation	The capability should support use cases where our value proposition can be highly differentiated
Unmet needs	The capability should support use cases that fulfill unmet needs of customers; give them the ability to do something new and valuable
Long term needs	The capability should support use cases that are stable and represent long-term needs
Time to market	The capability should support use cases that we can provide quickly
Low cost	The capability should support use cases that we can provide with low non-recurring costs
Fit our strategy	The capability should support use cases that match our strategy; create new opportunities

Criteria in the pattern may be stated in a variety of styles beyond the "should" statements shown above. Maximize/minimize statements are a common format.

The criteria pattern will not include threshold or goal values or weights (relative priorities) for each criterion. These attributes are specific to the problem definition to which the pattern is being applied.

A typical criteria pattern includes 7-12 criteria. Having criteria that have been proven through prior decision-making use greatly improves the quality of decisions by reducing the risk that an important criterion (and therefore stakeholder priority) will be overlooked. Proven criteria are more likely to be measurable, i.e. expressed in quantitative terms with defined units that support objective data gathering and performance estimation. Proven criteria are also more likely to be independent expressions stakeholder value, not redundant or overlapping factors that may skew the analysis.

Decision/criteria patterns, when used in combination, create a knowledge pull from the stakeholders. By explicitly tracing between stakeholder measures of effectiveness and the criteria that express these goals in the context of a specific decision, stakeholder goals that have been overlooked, i.e. have

not influenced the design, can be isolated. Similarly, gold-plating criteria that express results that the stakeholders don't value may be uncovered.

Other types of decision data may also be included in the decision pattern, but solution-focused information (alternatives, performance information, risks & opportunities) typically has less value and a shorter "shelf-life". Generally speaking, problem patterns evolve more slowly than solutions, particularly in technology-driven industries.

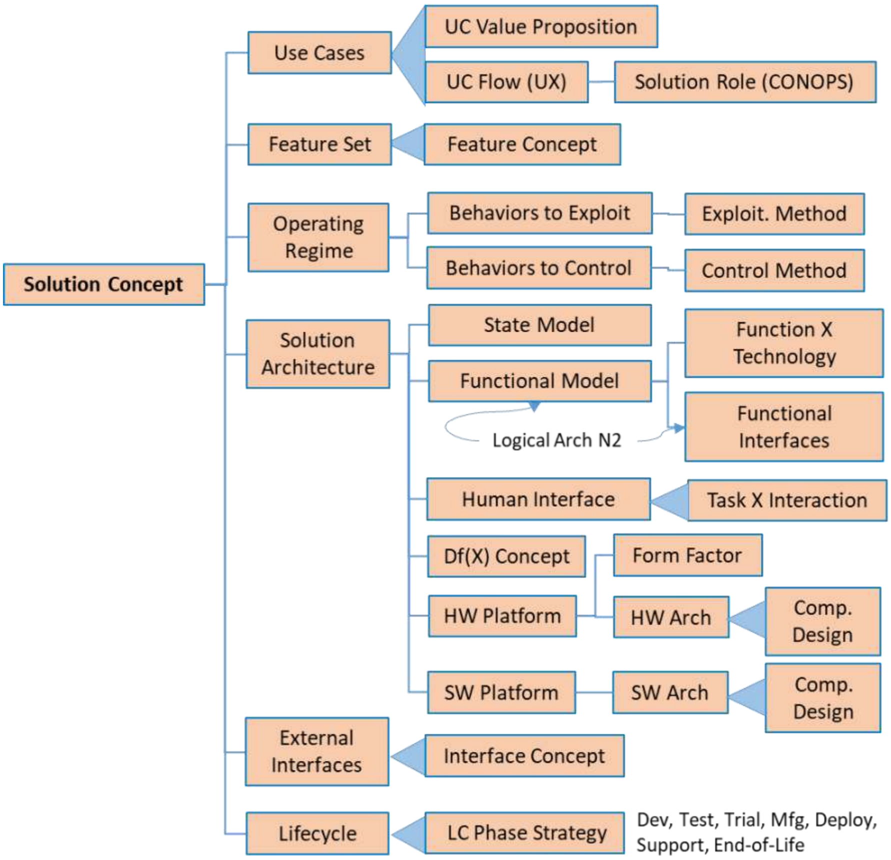
Beyond the branching logic described previously, decisions, as abstract entities that comprise the problem domain, don't directly interact. Decision interactions, e.g. conflicts, occur when the solution chosen in one decision creates derived requirements, those derived requirements create or modify criteria in a second, third or Nth decision and those criteria influence or invalidate recommended alternatives in the other decisions. As decisions are made and ratified, the tree structure of the DBS is transformed into a Decision Network. In situations with hard-to-solve problems and many constraints, it is common for these solution-driven interactions to trigger multi-decision tradeoffs. The best answer from the perspective of individual decisions, will often not combine to yield the best overall solution. Iteration will be required to determine the best-fit combined solution concept.

Available Patterns

The following decision patterns have been developed by the author, along with numerous partners, over the past three decades. They are listed in the order of their frequency of use on client-facing engagements and summarized in simplified graphical form. The reader is encouraged to note the common topology shared by these diverse patterns and to reflect on how these patterns reflect the need for any system to have sustainability across its lifecycle.

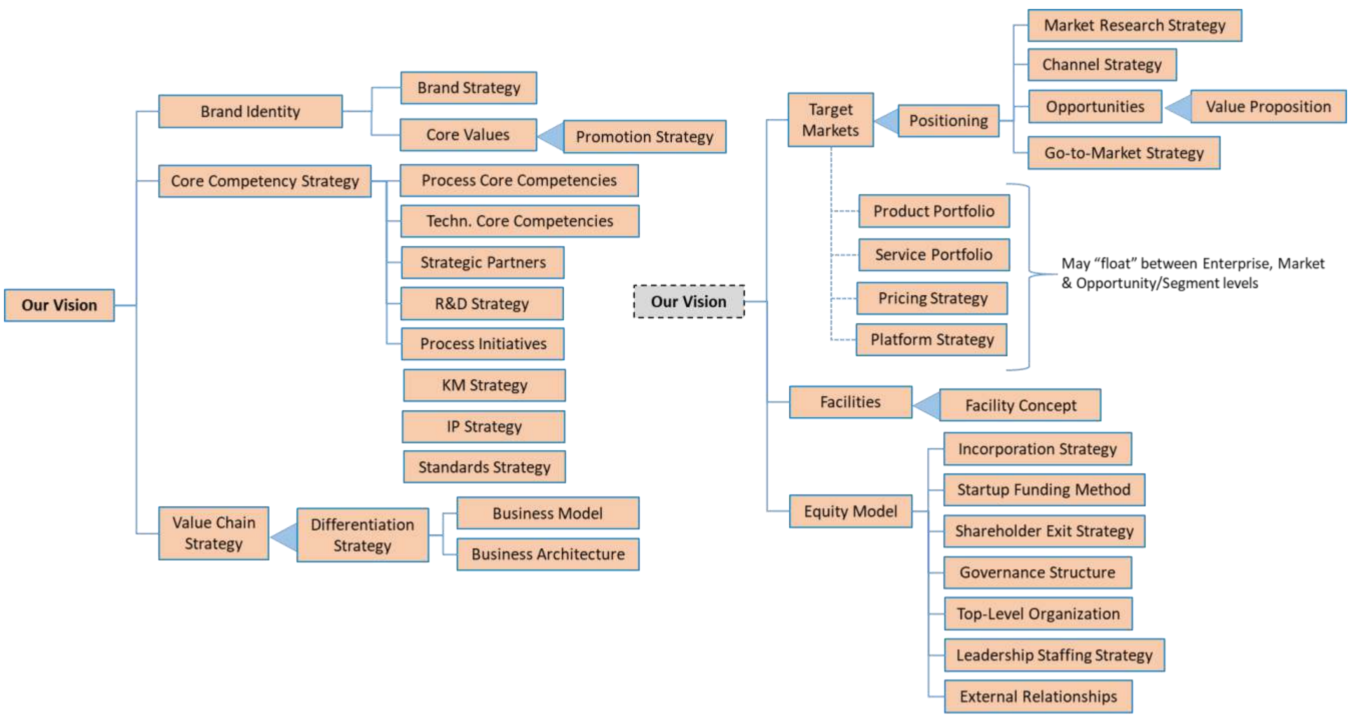
System/Product Design

The System/Product Design decision pattern was the first pattern developed by the author and has been the most frequently used and most valuable pattern. The full pattern has ~100 decisions.



Enterprise Strategy

The Enterprise Strategy decision pattern is comprised of ~60 decisions. This pattern has been used with enterprises, large and small, to design the business (or non-profit), its capabilities, infrastructure and organization, identify business models, markets and product portfolios and plan growth strategies. This pattern provides a top-level context for the other patterns (e.g. capability design, systems/product design, service design).

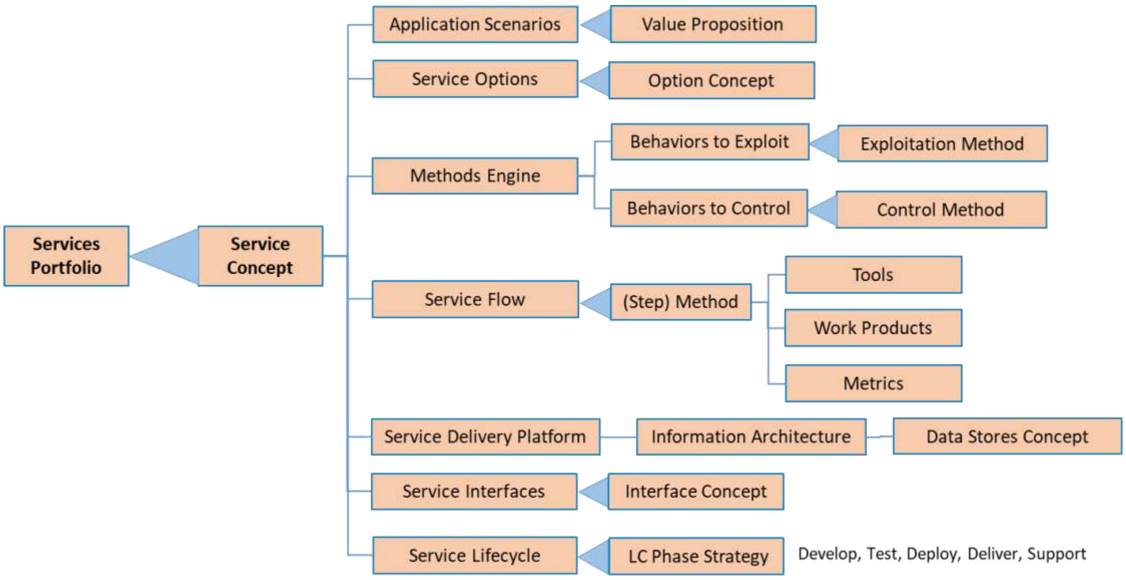


Process Capability Design (see Figure 4).

The Process Capability Design decision pattern consists of 14 decisions. It has been used for new capability design, strategic initiative design and continuous improvement of existing business processes.

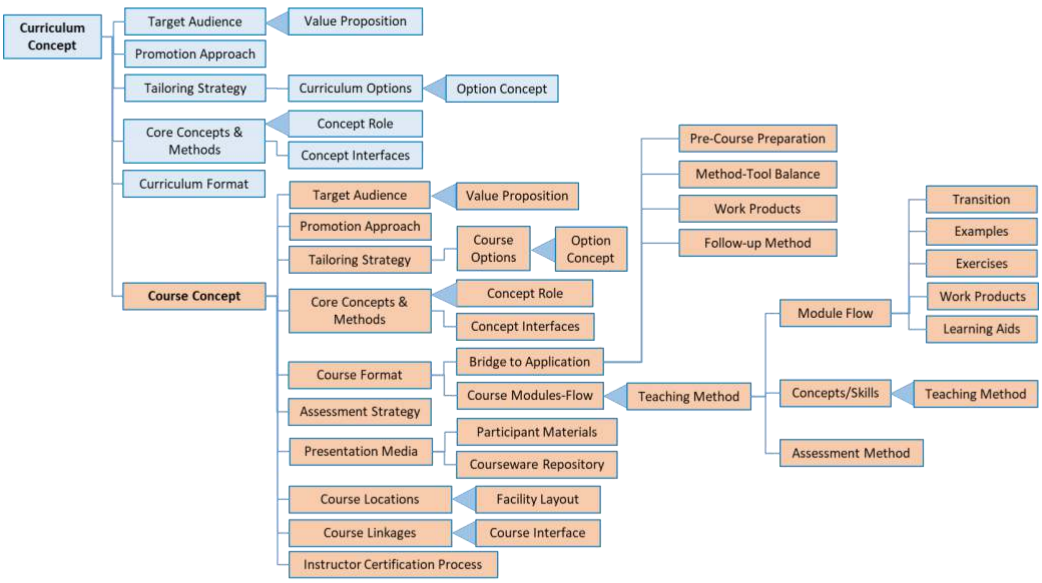
Service Design

The Service Design decision pattern contains ~25 unique decisions associated with the design of business services, primarily human-intensive processes. The Service Delivery Platform decision may trigger an instance of the System/Product Design decision pattern.



Curriculum/Courseware Design

The Curriculum/Courseware Design decision pattern, consisting of ~40 unique decision has been used to design an individual training course or an overall curriculum in either business or university contexts. Its use may be triggered as part of Service Design project.



Conclusions

This introductory paper has attempted to define decision patterns, overview the history of their discovery and use, elaborate on key concepts that differentiate decision patterns from other engineering artifacts and set the stage for future article(s) that dive deeper into the "So what?" benefits and challenges of effectively using the decision pattern construct. Stay tuned for a second installment soon.

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About the Author

John Fitch is a Principal Consultant and Course Presenter for Project Performance International. John brings over four decades of systems engineering, engineering management, consulting and training experience to the PPI team. In 2012, John was certified by INCOSE as an Expert Systems Engineering Professional (ESEP).

Within the field of systems engineering, John's career has focused on decision management, requirements management, risk management, systems design & architecture, product/technology road-mapping and innovation. In addition to defense/aerospace, John has guided initiatives in domains such as communications systems, software, energy, nanotechnology, medical devices, manufacturing systems, knowledge management and business process improvement.

The Data Analytics: Enabler for Systems Engineering

By Rick Hefner, PhD

Caltech Center for Technology and Management Education, California Institute of Technology

Data analytics involves inspecting, cleansing, transforming, and modelling data with the goal of discovering useful information, informing conclusions, and supporting decision-making. Since systems engineers rely on decision-making in conceiving, designing, integrating, and testing complex systems, it is not surprising that data analysis would be an important enabler. In this article, we examine the basic tenets and tools of data analytics and how they can be applied to developing complex systems.

Introduction

Successful systems engineering efforts rely on hundreds, if not thousands, of decisions. Historically, decision-making has relied on the experience and heuristics of the systems engineers involved. In their seminal text, The Art of Systems Architecting [1], Mark Maier and Eberhardt Rechtin describe heuristics as succinct expressions of lessons learned from one's own or others' experiences. They might take the form of guides to selecting the right architecture for a specific type of problem, or ideas for how to modify and existing designs to improve some property, like reliability.

As our systems become increasingly complex, it is tougher to make proper decisions based solely on experience. In some cases, we are developing unprecedented systems or using emerging technologies for which we have few applicable experiences. In other cases, we are applying systems engineering in relatively new domains, like health care and social sciences, where fundamental system principles are not widely known. Finally, we lack sophisticated methods for capturing the wisdom of an aging systems engineering workforce and passing their knowledge on to the next generation [2].

Numerous efforts are underway to address this knowledge gap. One approach is model-based systems engineering (MBSE), which attempts to capture knowledge about an evolving system, and use it to support decision-making. Information from past system development efforts, captured in a centralized corporate repository, can serve as guide to developers of future systems.

Data Analytics

The *data analytics* discipline is focused on extracting insights through the collection, organization, storage and reporting of data. It is part of the broader field of *data science*, and includes subfields such as *business analysis*, which uses data mining, statistical analysis, and predictive modeling to drive better business decisions.

The types of data analytics, and the questions they answer, include:

- *Descriptive analytics*: What has happened and what is happening right now? Uses historical and current data from multiple sources to describe the present state by identifying trends and patterns.

- *Diagnostic analytics:* Why is it happening? Uses data (often generated via descriptive analytics) to discover the factors or reasons for past performance.
- *Predictive analytics:* What is likely to happen in the future? Applies techniques such as statistical modeling, forecasting, and machine learning to the output of descriptive and diagnostic analytics to make predictions about future outcomes. Frequently depends on machine learning and/or deep learning.
- *Prescriptive analytics:* What do we need to do? Applies testing and other techniques to recommend specific solutions that will deliver desired outcomes.

Data Analytics as an Enabler for Systems Engineering

In systems engineering, analysis is driven by a *systems thinking* mindset – a system's behavior can best be understood in the context of its components and connections. Properties of the system, such as reliability, emerge from both the properties of the components and from the way they are connected. Data analytics can be a powerful enabler for making design decisions which drive these emergent properties.

For example, consider the design of an autonomous vehicle [3]-[5]. The systems engineering challenge is to integrate sensors and actuators with the objective of operating safely and efficiently. The related data analytics problem is to analyze sensor data to detect hazards and navigate in differing weather, day/night, and urban/non-urban environments.

Data analytics methods and tools can help with the design of more complicated and complex systems, where traditional systems engineering assumptions do not hold (Figure 1). With access to large types and numbers of external devices (e.g., Internet of Things), interfaces require new analysis methods. Furthermore, future systems will have access to enormous quantities of data (i.e., Big Data), which must be analyzed to be of value, but can yield valuable insights.

Traditional Systems Engineering Assumptions	Future Systems Characteristics
A stable, well-constructed set of requirements	Ill-defined requirements that are changed frequently
A well-defined set of stakeholders with stable expectations	A large, constantly changing set of stakeholders with changing expectations
Well-known and controllable constraints and system boundaries	Unknown constraints, porous (or nonexistent) boundaries

Figure 1: Comparison of Traditional and Future Systems

One example would be Reliability/Availability/Maintainability (RAM) analysis. In many companies, RAM engineering is not an integral part of the systems engineering process. There is no clear method for determining the stakeholders' RAM needs. Systems are designed and then checked for RAM, as opposed to building RAM in. If problems are encountered, there are often no easy solutions.

Data analysis can help solve this problem by predicting the RAM performance of a proposed systems design through methods such as:

- Prognostics and health monitoring (PHM)
- Design of Experiments (DOE)

- Robust design (RD)
- Design for variability (DFV)
- Design for manufacturing and assembly (DFM/A)
- Modeling and simulation methods

Numerous data analysis approaches can be used to augment the systems engineering process, such as:

- *Regression analysis:* A set of statistical processes used to estimate the relationships between variables to determine how changes to one or more variables might affect another
- *Monte Carlo simulation:* Used to model the probability of different outcomes in a process that cannot easily be predicted due to the intervention of random variables; frequently used for risk analysis
- *Factor analysis:* A statistical method for taking a massive data set and reducing it to a smaller, more manageable one
- *Cohort analysis:* Cohort analysis is used to break a dataset down into groups that share common characteristics, or cohorts, for analysis
- *Cluster analysis:* A class of techniques that are used to classify objects or cases into relative groups called clusters, to reveal structures in data
- *Time series analysis:* A statistical technique that deals with time series data, or trend analysis
- *Sentiment analysis:* Uses tools such as natural language processing, text analysis, computational linguistics, and so on, to understand the feelings expressed in the data

Creating-Driven Organization

Introducing data analysis into a systems engineering organization will require some fundamental changes in culture and skill set [6]. Positive steps in that direction include:

- Bring as much diverse data and as many diverse viewpoints to any situation as is possible
- Use data to develop deeper understanding of the business context and the problem at hand
- Develop an appreciation for variation, both in data and in the overall business
- Deal reasonably well with uncertainty, which means recognizing that mistakes may be made
- Recognize the importance of high-quality data and invest in trusted sources and in making improvements

Summary

Data analytics is a powerful enabler for systems engineering. Adoption of data analytics methods and tools, in conjunction with a systems thinking mindset, will allow systems engineers to address some of the challenges and opportunities associated with future systems.

List of Acronyms Used in this Paper

Acronym	Explanation
MBSE	Model-Based Systems Engineering
RAM	Reliability/Availability/Maintainability

[1] Rechtin, E., & Maier, M. W. (1997). The art of systems architecting. Boca Raton: CRC Press.

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About the Author

Rick Hefner, PhD, specializes in systems development and maintenance, project management, process improvement, and technology transfer. His experience spans over 40 years. Dr. Hefner currently serves as Executive Director for the Center for Technology and Management Education at the California Institute of Technology, where he is responsible for developing and delivering professional and executive training programs. Dr. Hefner has worked with companies in the aerospace, defense, communications, electronics, and health sciences industries, including Applied Materials, Applied Physics Laboratory, Ares Management, Boeing, DRS Technologies, Halliburton, Herbalife, Honeywell, Jet Propulsion Laboratory, John Deere, L-3, L3Harris, Maytag, Motorola, Northrop Grumman, Pacific Bell, Raytheon, Schlumberger, Southern California Edison, St. Jude Medical, Toshiba, TRW, the U.S. Navy, and Xerox.

"

Every requirement is a constraint (that is its purpose!). Every constraint is not a requirement.

ROBERT HALLIGAN

The Effect of Analytical Thinking Skills on Performance in Stock-Flow Analysis

by René King

Email: rking@ppi-int.com

This article provides a brief overview as well as some additional insights based on the research and findings described in the paper titled 'Analytical thinking, Little's Laws Understanding and Stock-Flow Performance: Two Empirical Studies' by Rosa Hendijani

See System Dynamics Review vol 37, No 2-3 (April-September 2021): 99–125

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Overview

System dynamics (SD) is a methodology commonly used to assess effects over time in various personal, professional, and societal contexts, for example, the impact of increasing greenhouse gases on climate change and the effect of diet on our health. System dynamics analyses involve stocks and flows that need to be kept under control to prevent detrimental effects within a system. Stocks are resources that accumulate and deplete, and flows are the influx and outflux of certain items that lead to the accumulation or depletion of stocks. The author of the article mentioned above suggests that individuals with higher-order analytical thinking skills tend to perform better in stock-flow analyses than those who make decisions using intuitive techniques.

Stock-Flow Failure occurs when individuals use intuitive decision-making techniques and apply correlation heuristics, e.g., expecting that the stock level correlates with the magnitude of inflow or outflow and not the relationship between the two rates. A stock will accumulate when the inflow rate exceeds the flow and will deplete in the opposite case e.g. on a highway, the quantity of cars on the high during a given period would be a stock while the number of cars on-ramping or off-ramping onto the high-way per minute could be a flow. Stock-Flow Failure is observed in knowledgeable and educated individuals, including engineers, mathematicians, scientists, and doctors.

Decision Making and Analytical Thinking

The paper focuses on Little's Law (LL) as a mediator between analytical thinking and stock-flow performance. A model that proposes mediation suggests the independent variable influences the mediator variable which influences the dependent variable (see Figure 1). A mediation analysis can clarify the relationship between the independent and the dependent variable, particularly when these variables do not have an apparent direct connection (MacKinnon, 2008).

Little's Law is a prevalent queuing problem in inventory management contexts, traffic management scenarios in operational contexts such as managing waiting time in supermarkets. Little's Law states that the average number of items in the queue (L) is equal to the average rate of arrival to the system (λ) multiplied by the average waiting time of the item in the system (W), i.e., $L = \lambda \times W$.

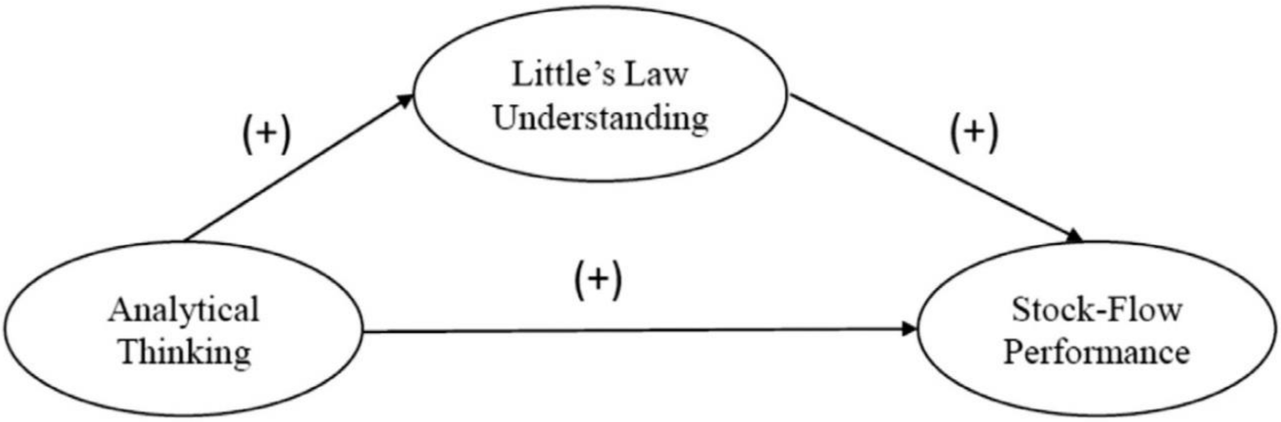

Figure 1: Relationship Between Study Variables [Hendijani, 2021]

The Experiment

Two hypotheses were tested via two studies.

- Hypothesis 1: *Analytical thinking has a positive effect on stock-flow performance*
- Hypothesis 2: *Little's Law understanding mediates the relationship between analytical thinking and stock-flow performance*

The two studies were set up as follows.

Study One involved a question set across four areas:

1. *Analytical thinking* was assessed using the Cognitive Reflection Test (CRT). The Cognitive Reflection Test involves asking three questions with a definite correct answer but is structured to entice one to select the incorrect answers using intuitive decision-making.
2. *An assessment of Little's Law understanding.* A test of Little's Law understanding involved asking several questions about various queuing problem contexts (queuing problems with different assumptions). In this case, Little's Law Understanding used problems as outlined by Little and Graves (2008).
3. *Stock-Flow assessment.* An assessment of the participant's understanding of a department store problem via questioning and questioning some higher-order stock-flow problems assess knowledge in this area.
4. *Demographic-type* questions

This study showed a positive relationship between Little's Law and the department store. There was also a stronger relationship between CRT results and stock-flow performance versus Little's Law and the stock-flow version. The meditation test showed a partial connection between analytical thinking and stock-flow performance.

Study Two involved the Near Bear Game (NBG). NBG is a common stock-flow decision-making problem about controlling inventory level in a case study where the quantity in demand jumps significantly during a simulated 50-week period. During this period, players have to balance the stocks and flows to meet the customer demand in as short a time frame as possible. The NBG includes delays and is thus a more complex assessment of stock-flow performance and is more representative of most real-life dynamic scenarios.

The independent variable was the score on the CRT test, the mediating variable was the understanding of Little's Law (assessed in a similar way to Study One), and the dependent variable was a stock-flow performance in NBG.

This study showed that those who performed better in CRT and LL resolved the balancing problem quicker, i.e., performed better in stock-flow performance. Both the direct effect of analytical thinking and the indirect impact of Little's Laws understanding were positively related to the performance in stock-flow analysis.

Conclusions of the study

Some recommendations from the study included that companies ought to include CRT and LL evaluations as part of their assessment of stock-flow assessment competency for a role involving system dynamics. Other conclusions included that the CRT performance has a stronger relationship to stock-flow performance than Little's Law understanding has alone but that Little's Law understanding is, in fact, a mediating device between Analytical Thinking assessment and assessment of Stock-Flow performance. Other results are captured in Hendijani's paper itself.

So what?

The study results show that analytical thinking skills have a positive correlation to system dynamics modeling skills. Thus, organizations could use analytical thinking tests in parallel with standard assessments to ascertain if an induvial was suited to an SD-related role or not. Little's Law and CRT tests are two examples of analytical thinking tests that may influence recruitment decisions. In addition, if an organization wanted to support the improvement of SD-modeling effectiveness, improving analytical thinking skills through conducting workshops/exercises centered around Little's Law and Cognitive Reflection Tests could elevate the stock-flow performance, hence SD-modeling point.

Access the paper by becoming a System Dynamics Society Member or by purchasing a pass to read the article on the Wiley website

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SYSTEMS ENGINEERING RESOURCES

Useful artifacts to improve your SE effectiveness

SysML Extension for Physical Interaction and Signal Flow Simulation

The Object Management Group (OMG) released, in May, 2021, an updated standard called SysML Extension for Physical Interaction and Signal Flow Simulation (SysPhS).

The update specifies standards for translations between:

- Overall systems engineering modeling, done with Systems Modeling Language (SysML)
- Simulations of physical interactions and signal flows within the system being engineered

Prior to this update, system engineers used SysML and other modeling languages to create a model of an intended system. Systems engineers then described to other-domain engineers (electrical, mechanical, production, etc.) what they needed and how their products fit into the system. The other-domain engineers used their own tools to specify system components and simulate their behavior. They then brought all the information together and incorporated it into a model of the overall system. However, differences between the system-level and component-level simulations often produced inconsistencies that were difficult for engineers to resolve.

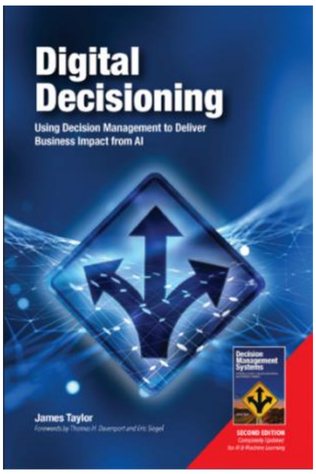
The update should improve system engineering efficiency and reliability. It shows how physical interactions and signals work together in a single system. It also includes a method for debugging physical interaction models, which are more difficult than signal flow models, due to bidirectional interactions between components.

The SysPhS standard includes a platform-independent SysML library of simulation elements that can be reused in system models.

See OMG details of the standard here.

The U.S. National Institute of Standards (NIST), along with ten other global organizations, contributed to the standard. See NIST press release here.

Digital Decisioning – Using Decision Management to Deliver Business Value from AI

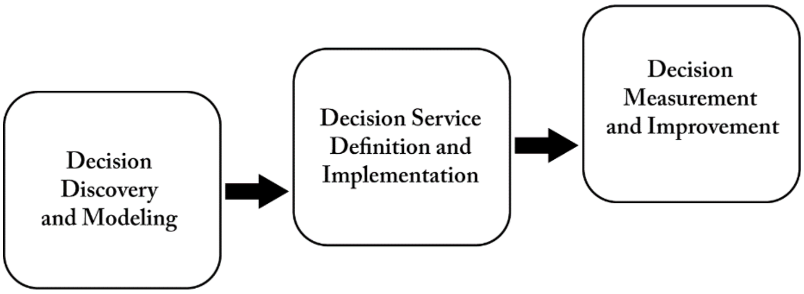


Across the globe organizations are seeking to make their customer-facing and internal business systems “smarter”. This book, published by James Taylor in late 2019, introduces the concept of Digital Decisioning in a short, non-technical format. Digital Decisioning, for those not familiar with the term, focuses on identifying and automating transactional decision-making, so your systems act intelligently on your behalf. It delivers systems that make precise, consistent, real-time decisions at every touch point.

Digital Decisioning is widely held as one of the most effective way to put machine learning and artificial intelligence to work. It can be used to improve customer experience, reduce fraud, manage risk, increase business agility and drive business growth. By combining machine learning that applies data to decision-making with explicit business logic, it guarantees the agility, transparency and compliance that established companies and regulated industries demand. By focusing on decision-making, it supports continuous learning and improvement.

Described as “Essential reading for COOs looking to rigorously improve automation through AI”, the book is based on dozens of successful projects around the world. It lays out the basic elements of the approach in a practical how-to guide. Aimed at managers, not technical teams, it aims to focus machine learning and artificial intelligence efforts. It emphasizes practical “do this next” advice delivered in non-technical terms, describing the business value and impact of critical technologies without diving into technical detail. Stories of real implementations, real companies, show what can be done.

The book has “a wealth of practical knowledge and advice for beginners and experts alike”. It introduces the opportunity and terminology of AI, explains the business benefits of digital decisioning and outlines the four key principles that underpin successful projects. It introduces a practical three phase approach to delivering digital decisioning based on decision modeling, the right mix of technologies and continuous improvement.



This is a completely updated version of an established and popular book on Decision Management, and has forewords by leading analytic experts, Tom Davenport and Eric Siegel.

As one reviewer said:

“I’ve worked as a C-level executive in multiple insurance companies and engaged countless strategy consultants, IT consultants and technology vendors over the past two decades. This book describes the only approach that has actually allowed me to operationalize predictive models and deliver real ROI!”

James Taylor is CEO of Decision Management Solutions and one of the world’s foremost thinker, writer and consultant on using the decision management approach to deliver Digital Decisioning.

Taylor, J. (2019). Digital Decisioning: Using Decision Management to Deliver Business Impact from AI. Florida: Meghan-Kiffer Press.

- ISBN: 9780929652641
- Pages: 202

Digital Decisioning is available from a variety of global booksellers, including:

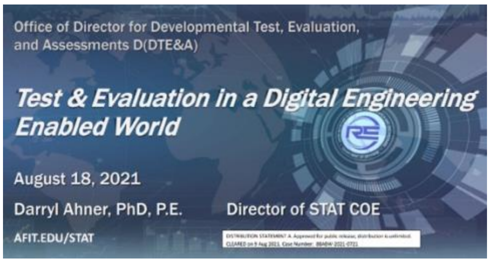
- Barnes & Noble
- Amazon UK
- Booktopia - Australia
- Also available in Japanese

SERCTALKS Three-Part Test and Evaluation Series

The Systems Engineering Research Center (SERC) recently completed a three-part series on the future of Test and Evaluation as part of its SERCTALKS research webinars. Moderated by Dr. Laura Freeman, SERC Research Council Member, the series hopes to stimulate an ongoing and more collaborative dialog between academia, government and industry sectors on this important topic. As such, these talks may be valuable resources for anyone seeking to improve their Test and Evaluation practices in a changing technology landscape.

The three talks that comprise the Test & Evaluation series are summarized below:

What Does Test & Evaluation Mean in a Digital Engineering Enabled World?



Date: 18 August 2021

Speaker: Dr. Darryl K. Ahner, P.E., Director, Scientific Test and Analysis Techniques Center of Excellence (STAT COE), Air Force Institute of Technology (AFIT)

Abstract: Testing has often been looked at as a (un)necessary evil. In order for testing to be value added, it must not take too much time, provide quality information, and provide timely information to appropriate affect systems engineering and acquisition decisions. In this talk we will discuss the demand for testing events, the Scientific Test and Analysis Techniques process (since STAT is mandated in DoD policy anyway), and what test planning may look like in a digital engineering environment. Examples of efficient and effective test planning will also be discussed, both those that were conducted during development and those developed post deployment.

Download slides:

Progress in Test and Evaluation of AI-Enabled Systems in the DoD.

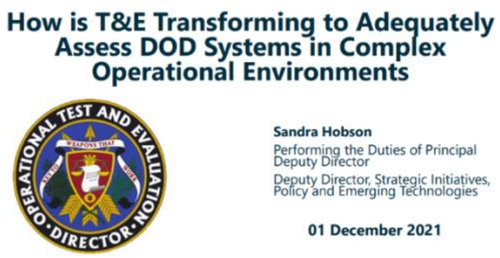
Date: 29 October 2021

Speaker: Dr. Yevgeniya "Jane" Pinelis, Chief, Test, Evaluation, and Assessment, Department of Defense Joint Artificial Intelligence Center (JAIC)

Abstract: Though the objectives of independent government test and evaluation (T&E) are similar between traditional and AI-enabled systems (AIES), the science, practice, skills, and infrastructure necessary to evaluate these data-dependent systems do require an update. Over the last two years, the DoD Joint AI Center (JAIC) has led the DoD test community in identifying and filling the gaps in T&E of AI. We have made great progress, in partnership with other DoD test stakeholders, academia, and industry. Together, we have put forward T&E frameworks, tools, and contracting approaches. This talk will discuss our existing challenges, current and aspirational solutions, and the way ahead for the DoD T&E of AIES.

Download slides:

How is T&E Transforming to Adequately Assess DoD Systems in Complex Operating Environments?



Date: 1 December 2021

Speaker: Dr. Sandra Hobson, Deputy Director for Strategic Initiatives, Policy and Emerging Technologies, Office of the Director, Operational Test and Evaluation, Office of the Secretary of Defense

Abstract: The Director, Operational Test & Evaluation (DOT&E) is senior advisor to the Secretary of Defense on operational test and evaluation (OT&E) and live fire test and evaluation (LFT&E) in the Department of Defense (DoD). Ultimately, the office of DOT&E is responsible for ensuring testing is adequate to confirm operational effectiveness, suitability, survivability, and lethality of defense systems in combat use. The technologies we are testing today and will in the future require that we rethink classical approaches to T&E. As the National Defense Strategy notes, "We cannot expect success fighting tomorrow's conflicts with yesterday's weapons or equipment." Similarly, we need to modernize T&E assessment tools, infrastructure, and expertise.

In this talk, I will discuss the critical role DOT&E plays in ensuring we provide systems that work to our warfighters. I will discuss how the DOT&E Science and Technology Strategic Plan is focusing on making advancements in current T&E CONOPS in the technology areas of Software, Cybersecurity, and Next-Generation capabilities. I will also discuss the need for an integrated T&E lifecycle and how digital transformation plays a key role in changing how we do business. Finally, transformation will require us to engage the T&E workforce in education and training on new methods. New partnerships with communities pioneering new methods (to including the SERC network in academia) will assist in our transformation.

Download slides:

Recordings are available for each of the talks on the SERC YouTube Channel.

See previous SERC TALKS series and topics here.

IEEE Standard Model Process for Addressing Ethical Concerns During System Design

The IEEE Standards Association (IEEE SA) released a new standard in September 2021 to provide a clear methodology to analyze the human and social values that are relevant for an ethical system engineering effort. IEEE 7000™-2021 - ***IEEE Standard Model Process for Addressing Ethical Concerns During System Design***, is recommended for use by organizations that seek to apply broader ethical value criteria and minimize risk, thereby helping to strengthen relationships with their end users and customers.

Both system/product developers and end users may benefit from this process that considers ethical issues early in the system life cycle, along with system functionality and performance. The intent of the standard is to align products and services with results that honor the contextual values of customers, citizens, and society at large. The standard is particularly applicable to innovation in Artificial Intelligence Systems (AIS) where algorithms invisible to users still may deeply affect the users' data, identity, and values.

This standard provides:

- A system engineering standard approach for integrating human and social values into traditional systems engineering and design.
- Processes for engineers to translate stakeholder values and ethical considerations into system requirements and design practices.
- A systematic, transparent, and traceable approach to address ethically-oriented regulatory obligations in the design of autonomous intelligent systems.

IEEE 7000-2021 is built upon Value-based Engineering (VbE), a methodology providing ways to elicit, conceptualize, prioritize and respect end user values in system design. VbE can reduce project risks by considering potential harm to users and society beyond those harms created by the physical failures associated with a product or service.

Click here for more details or to purchase or view the IEEE 7000-2021 Standard.

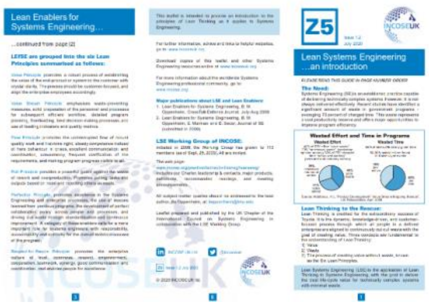
Read the IEEE SA press release.

Definition: Composable design

"Composable design is a systems architecture and development concept focusing on composing new systems from known components, designs, product lines, and reference architectures as opposed to focusing on “blank sheet” designs based on requirements decomposition alone" (Oster and Wade, 2013).

Christopher Oster and Jon Wade, "Ecosystem Requirements for Composability and Reuse: An Investigation into Ecosystem Factors That Support Adoption of Composable Practices for Engineering Design’, Systems Engineering, December 2013.

INCOSE UK Systems Engineering zGuides



INCOSE UK has produced a series of guides concerning various aspects of systems engineering. These one-page, double-sided resources (intended to be folded into a three-panel Z-shaped format) are intended to be passed along to individuals who infrequently interact with systems engineering tasks. Generally written in a What – Why – How flow, each topic is addressed in language that can reduce communication barriers among team members.

Topics addressed include:

- Systems Engineering
- What is Systems Engineering?
- Enabling Systems Engineering
- How Systems Engineering Can Save your Business Money
- SSM - Soft Systems Methodology
- Lean Systems Engineering
- SYSTEMS ENGINEERING RESOURCES
- Systems Engineering Competency Framework
- What is Systems Thinking?

- System Architecture
- Project Management and Systems Engineering
- Human Factors for System Engineers
- Systems Engineering and Project Management – Top Ten Tips
- An Introduction to systems approaches for SMEs

Access zGuides here.

PPI RESOURCES

PPI offers a multitude of resources available to all of our clients, associates and friends! Click on any of the links below to access these resources today.

Systems Engineering FAQ: https://www.ppi-int.com/resources/systems-engineering-faq
Industry-related questions answered by PPI Founder and Managing Director Robert Halligan.

Key downloads: https://www.ppi-int.com/keydownloads/
Free downloadable presentations, short papers, specifications and other helpful downloads related to requirements and the field of Systems Engineering.

Conferences: https://www.ppi-int.com/resources/conferences-and-meetings/
Keep track of systems engineering-relevant conferences and meeting dates throughout the year.

Systems Engineering Goldmine: https://www.ppi-int.com/se-goldmine/
A free resources with over 4GB of downloadable information relevant to the Engineering of systems and a searchable database of 7,800+ defined terms. You can expect the content of the SE Goldmine to continue to increase over time.

Systems Engineering Tools Database (requires SEG account authorization to log in): https://www.systemsengineeringtools.com/
A resource jointly developed and operated by Project Performance International (PPI) and the International Council on Systems Engineering (INCOSE). The SETDB helps you find appropriate software tools and cloud services that support your systems engineering-related activities. As a PPI SEG account holder, you have ongoing free access to the SETDB.

PPI SyEN Newsjournal (actually a substantial monthly SE publication): https://www.ppi-int.com/systems-engineering-newsjournal/
You're already reading our monthly newsjournal! However click on the link to access the history of 100+ monthly newsjournals containing excellent articles, news and other interesting topics summarizing developments in the field of systems engineering.

Psychology and Systems Engineering: Transdisciplinary Systems Engineering in Action
by Scott Jackson, PhD

A topic of popularity in systems engineering in recent years is transdisciplinarity. According to Madni [1, p. xi] "transdisciplinary systems engineering is an integrative thematic discipline that reaches beyond engineering to other disciplines to identify and leverage new concepts and relationships that can potentially make complex system problems tractable and amenable solutions." Cross-disciplinary simply means the treatment of multiple disciplines, while transdisciplinary means the application of specific techniques in this pursuit. The techniques include, for example, interactive story telling.

There are few disciplines more divergent than psychology and systems engineering. Psychology brings to the table, first the concept of cognitive bias. According to [2] cognitive bias is a mental shortcut resulting in a mistake in reasoning. Hence, cognitive bias causes decisions to be flawed.

In contrast, systems engineering [3] calls for decisions to be "objective". Here we have a potential conflict. One source states that decisions may be "flawed" due to the mental phenomenon called cognitive bias. The other calls for decisions to be objective. So how can both statements be right? In the end, they can't. If a decision is made, no matter how objectively, this decision will be flawed due to cognitive bias.

The next question is whether cognitive bias can be controlled just by willing it to go away. The answer is no. Furthermore, Thaler [4] states that all human beings experience cognitive bias to some degree. It is true that some decisions may be minor and therefore the consequence will have a minimal effect. This situation is not the focus of this paper.

So, what are the best ways to control cognitive bias? The short answer is that they can be controlled by external individuals or groups. As an example, the airline industry has adopted a program called CRM (crew resource maintenance). The purpose of this program, like others, is to train crew members on an aircraft how to warn pilots of impending dangers, such as flying into a mountain. This is one of the strongest ways to control operational decisions. Cognitive bias affects both design decisions and operational decisions. Of the case studies reviewed, operational decisions have been the most serious. Among these the Tenerife disaster has been the worst disaster in aviation history with 583 casualties. Researcher McCreary [5] showed that cognitive bias was the root cause of this disaster.

In summary, cognitive bias is a phenomenon experienced by all human beings that can endanger many lives. Efforts to control this phenomenon should be taken at the organizational level. The case study below shows that cognitive bias can play a role in different contexts.

Part 2. Hypothetical Case Study

Decisions can be flawed for straightforward reason such as pressing the wrong button, which was the case for the Cali accident in 1995 in which the pilot flew the airplane into a mountain instead of landing it according to [6]. This kind of error is called a slip error.

Cognitive bias errors pertain to flaws which are psychological in nature. These flaws occur when the decision maker is suffering from an emotional overload or has a prior belief similar to the situation in hand. In connection to the concept of cognitive bias and its effect on the inability of humans to make rational decisions, this paper presents here a hypothetical case study pertaining to a decision many Americans are struggling with, namely, whether or not to be vaccinated against the coronavirus that has been ravaging the country in recent years. This paper does not take a position whether to be vaccinated or not vaccinated. It does, however, present the decision in the light of the cognitive bias which influences the outcome. This is not a design decision, but it is a decision which many people are struggling with. Hence, cognitive bias flaws pertain to many decisions in different contexts.

In this case study the author has received a communication telling him that a cousin in another state has been hospitalized with a serious illness. The name of the illness was not revealed. The age of the cousin is 75.

The cousin has a son who has expressed the following belief: The son believes that his mother, the cousin, is suffering from a vaccine side effect.

- **Red flag warning No. 1**: the son's belief is based entirely on a prior belief that the virus vaccine may result in the virus itself.
- **Red flag warning No. 2**: The son did not reveal any opinion by a medical authority, such as a doctor. In this case the medical authority would have performed the independent authority role recommended for high-risk decisions.

In summary, the following rules should be helpful in establishing a further course of action if you become ill during a pandemic:

- **Rule 1**: Discount any theories on the origin of your illness not validated by a medical authority.
- **Rule 2.** Follow the medical authority's advice for the treatment of this illness.

That should be it. Good health and good living.

[1] A. M. Madni, Transdisciplinary Systems Engineering; Exploiting Convergence in a Hyper-Connected World. New York: Springer, 2018.

[2] S. Abkari. "Cognitive Bias." https://greatminds.consulting/insight/cognitive-bias-a-mental-shortcut-that-causes-a-mistake-in-reasoning (accessed 2021).

[3] INCOSE, Systems Engineering Handbook, 4 ed. Dan Diego: Internatonal Council on Systems Engineering (INCOSE), 2015.

[4] R. H. Thaler, "Cognitive Bias Question," 14 November ed: Burnham 2021.

[5] J. McCreary, M. Pollard, K. Stevenson, and M. B. Wilson, "Human Factors: Tenerife Revisited," Journal of Air Transportation World Wide, vol. 3, no. 1, 1998.

[6] NTSB, "Cali Accident," National Transportation Safety Board, Washington DC, 1995. [Online]. Available: https://www.ntsb.gov/_layouts/ntsb.aviation/brief2.aspx?ev_id=20001207X04990&ntsbno=DCA96RA020&akey=1

FINAL THOUGHTS

I hope you found at least one or two segments of this edition that have piqued your interest or provided some food for thought. We've covered various perspectives on the use of data in empowering our decision making across various areas of the organization. Our authors have made a case for why structuring and executing decisions consciously leads to better results and why the quality of data we use to inform those decisions is more important than ever.

As Syenna is on holiday for the month, we thought we'd go out in Syenna fashion with some data science humor …

There are two kinds of data scientists. 1.) Those who can extrapolate from incomplete data.

There are 10 kinds of people in this world. Those who understand binary and those who don't.

Did you hear the one about the statistician? Probably….

Two random variables were talking in a bar. They thought they were being discrete, but I heard their chatter continuously.

Old age is statistically good for you – very few people die past the age of 100.

"

Make everything as simple as possible,
but not simpler

ALBERT EINSTEIN