PPI SyEN

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Conquering Complexity with Models and Frameworks?

DIGITAL TRANSFORMATION
Creating smart and flexible enterprises

DIGITAL MODELING
A blueprint for decision making

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PPI SyEN

EMAIL: PPISyEN@PPI-Int.com

EDITORIAL STAFF

Editor
John Fitch

Editor-in-Chief
Robert Halligan

Managing Editor
René King

PRODUCTION STAFF

Marketing Manager
Benjamin Bryant

Graphic Designer
Matthew Wong

Marketing Coordinator
Rebeca Carneiro

PUBLISHER

PROJECT PERFORMANCE INTERNATIONAL

Project Performance International
2 Parkgate Drive
Ringwood, Vic 3134 Australia
Tel: +61 3 9876 7345

Tel Brazil: +55 12 9 9780 3490
Tel UK: +44 20 3608 6754
Tel USA: +1 888 772 5174
Tel China: +86 188 5117 2867

www.ppi-int.com

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WELCOME

Hello friends of PPI. Welcome to the first edition of PPI SyEN for 2022! This edition covers a range of topics related to this month's theme, 'Conquering Complexity with Models and Frameworks.' When reading through this month's exciting edition, a few areas of interest within the systems engineering world stand out as recurring: Artificial Intelligence, Machine Learning, and Cyber Security. Indeed we are stepping into the era of Industry 4.0. It is no surprise to a systems engineering practitioner that the pathway from our 'as-is' to the 'to-be' relies on effective modeling and decision-making. That is why I am thrilled to bring you this month's edition, as we'll be tackling all of the above.

In SE news, we see updates within major engineering societies – IEEE and INCOSE. We also learn of significant steps that the engineering practice is taking as far as accreditation is concerned. As always, some riveting SE-related conferences have occurred and are coming up. We've captured some takeaways from leading-edge meetings that have transpired recently. We also highlight some of the areas that research bodies such as SERC recommend for doctoral research as we aim to explore societal and economic elements of our world. Of course, any systems solution in Industry 4.0 will be influenced by more than just the technological aspects.

This month we bring two fantastic Feature Articles. Firstly Scott Philips unpacks all elements needed to understand Capability Architecture for Industry 4.0. No stone is left unturned as Scott explores the Digital Transformation of the Manufacturing Enterprise. If you're searching for a paper that demystifies Industry 4.0 in a palatable way, this is the article for you.

Secondly, James Taylor provides an overview of Decision Model and Notation (DMN) by first making a case for why we'd want to formalize our decision-making process and then providing a smooth walk-through of DMN. This article is perfect for anyone looking to increase logic and reduce risk in decision-making, a piece not to be missed.

As always, we conclude this edition with some valuable resources for all of our readers. Whether you're searching for excellent SE-related papers to read, Infrastructure Architecture Frameworks, or a Risk Management Framework related to Artificial Intelligence, there is something for you in this edition. I hope you enjoy reading it as much as I did! Until next month, take care!

Regards

René

Managing Editor, PPI SyEN

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:

- 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

PPI defines systems engineering as:
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

IEEE 2022 EMS Election Results

The IEEE Technology & Engineering Management Society (TEMS) encompasses the management sciences and practices required for defining, implementing, and managing engineering and technology. Specific topics of interest include: technology policy development, assessment, and transfer; research; product design and development; manufacturing operations; innovation and entrepreneurship; program and project management; strategy; education and training; organizational development and human behavior; transitioning to management; and the socioeconomic impact of engineering and technology management.

TEMS has announced its 2022 election results with:

- Ravikiran Annaswamy elected as President-Elect and stepping in as President starting in 2022.
- Sudeendra Koushik elected as Vice President of Conferences
- Gus Gaynor elected as Vice President of Publications for his second term
- Karl Arunski elected as Vice President of Education
- Five members elected to the Board of Governors: Chunguang (April) Bai, Sabine Baumann, Gustavo Giannattasio, Tariq Samad, Mark Wehde

TEMS is the largest management society in the world, with over 3300 members in 61 local chapters, 15 joint chapters and 20 student branches. TEMS hosts 25 conferences annually, publishes a diverse set of journals, as well as providing a rich set of online resources through IEEE TEMS TV.

ABET Approves Accreditation Criteria for Systems Engineering Programs

The ABET, incorporated as the Accreditation Board for Engineering and Technology, Inc., is a USA-based nonprofit, non-governmental organization with ISO 9001:2015 certification that accredits post-secondary college and university programs in applied and natural science, computing, engineering and engineering technology. ABET has a global reach, accrediting a total of 4,361 programs at 850 colleges and universities in 41 countries.

The ABET Criteria for Accrediting Engineering Programs are based upon the knowledge, skills, and behavior that students acquire in a program via the curriculum. Students are expected to acquire Student Outcomes (SOs) of the program through different courses in the curriculum.

ABET serves the interests of its 35 member societies (including INCOSE) that together represent more than 1.5 million professionals around the world. ABET societies:

- Establish accreditation criteria that represent the threshold set of knowledge, skills and abilities needed for successful entry into their respective technical fields.
- Provide more than 2,200 dedicated volunteer experts (Program Evaluators) who conduct the hands-on work of accreditation.

- Ensure that programs meet the quality standards that produce graduates prepared to enter a diverse, global workforce.

After a 20 year journey, the ABET Engineering Area Delegation and Board of Delegates has approved and accepted the Systems Engineering Criteria defined by INCOSE and six other professional societies. ABET will implement these updates into its 2022-2023 Criteria for Accrediting Engineering Programs to guide subsequent program evaluations.

With this approval, systems engineering joins more than two dozen other engineering disciplines with approved special criteria that drive the accreditation of academic programs across the globe.

PPI founder and Managing Director Robert Halligan said of this news:

"I view it as inevitable that, over time, systems engineering will appear in every undergraduate engineering degree program worldwide as an integral component of the discipline of engineering. Acceptance by ABET of the INCOSE-developed Systems Engineering Criteria is a vital development in that direction. Future milestones beyond just engineering curricula will be an influence of systems engineering on the content of PMI's PMBOK, and ultimately, the incorporation of systems engineering principles, under another name, in every MBA program worldwide."

Learn more about ABET. See ABET press release.

Purdue University Collaboration with INCOSE

Purdue University (West Lafayette, Indiana, USA) is joining the INCOSE Corporate Advisory Board (CAB). As part of a collaborative initiative with INCOSE on systems thinking and systems engineering, Purdue will offer a three-credit graduate-level online course that will qualify learners for certification as an associate systems engineering professional (ASEP). The course, scheduled for initial delivery during the summer of 2022, will be available as an elective for students in Purdue's online systems graduate certificate and interdisciplinary master's in systems engineering programs.

Details here.

INCOSE Chapter Updates - Asia-Oceania

The Q42021 updates of the INCOSE Asia-Oceania chapter report the following highlights:

The INCOSE India Chapter organized its second big event this year, the virtual International Symposium on Artificial Intelligence-Machine Learning in Safety-Critical Systems, held on the 21st and 22nd of October 2021. This event provided 600 participants with the opportunity to gain valuable insights concerning the fast-moving field of AI/ML and its applications in industries such as aerospace, automotive, industrial automation and healthcare. For more information, see the India Chapter home page.

The Singapore Chapter hosted an Introduction to Model-Based Systems Engineering (MBSE) and its Adoption Roadmap webinar on 20 October 2021, delivered by Robert Ong. The meeting also served as a reboot of the chapter's activities after an interruption caused by the COVID-19 pandemic. For more information, see the Singapore Chapter home page.

Appreciation for Kerry Lunney's Service as INCOSE President from 2020-2021

by René King, ASEP, MSc Eng (PPI Senior Engineer)

As we approach the INCOSE International Workshop (IW2022), to be held in hybrid format from 29 January - 1 February 2022, several INCOSE leaders are ready to hand over the baton to make way for elects and co-chairs to step into their roles. Such is the same for Kerry Lunney, who is completing her second year of a two-year term as President of INCOSE.

I interviewed Kerry Lunney as part of the Spotlight feature for PPI SyEN 101. I was left with the question: "how does she do all of this with the same 24 hours in a day that I have?" Kerry is currently Country Engineering Director and Chief Engineer for Thales, Australia. Thales gave its full blessing to Kerry as she stepped into the president-elect role, following Garry Roedler's leadership. However, no one could have predicted the challenges that would have followed in Kerry's first year as the seriousness of the COVID-19 pandemic became evident in early 2020.

INCOSE's membership, offerings and the size of its volunteering group is growing rapidly. It is not difficult to imagine how challenging the role of INCOSE President must be in ordinary circumstances. It is the ultimate systems engineering role, balancing multiple stakeholder goals, the expectations of finding systems solutions to address the problems in our modern world and all the strategic and tactical aspects that rely on the President's inputs. This challenge was multiplied in 2020 as the world was struck with sudden and dramatic shifts imposed by the COVID-19 pandemic. It is PPI's opinion that Kerry Lunney, in leading INCOSE, led the Society to transform despite the fact that INCOSE is still largely a volunteer-based organization. Some of the highlights in INCOSE's achievements during the period of 2020-2021 include, but are not limited to:

- Growing the INCOSE membership to its current size of 19,300 members across 77 countries.
- Conduct of effective, well-supported virtual workshops and symposiums including the IS2020, IS2021 and IW2021.
- Supporting INCOSE chapters and working groups in moving toward remote development and meetings.
- Strengthening the value proposition and impact of the Certification Program (currently sitting at 3891 Systems Engineering Professional (SEPs) as of 8 December 2021.
- Transitioning to a computer-based form of delivering the INCOSE Knowledge Exam, which can now be taken from almost any internet-connected computer, thus reducing the friction to obtaining INCOSE certification.
- Introducing academic equivalency for more than 12 universities, thus enabling students to gain SEP certification without writing the INCOSE Knowledge Exam - again reducing the friction to SEP certification.

Throughout Kerry's two years as President during this challenging time, the bandwidth of communication from the President to the INCOSE membership was high. Kerry released frequent public statements concerning INCOSE's plans and responses to the pandemic, where the health and safety of INCOSE's members and volunteers was prioritized while the effort towards making progress across various INCOSE's objectives was maintained and even bolstered.

In PPI SyEN 101, Kerry stated that the pandemic affected all aspects of INCOSE. Some outreach initiatives had been postponed and other technical societies and organizations focused on survival and adjusting to the disruption. However, there were also significant wins for the Society as INCOSE moved forward on many fronts, in particular in the areas of 'subject-knowledge enrichment' through dedicated work on the areas of digital engineering concepts, MBSE, Future of Systems Engineering (FuSE) and Grand Challenges.

As INCOSE prepares to release the SE Vision 2035 in early 2022, it will be interesting to learn of the areas in which INCOSE plans to expend energy in the next decade and beyond. Kerry hints at a focus on addressing the interconnectedness and interdependencies across various systems and solutions and highlighting the importance of self-driven education and training. It will be up to the new President, Marilee Wheaton, with the support of INCOSE's outstanding leadership and membership, to drive the organization forward following in the formidable footsteps of Kerry Lunney. From PPI to INCOSE and particularly to Kerry Lunney, we salute the way you have handled the massive challenge of managing and directing the most influential SE Society during this challenging time.

Prior to becoming President of INCOSE, Kerry was the first INCOSE ESEP in Australia, served as Asia-Oceania Director and is a Fellow of Engineers Australia, to name just a few of the impressive achievements in her engineering career.

CONFERENCES, MEETINGS & WEBINARS

Events of relevance to systems engineering

INCOSE San Diego Chapter: Managing Architectural Complexity Presentations

On 17 November, 2021, the INCOSE San Diego (USA) chapter hosted two presentations that addressed the management of system and software complexity by use of MBSE techniques.

The first presentation, by Ms. Heidi Jugovic of SAIC, was titled "Managing Architectural Complexity for Digital Transformation" and had been previously presented as a keynote at the Design Structure Matrix (DSM) Conference in October, 2021. Key points include:

- The primary reason to pursue digital transformation/MBSE is the ability to manage complexity. The level of complexity inherent in today's systems is impossible to manage without a better set of methods/models.
- A focus on model craftsmanship is not enough; determine the model's stakeholders and uses first to drive an appropriate level of model completeness and fidelity. Too much time is spent on building good models; not enough on using them effectively.
- Formal languages and diagrams improve rigor, communication and consistency out-of-the-box, but diagrams introduce their own form of complexity if just used a pictures.
- Models can enable rigorous evaluation of architecture "goodness" factors such as cohesion, coupling, cycles, etc.
- Native MBSE/SysML tools can visualize dependencies, but Design Structure Matrices (DSMs) are a better tool to analyze and gain insight across a diverse set of dependencies and behavioral and structural interfaces.
- DSM techniques may be used to automatically check architectural compliance over time and reduce architecture decay.
- Models are only the first step in the Digital Engineering (DE) architecture journey. We must leave behind the old way of using architecture models as pictures and move toward semi-automated analyses of architectures.

The second presentation by Mr. Michael Vinarcik, also of SAIC, was titled "Level-up Your Architecture Game: Enhanced Design Structure Matrices and System Modeling throughout the Lifecycle". Key points include:

- There is a growing emphasis among customers in Modular Open System Architecture (MOSA) to enable the transition of software to micro-services and to improve sustainability.
- MOSA requires enforcement of an architecture from concept to execution.
- DSMs are a proven technique to show the dependencies between architecture elements.
- Lattix, a commercial DSM tool, may be used to analyze software for architectural compliance, both up-front evaluation of a proposed architecture and evaluation of as-written code vs. the defined architecture and its rules.
- Purpose-built DSM tools can provide better direct architecture analysis capabilities than standard SysML diagrams.
- Model quality is a prerequisite for DSM-enabled architecture analysis, particularly complete capture of relationships.

- Architecture analysis tools and associated clustering algorithms can uncover opportunities for complexity reduction through repartitioning and for enforcement of architecture rules during design.
- Architecture analysis tools can be used to detect defects in as-written code to uncover and resolve architecture degradation.

View the presentations here. See the full San Diego Chapter Video Library.

SERC Sponsor Research Review Highlights

The Systems Engineering Research Center (SERC) completed its annual SERC Sponsor Research Review (SSRR) on 3 November 2021. Mr. Maynard Holliday, U.S. Director of Defense Research and Engineering for Modernization provided the keynote address highlighting:

- Legacy system challenges to modernization
- Spanning the "valley of death" to get academic innovations to the warfighter
- Increased focus on relationships across modernization themes
- On-going need for help from SERC and academia to help the DoD identify blind spots

View the keynote.

After the keynote, Dr. Dan DeLaurentis, SERC Chief Scientist, led a panel discussion on DoD modernization priorities. Highlights include:

- Creating methods and approaches that ensure that AI follows the commander's intent and is auditable
- Opportunities for synergy between cyber and systems engineering communities
- Non-traditional utilization of technologies
- Supply chain resilience
- System autonomy strategies

View the modernization priorities panel.

A second panel, led by Mr. Tom McDermott, SERC Deputy Director, focused on Systems Engineering Modernization initiatives. View the panel here.

The SSRR was followed on 4 November by two tutorials:

- Digital Engineering Tutorial by Dr. Mark Blackburn of Stevens Institute of Technology – Skyzer Surrogate Pilot Overview and MBSE Cost Model Use Case with Model Tour Demonstration
- Security Engineering Tutorial by Dr. Peter Beling (Virginia Tech) – SERC Systems and Cyber Resilience Modeling.

For details, see the SERC announcement and event archive page.

SERC Doctoral Students Forum (SDSF)

On 4 November, 2021, the Systems Engineering Research Center (SERC) hosted the SERC Doctoral Students Forum (SDSF). This event featured ten presentations on cutting edge research in systems engineering by doctoral fellows and students. The diverse set of research topics included:

- A Systematic Mapping Study of Systems Security Engineering for Modular Open Systems

- Quantitative Methods for Set-Based Design (SBD)
- Model Based Exploration of Historical Cases to Generate Insights
- Ecology-Inspired Design of Resilient and Affordable System of Systems
- Architecting Smart City Digital Twins
- Quantitatively Analyzing Defensive Actions in Cyberattacks
- Engineering Intelligent Systems: A Systems Theoretic Perspective
- Complexity at the Requirement Stage – A Novel Paradigm for System Development
- Leveraging Systems Theory to Achieve Verification Agility
- Reexamining the Logical Foundation of Engineering Decision Making Under Uncertainty

The latter presentation, by Mr. Christopher White, University of Alabama Huntsville, advised by Dr. Bryan Mesmer, won the "Best Student Presentation" award.

View presentations and posters here.

Webinar: A Design Thinking Roadmap for Process Improvement

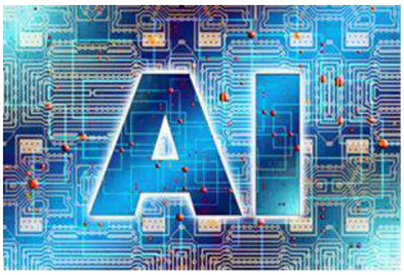
The INCOSE Chesapeake Chapter as part of their virtual/online monthly meeting and lecture on 16 February 2022 (6:00 – 8:00 PM, EST) will host a webinar concerning the application of Design Thinking techniques to a process improvement problem. This presentation will provide a design thinking roadmap for navigating the unknown, discovering the most pressing problems, and ideal solutions for process improvement, while creating a common vision for the organization.

The presenter, Lymari Castro-Diaz, is a Systems Engineer at the Department of Defense (DoD). In her 19 years working in the DoD, she has provided systems engineering expertise to a variety of complex missions and strategic initiatives.

Attendees will be eligible to win a "door prize": Innovating for People - Handbook of Human-Centered Design Methods by the LUMA Institute.

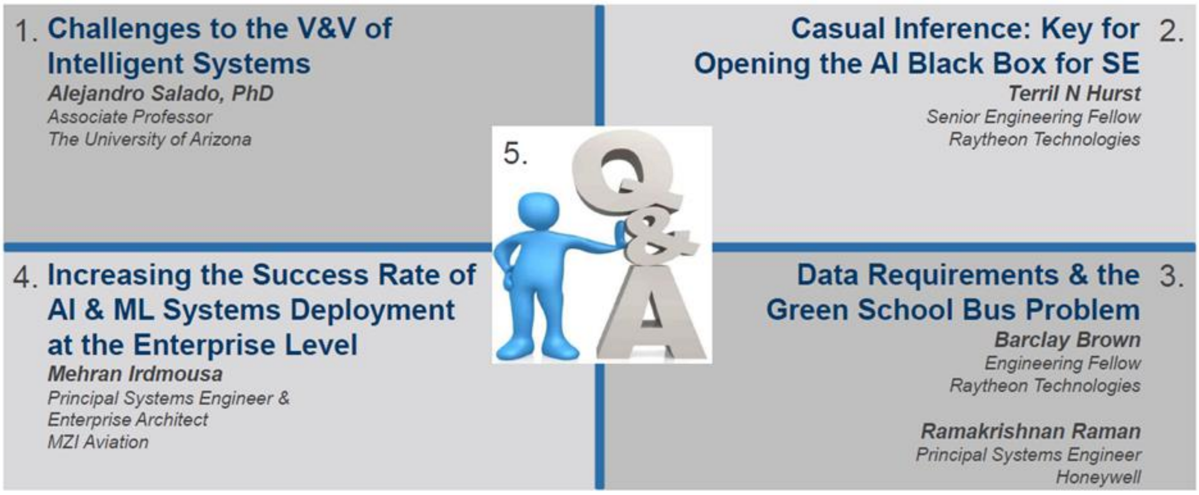
Details and registration here. Download the event flyer.

Systems Engineering Pathways to AI Now!



On 9 November, 2021, INCOSE President Kerry Lunney hosted an online mini-event on ***Artificial Intelligence, Systems Engineering Pathways to AI Now!*** In her welcoming remarks, Lunney highlighted the diversity of opinion associated with both the risks and promise of AI. She also noted the role of INCOSE's Artificial Intelligence Systems Work Group in contributing to the international AI community through participation in research, publication and AI-related global events.

Four guest speakers shared their expertise and insights concerning the incorporation of AI in the disciplines of systems engineering.



Alejandro Salado presented ***Challenges to the V&V of Intelligent Systems*** to explore the fundamental misalignment between current approaches to designing and executing verification and validation (V&V) strategies and the nature of intelligent systems. Current V&V approaches rely on the assumption that system behavior is preserved during a system's lifetime. However, intelligent systems are developed so that they evolve their own behavior during their lifetime; such is the purpose of AI. This misalignment makes existing approaches to designing and executing V&V strategies ineffective for systems that embed AI. As a result, it will be no longer sufficient to complete developmental V&V in the laboratory and assume that the behavior will be replicated in an operational environment.

Salado provided a systems-theoretic explanation for (1) why AI learning capabilities create a unique and unprecedented family of systems, and (2) why current V&V methods and processes may not be fit-for-purpose in the context of systems with high autonomy. Salado proposed a paradigm shift in the practice of V&V by delineating a set of theoretical advances and process transformations that could support such a shift.

Terril Hurst addressed the topic of ***Causal Inference: Key for Opening the AI Black Box for Systems Engineering*** highlighting the distinctions between "black-box" machine-learning techniques and the potential offered by a more recent development, called causal inference. Causal inference, popularized by computer scientists such as Judea Pearl and Adnan Darwiche, enable/require analysts to pose probabilistic models based upon their evolving understanding of cause-effect relationships within an engineered system. In Pearl's words: "You are smarter than your data."

The presentation described the basics and benefits of causal inference, which is founded upon a combination of propositional logic and Bayesian analysis. Causal diagrams and Bayesian networks were illustrated, that when developed collaboratively using simple protocols, enable quantifying uncertainty for making decisions.

Causal inference is based on a combination of prior knowledge/understanding and the analysis of data obtained either from observational studies (for example, reliability) or designed simulation and real-world experiments. Successes and challenges were highlighted for adopting causal inference, including the need to update skills to reason using the associated mathematics and protocols.

Barclay Brown and Ramakrishnan Raman tackled ***Data Requirements and the Green School Bus Problem***. As AI and machine learning-based subsystems and components become more prevalent in complex systems, the importance of training data is driving a new specialty within the systems engineering discipline of requirements engineering. Traditionally, system requirements included functional and non-functional requirements, including the "-ilities" such as reliability, dependability, durability, sustainability and others. For systems that include machine learning capabilities, Brown and Raman proposed the additional discipline of data requirements.

Successful data requirements engineering is necessary to prevent headline-making AI failures, which appear mysterious and frightening to both engineers and the public, but which can often be traced to relatively simple problems in the engineering of the data used to train the system. The best algorithm cannot overcome poor training data.

The systems engineer must be concerned with a new kind of system requirements, data requirements. Data requirements specify how much and what kind of data must be made available to the AI subsystem for training and testing. Systems engineers must learn enough about the environment in which the system will operate and about the situations it could encounter to fully specify the data required to successfully train it. More than the machine learning developer or even the data scientist, it is the systems engineer who will be aware of the system of which the AI subsystem is a part, and also the larger context of the entire system in the environment where it will operate.

Mehran Irdmousa shared on ***Increasing the Success Rate of AI and ML Systems Deployment at the Enterprise Level*** to address the prevailing problem that many AI-based projects fail to be operationalized to the field or even if they do, many do not meet the intended objectives of the original design. There is a need for exploratory research aimed at increasing the operationalization success of AI-based systems. This nascent research area opens up a new case of systems engineering for AI (SE4AI) with the potential for bringing a systems engineering discipline, Enterprise Architecture (EA), into AI and machine learning (ML) system-based designs.

INCOSE members may access the event video and presentations here. The event video is available for non-members here.

Submissions and Registrations Open for 2022 International System Dynamics Conference

The System Dynamics Society announces the opening of submissions and registrations for the 2022 International System Dynamics Conference, a hybrid conference to be held on 18-22 July, 2022. The in-person portion of this 40th annual conference will take place in Frankfurt, Germany. The conference is a gathering of people from all over the world who are interested in the practice of System Dynamics and systems thinking, appealing to audiences across industry and academia, whether newcomers, experienced practitioners or thought leaders.

The conference theme is "Diversity" and the conference will highlight multiple dimensions of this topic, including:

- How does diversity in teams encourage innovation and enhance decision-making and problem-solving?
- How do race, class, gender, ethnicity, ability, etc. intersect and shape society?
- How do qualitative and quantitative modelling intersect and shape the 'field' of System Dynamics?
- How can System Dynamics work with and learn from related approaches?
- How can the experience of a diversity of practitioners be leveraged to increase the use of System Dynamics?
- How do we create and select teaching materials with a diverse gender, national and ethnic representation?

Beyond Diversity, the conference seeks contributions across numerous "threads" including:

- **Business and Strategy:** Features applications of System Dynamics in businesses and organizations including strategy development, profitability, marketing, competitive dynamics, product launches, project dynamics, and accounting.
- **Environment and Resources:** Emphasizes dynamics of natural resource management and policy for the environment including food, water, energy and climate change, pollution, environmental laws and regulation, and ecology.
- **Learning and Teaching:** The manner in which system skills are taught and learned including pedagogy, learning experiments, curriculum development, workshop design, and interactive activities designed to be part of an educational experience.
- **Operations:** Includes business and other process operations including capacity management, quality control, operations management, supply chains, workflow, queuing, and workforce planning.
- **Psychology and Human Behavior:** Explores the dynamics within and between social groups, including social environments or individual psychological factors, and spanning families, organizations, and societies.
- **Security, Stability, and Resilience:** Investigates issues related to security, stability, and resilience, including defense, social and international conflict, military operations, insurgency, counterinsurgency, cybersecurity, disinformation, safety, disaster management, peace engineering, justice, (financial and economic) crime, policing, incarceration, socioeconomic inequality, and food-energy-water security.
- **Transport and Mobility:** Covers all aspects of transportation systems and mobility, including transport and urban planning policies; new services, technologies or business models; de-carbonization and sustainable mobility; transport and health; and freight and logistics.
- **Economics:** Features papers improving understanding of economic dynamics including macroeconomics, microeconomics, trade, business regulation, economic development, economic policy, insurance, and risk management.
- **Health:** Applies System Dynamics to issues related to health and health care including health policy, health services research, population health, and physiology.
- **Methodology:** Welcomes contributions to System Dynamics modeling and simulation including quantitative and qualitative aspects of model development, model analysis, validation, graphical presentation formats, computational techniques, and integration of System Dynamics with other approaches such as Artificial Intelligence and Predictive Analytics, among others.
- **Public Policy:** Covers issues including governance, social welfare, equity, justice, political science, urban dynamics, and infrastructure.
- **Stakeholder Engagement:** Emphasizes engaging and influencing stakeholders through participatory activities such as group model building, facilitation, facilitated modeling, games and management flight simulators with emphasis on assessing the impact of the engagement.

Contact the program chairs between 20 January and 18 March for instructions concerning submissions to your topic of interest.

In addition to the topics in the main program, the conference will include a range of companion events:

Summer School: Held online two weeks before the annual conference, Summer School provides a unique opportunity to learn (or review) System Dynamics while getting exposure to real-world applications of the method.

Student-Organized Colloquium: A one-day event organized by the Student Chapter of the System Dynamics Society held on the first day of the Conference.

Publishing Assistance Workshop: Held after the conference, seasoned mentors provide authors with one-on-one guidance and expertise in the development of their manuscript for submission to top academic journals in their chosen field.

Modeling Assistance Workshop: Seasoned mentors offer conference participants the opportunity to obtain one-on-one coaching on specific System Dynamics modeling questions.

Model Expo: Authors who are presenting model-based work will have an opportunity to show their model to others and let them interact with it.

See more details here.

Capella 2022 Annual Message

Juan Navas, MBSE expert at Thales Corporate Engineering, will present a webinar, the Capella 2022 Annual Message, on 17 February 2022 to highlight the evolving capabilities of the Capella MBSE tool suite. Topics include:

- Major events concerning Capella during 2021.
- Capella roadmap for 2022.
- New features included in the latest version of Capella.

Register here.

Upcoming PPI-Live-Online™ Systems Engineering Five Day Courses

P006-870-1	Europe UTC +1:00 (CET 9:00) PPI Live-Online	14 Feb - 18 Feb 2022
P006-870-2	United Kingdom UTC +0:00 (GMT 8:00) PPI Live-Online	14 Feb - 18 Feb 2022
P006-870-3	South Africa UTC +2:00 (SAST 10:00) PPI Live-Online *(Only available in South Africa)*	14 Feb - 18 Feb 2022
P006-872-1	Asia UTC +8:00 (SGT 5:00) PPI Live-Online	21 Feb - 25 Feb 2022
P006-872-2	Oceania UTC +11:00 (AEDT 8:00) PPI Live-Online	21 Feb - 25 Feb 2022
P006-873-1	North America UTC -6:00 (MDT 8:00) PPI Live-Online	21 Mar - 25 Mar 2022
P006-873-2	South America UTC -3:00 (BRT 11:00) PPI Live-Online *(Only available in South America)*	21 Mar - 25 Mar 2022
P006-874-1	Asia UTC +8:00 (SGT 5:00) PPI Live-Online	28 Mar - 01 Apr 2022
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P006-882	São José dos Campos, Brazil *(Only available in South America)*	25 Apr - 29 Apr 2022

Register for an upcoming course in your location here.

FEATURED ARTICLES

Capability Architecture for Industry 4.0 – Digital Transformation of the Manufacturing Enterprise

by Scott Phillips, Founder, I4Score

Email: sphilliips@i4score.com

Abstract

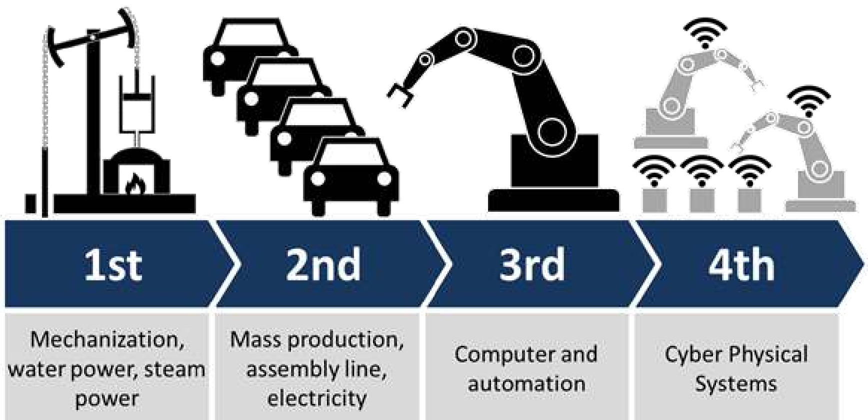
Manufacturing companies around the globe are in the midst of a digital transformation, commonly known as Industry 4.0. Enabled by a converging host of new data-centric technologies, manufacturers are seeking to create smarter, more flexible manufacturing enterprises that may improve Profitability, On-time Delivery and Overall Equipment Effectiveness (OEE). This paper presents a capability architecture for the digital transformation of a manufacturing enterprise. This architecture frames the fundamental decisions that such a business must make on its journey toward increased competitiveness when leveraging Industry 4.0 technologies.

The framework of "Jobs-to-be-Done" (JTBDs) is applied to link the goal of a Data-Driven System Architecture to the Organizational Capabilities and Strategic Partnerships required to achieve it.

Though the examples in this paper will focus on smart manufacturing, the principles behind the capability architecture are applicable to any organization seeking the benefits of digital transformation.

Background

In 2011, Dr. Kagermann, Dr. Wolfgang Wahlster of the German Research Center for Artificial Intelligence (DFKI) and Dr. Wolf-Dieter Lukas from the Federal Ministry of Research and Education presented the results of the work of the advisory group across various domains, including Industrie 4.0, which from then on became broadly known [1]. In 2013, Plattform Industrie 4.0 was created by Bitkom (Germany's digital association), VDMA (German Mechanical Engineering Industry Association), and ZVEI (Germany's Electrical Industry).



Source: Christoph Roser - AllAboutLean.com. [2]

Extracts from early published papers refer to the technological evolution from embedded systems to cyber-physical systems… INDUSTRIE 4.0 represents the coming fourth industrial revolution on the way to an Internet of Things, Data and Services. Decentralized intelligence helps create intelligent object networking and independent process management, with the interaction of the real and virtual worlds representing a crucial new aspect of the manufacturing and production process.

Industry 4.0 Enabling Technologies

From a technology perspective, Industry 4.0 is often represented as the digital transformation of industrial organizations enabled by a set of technologies as suggested by the Boston Consulting Group in a publication from 2015 [3]. These enabling technologies or pillars have all matured and converged to solve a wide assortment of problems in new ways and have also become more accessible to small and medium sized organizations in terms of cost and implementation.

Big Data and Analytics

Analytics based on large data sets has emerged only recently in the manufacturing world, where it optimizes production quality, saves energy, and improves equipment service. In an Industry 4.0 context, the collection and comprehensive evaluation of data from many different sources, production equipment and systems as well as enterprise- and customer-management systems, will become standard to support real-time decision-making.

Autonomous Robots

Manufacturers in many industries have long used robots to tackle complex assignments, but robots are evolving for even greater utility. They are becoming more autonomous, flexible, and cooperative. Eventually, they will interact with one another and work safely side by side with humans and learn from them. These robots will cost less and have a greater range of capabilities than those used in manufacturing today.

Simulation

In the engineering phase, 3-D simulations of products, materials, and production processes are already used, but in the future, simulations will be used more extensively in plant operations as well. These simulations will leverage real-time data to mirror the physical world in a virtual model, which can include machines, products, and humans. This allows operators to test and optimize the machine settings for the next product in line in the virtual world before the physical changeover, thereby driving down machine setup times and increasing quality.

Horizontal and Vertical Systems Integration

Most of today's IT systems are not fully integrated. Companies, suppliers, and customers are rarely closely linked. Nor are departments such as engineering, production, and service. Functions from the enterprise to the shop floor level are not fully integrated. Even engineering itself, from products to plants to automation, lacks complete integration. But with Industry 4.0, companies, departments, functions, and capabilities will become much more cohesive, as cross-company, universal data-integration networks enable truly automated value chains.

The Industrial Internet of Things

Today, only some of a manufacturer's sensors and machines are networked and make use of embedded computing. They are typically organized in a vertical automation pyramid in which sensors and field devices with limited intelligence and automation controllers feed into an overarching manufacturing process control system. But with the Industrial Internet of Things, more devices, sometimes including even unfinished products, will be enriched with embedded computing and connected using standard technologies. This allows field devices to communicate and interact both with one another and with more centralized controllers, as necessary. It also decentralizes analytics and decision-making, enabling real-time response.

Cybersecurity

Many companies still rely on management and production systems that are unconnected or closed. With the increased connectivity and use of standard communications protocols that come with Industry 4.0, the need to protect critical industrial systems and manufacturing lines from cybersecurity threats increases dramatically. As a result, secure, reliable communications as well as sophisticated identity and access management of machines and users are essential.

The Cloud

Companies are already using cloud-based software for some enterprise and analytics applications, but with Industry 4.0, more production-related undertakings will require increased data sharing across sites and company boundaries. At the same time, the performance of cloud technologies will improve, achieving reaction times of just several milliseconds. As a result, machine data and functionality will increasingly be deployed to the cloud, enabling more data-driven services for production systems. Even systems that monitor and control processes may become cloud-based.

Additive Manufacturing

Companies have just begun to adopt additive manufacturing, such as 3-D printing, which they use mostly to prototype and produce individual components. With Industry 4.0, these additive manufacturing methods will be widely used to produce small batches of customized products that offer construction advantages, such as complex, lightweight designs. High-performance, decentralized additive manufacturing systems will reduce transport distances and inventory.

Augmented Reality

Augmented-reality-based systems support a variety of services, such as selecting parts in a warehouse and sending repair instructions over mobile devices. These systems are currently in their infancy, but in the future, companies will make much broader use of augmented reality to provide workers with real-time information to improve decision-making and work procedures.

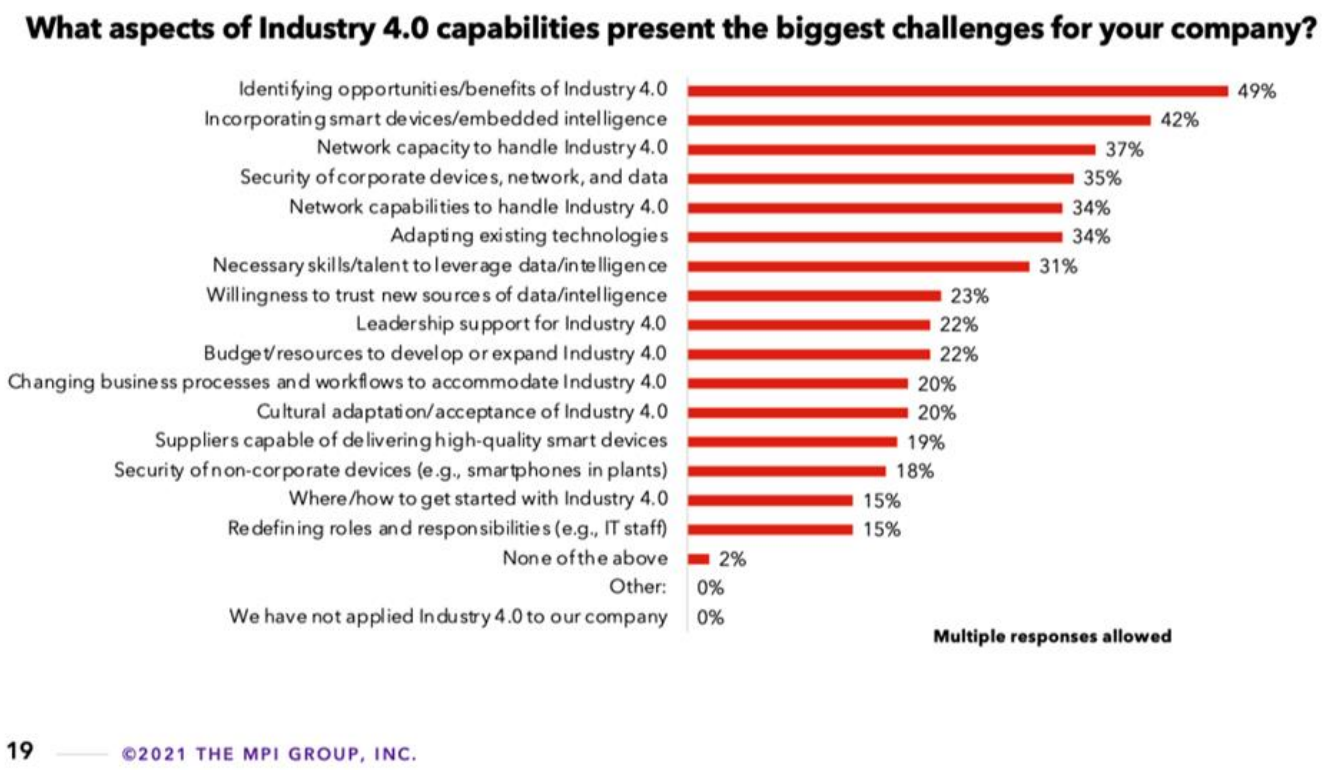
Digital Transformation

Digital Transformation (DX) can be defined as the cultural, organizational and operational change of an organization, industry or ecosystem through a smart integration of digital technologies, processes and capabilities across all levels and functions in a staged and strategic way. While Digital Transformation is applicable to all types of organizations, Industry 4.0 can be framed as the Digital Transformation of industrial enterprises, including manufacturing.

But leading an enterprise transformation with a technology focus is a recipe for failure. In their book, “The Technology Fallacy” [4], Kane, Phillips, Copulsky and Andrus argue that digital disruption is primarily about people and that effective digital transformation involves changes or organizational dynamics and how work gets done. A focus only on selecting and implementing the right technologies is not likely to lead to success.

Each of these technologies needs to be understood in terms of the improved functionality and performance that they the offer, their contribution to the manufacturing enterprise capability. Rather than a technology “push”, we want the competitive and sustainability needs of the enterprise to create a "pull" that demands better technologies because of the increased value that they deliver. Identifying that pull also enables consideration of such technologies as an integrated set of solutions, layered on top of existing technologies, in such a way that the whole (emergent properties of the entire system) is much greater than the sum of its parts.

According to research conducted by The MPI Group in 2021 [5], Industry 4.0 is delivering improved productivity and profitability when applied to plant operations, processes, and supply chains, but implementation challenges remain. As indicated by the chart below, manufacturers struggle with various aspects of people, process and technology capabilities in-house and/or are missing strategic partnerships to assist. Most of the challenges highlighted in the chart can be mapped directly to one or more of the nine organizational capabilities described later in this article.



Organizational Capability Model

There are nine organizational capabilities which are important to successful Digital Transformation. The nine organizational capabilities are grouped into the three categories of People, Process and Technology. Few organizations will possess these capabilities to the degree necessary to successfully exploit the enabling technologies of Industry 4.0 to achieve their enterprise objectives. Consequently, the critical steps for successful Digital Transformation are to conduct an organizational capability assessment, identify the gaps, create development plans to close the gaps over time and identify third-party implementation partners to engage in the short run.

People Capabilities

With enough capital, any organization can acquire the latest technology. But without the right leadership, workforce and strategy, it will take too long to earn a return on the investment. Companies with high levels of leadership quality and workforce engagement are significantly more likely to outperform their peers financially. Successful Digital Transformation requires a people development roadmap in parallel with a technology adoption roadmap.

Leadership

The capability to understand and leverage Digital Transformation principles, solutions and technologies to ensure the company's future competitiveness. Organizational leaders should possess a transformative vision based upon knowledge of market trends and business acumen. Leaders should also have a basic understanding of technology based upon pre-existing experience including digital literacy. Leaders need to be able to develop and maintain a culture which is change-oriented, open-minded, adaptable and innovative.

Workforce

The capability to create training programs in order to develop the skills and culture required for successful Digital Transformation. Data-driven processes will fundamentally alter the nature of work going forward. From a soft skills perspective, Digital Transformation will require workers to develop a change-oriented perspective, strategic thinking and interpersonal skills. From a hard skills perspective, Digital Transformation will lean heavily on process automation, systems integration and business intelligence.

Strategy

The capability to develop a plan to digitally transform an enterprise, including the establishment of priorities, formulating a roadmap, and developing a system of practices and processes to translate Digital Transformation into real business value. A strategic plan should be created by the leadership team with input from the organization. The goals should be clear, focused on effectiveness, and agreed between all levels of management, to ensure they are realistic and achievable.

Process Capabilities

The capability to create and maintain effective and efficient processes to achieve business goals. People manage processes. Everything a business does is managed according to a process. Whether you're investing in people or technology, any investment in a bad process will yield a poor return. Process considerations are a critical element of Digital Transformation. Lean methodologies should be pursued to eliminate waste within the process in order to reduce the investment in technology required to automate the process.

Business Process Management

The capability to deploy and sustain Business Process Management (BPM) throughout the organization. BPM is a discipline that uses various methods to discover, model, analyze, measure, improve and optimize business processes. A business process coordinates the behavior of people, systems, information and things to produce business outcomes in support of a business strategy.

Manufacturing Process Improvement

The capability to employ a variety of process improvement tools and techniques to improve manufacturing processes, eliminate waste and focus on the activities which create value for the customer. Achieving a culture of continuous process improvement is vital for staying ahead or even keeping up with your competitors. As a methodology, Lean offers a variety of tools that can help with that. The Lean tool kit includes practices such as Just-in-time-Production, Kanbans, 5S, 5 Whys, Gemba Walks, DMAIC and others.

Data Management and Governance

The capability to govern how data is being managed and processed throughout the organization. This includes the processes to create and implement data architectures, policies, and procedures that manage the full data lifecycle needs of an organization. Data governance helps answer questions such as: Who has ownership of the data? Who can access what data? What security measures are in place to protect data and privacy? How much of our data is compliant with new regulations? Which data sources are approved to use?

Technology Capabilities

The capability to discover, introduce and maximize the return on investments in information and operating technologies. Having people and process capabilities in place should be a prerequisite for implementing new technology and increases the likelihood of a successful Digital Transformation. Process automation both in the administrative and production areas of the business were a hallmark of Industry 3.0 and continue to play a critical role in Industry 4.0. What is different is the concept of integrated Cyber-physical Systems (CPS). When digitally transforming in the era of Industry 4.0, it is important to ensure that the technology implemented in one area will integrate with technology in other areas.

Process Automation

The capability to automate business, manufacturing and support processes across all layers of the business hierarchy including the flexibility to reconfigure processes and re-task machines to create a greater variety of products with shorter turnaround times. While automation has been and will continue to be a key enabler for companies, the role of automation is changing. To cope with rising demand for smaller batches and on-demand production, it is no longer sufficient to simply maximize efficiency. Digital Transformation enables an organization to adapt quickly to changing market needs as automation needs to be flexible instead of fixed.

System Integration

The capability to increase the level of interconnectedness between the equipment, machines, people and systems that reside within all levels of the business hierarchy including how data is exchanged and analyzed. This includes data connected from the field layer and production floor up through enterprise business planning and supply chain management. Digital Transformation requires that data flows freely and transparently up and down and across these levels so that both strategic and tactical decisions can be data-driven. The vertically and horizontally integrated enterprise gains a crucial competitive edge by being able to respond appropriately and with agility to changing market signals and new opportunities.

Business Intelligence

The capability of the business to be able to develop Information Technology and Operating Technology enabled systems at all layers of the business to be able to identify and diagnose deviations, identify likely causes, predict risks and prescribe mitigations ahead of time. The benefits to be derived from added intelligence are significant and far-reaching. With technologies such as cloud computing and artificial intelligence, the vast quantities of data generated can be processed and translated into actionable insights to diagnose problems and identify opportunities for improvement.

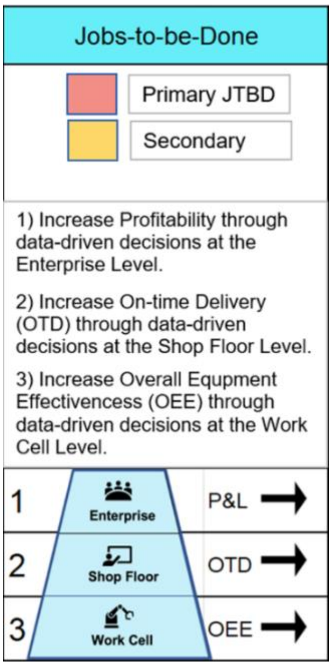
Realizing the Capability Architecture

There are a nearly unlimited ways to combine the nine capabilities described above into an enterprise level system. From observation and experience across a diverse range of manufacturers, the author has synthesized a roadmap that can guide a manufacturing business toward achieving its goals associated with an Industry 4.0 /Digital Transformation initiative.

The intent of this roadmap is to help businesses avoid three types of failures related to any complex strategic enterprise "design" initiative:

- Decisions overlooked
- Decisions poorly made
- Decisions poorly implemented

Jobs-to-be-Done



The concept of Jobs-to-be-Done was popularized by Anthony Ulwick in his book "What Customers Want" published in August 2005 [6]. Jobs-to-be-Done (JTBD) is part of a larger framework called Outcome Driven Innovation (ODI). While ODI was initially targeted at corporations and startups searching for innovative new products, it can also be used to identify critical pain points within the operations of a company and describe the JTBDs that a solution set needs to address. A Job Map is used as a visual depiction of the core functional job, deconstructed into its discrete process or job steps, which explain step-by-step exactly what the primary actor is trying to get done.

The following illustrations demonstrate the application of the JTBD framework in the context of potential Industry 4.0 solutions. The Core Functional JTBD demonstrated in this example is to "Increase profitability at the enterprise level of the organization by improving information value and enabling data-driven decisions."

Although we will use enterprise profitability as our JTBD example, the methodology would typically also be used on performance metrics at the shop floor level (e.g. OTD = On-Time Delivery) and at the work cell level (e.g. OEE = Overall Equipment Effectiveness).

Job Step 1 - Accelerate the timeliness value of information to support faster decisions by improving the creation stage of the information value loop. (Solutions could include - sensors, NLP, RFID, etc.)

Job Step 2 - Increase the analytical value of information to support smarter decisions by increasing the volume of information created and available for decision support. (Solutions could include - machine monitoring, vision systems, etc.)

Job Step 3 - Increase the efficiency value of information to support more efficient decisions by increasing the interoperability of System-to-System interfaces to enable direct, automated interfaces and reduce human intervention. (Solutions could include ERP integrations, APIs, etc.)

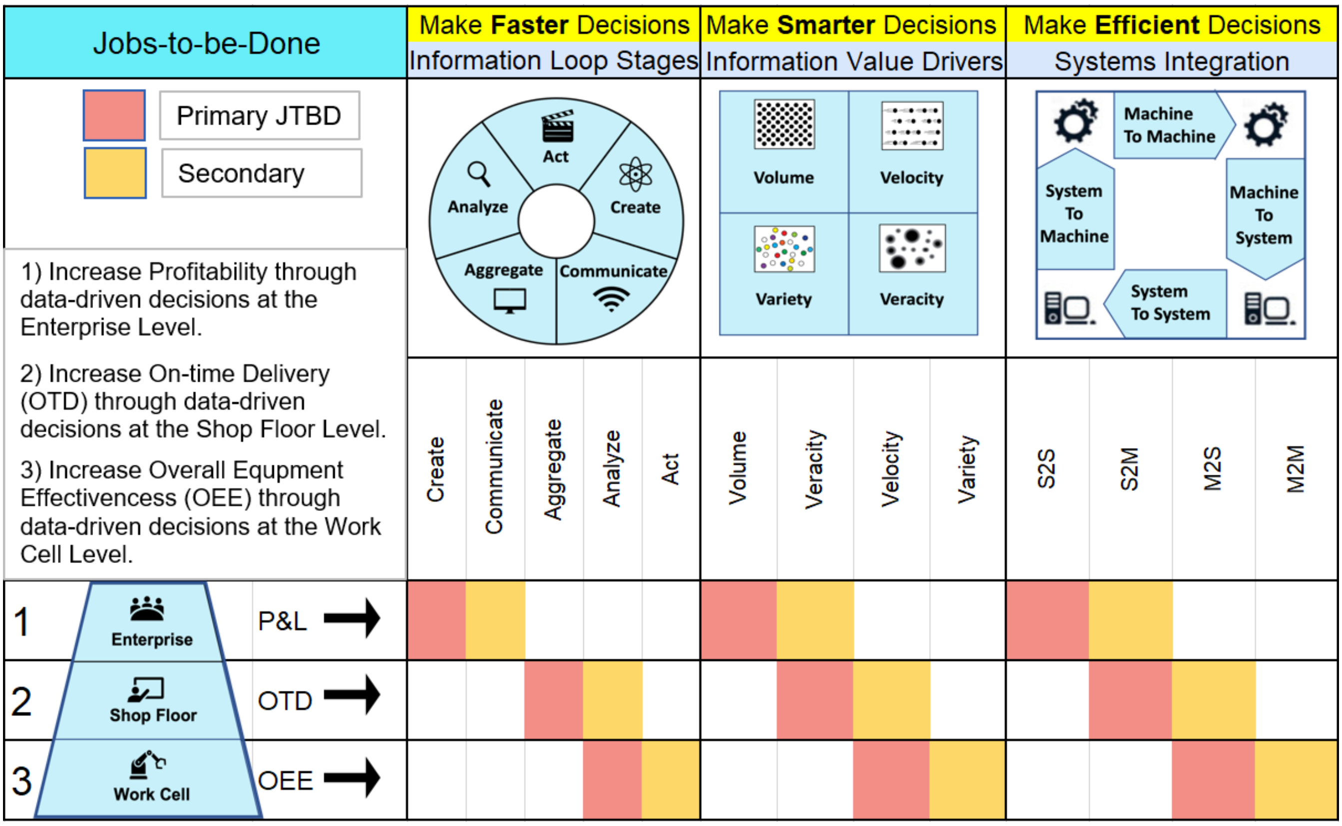
Job Step 4 - Confirm which future state system architecture is best suited to enable Job Steps 1, 2 and 3.

Job Step 5 - Further develop the Leadership, Workforce Development and Strategy Deployment organizational capabilities to improve the potential to deliver the future state architecture.

Job Step 6 – Identify strategic partnerships with Educators and Management Consultants to increase the Industry 4.0 domain knowledge and supplement gaps in the organization's People Capabilities in the short term.

Make Faster, Smarter and Efficient Decisions

The roadmap uses a framework of Information Value Loops as a generalized functional model for making any process smart and learning (ever smarter). In this context, we are less interested in the traditional functions of manufacturing; more on the knowledge-centric processes that control them and by which they learn/improve continuously, i.e. get smart. This framework was introduced by Deloitte consulting in an article from 2015 [7] .



Job Step 1: Making Decisions Faster

Information Timeliness Value is the degree to which information arrives in time to inform fast decisions with the following scale offering context from least value (1) to most value (5):

- 1. Always late
- 2. Sometimes late
- 3. Mostly on time
- 4. Always on time
- 5. Real-time

Deloitte defines the 5 stages of information value creation and the corresponding categories of Industry 4.0 enabling technologies as follows:

- **Create** - The use of sensors to generate information about a physical event or state. Sensors are solutions for this stage, defined as a device that generates an electronic signal from a physical condition or event.
- **Communicate** - The transmission of information from one place to another. Networks are a solution for this stage, defined as a mechanism for communicating an electronic signal.
- **Aggregate** - The gathering together of information created at different times or from different sources. Standards and protocols are a solution for this stage, defined as commonly accepted prohibitions to or prescriptions for action.

- **Analyze** - The discernment of patterns or relationships among phenomena that leads to descriptions, predictions, or prescriptions for action. Augmented intelligence is a solution for this stage, defined as analytical tools that improve the ability to describe, predict, and exploit relationships among phenomena.
- **Act** - Initiating, maintaining, or changing a physical event or state. Augmented behavior is a solution for this stage, defined as technologies and techniques that improve compliance with prescribed action.

In the example provided here, the organization determined that improvement in the **Creation** Stage of the information value loop was required to accelerate the timeliness of their information to support **faster decisions**. Improving the **Communication** Stage was the second highest job step priority. This company was a relatively small, family-owned and family-managed manufacturer. The family goals were to sustain the business and hand it down to future generations, not grow it per se. Consequently, the company lacked professional management and the operational processes and systems were antiquated. This is often referred to as an "Accidental System Architecture". From an Information Creation perspective, this company was collecting shift data manually on paper logs and transferring it several times, resulting in inaccurate and delayed information. They needed to consider adding more human-machine interfaces for the operators to input data and/or implement automated data capture solutions.

Job Step 2: Making Decisions Smarter

Information Analytical Value is the degree to which information delivers the analytical insight necessary to inform smart decisions, evaluated from least value (1) to most value (5):

- 1. Hindsight: Did something happen?
- 2. Descriptive Insight: What happened?
- 3. Diagnostic Insight: Why it happened?
- 4. Predictive Foresight: What will happen?
- 5. Prescriptive Foresight: What should we do about it?

As noted by Deloitte, getting information around the Value Loop allows an organization to create value; how much value is created is a function of the "value drivers" which capture the characteristics of the information that makes its way around the Value Loop. The following four information loop value drivers are adapted from the synthesis of many Big Data frameworks, some with as few as three dimensions and some with as many as nine or ten. These four were selected based on their relevance to industrial operations and their Mutually-Exclusive Collectively-Exhaustive (MECE) nature as a group.

- **Volume** – Data at rest. The number of instances of the same action that inform subsequent action. Data collected, stored and available for use in the size of megabytes, gigabytes, terabytes, petabytes, etc.
- **Velocity** – Data in motion. The interval between opportunities to adapt action based on new information. Data actively moving between locations through a network such as streaming data, process control data, etc.
- **Variety** – Data in many forms. The number of different dimensions of an action on which information informs subsequent action. Structured, unstructured, text, natural language, multimedia, etc.
- **Veracity** – Data in doubt. Unreliable due to data inconsistency, incompleteness, ambiguities, latency, deception, etc.

In the family business example, the organization determined that improving the Volume value driver was required to improve the analytical value of their information to support smarter decisions. Improving the Veracity value driver was the second highest job step priority. Given the small, family-owned nature of the manufacturer, they suffered from management by tribal knowledge. From a data Volume perspective, they were missing significant amounts of data related to worker productivity, asset performance and process quality. They needed to evolve from manual data entry, paper, and spreadsheets to the implementation of data networks and software applications.

Job Step 3: Making Decisions Efficiently

Information Efficiency Value is the degree to which operating and information technology is leveraged to maximize human efficiency in terms of decisions made and actions taken, evaluated from least (1) to most (5):

- 1. Technology is not leveraged - Manual processes, tribal knowledge.
- 2. Technology advises - Machines provide information, but humans act and make decisions (e.g., digital work instructions, digital job traveler).
- 3. Technology assists - Machines act, but humans make decisions (e.g., human machine interface).
- 4. Technology augments - Machines collaborate with humans to act and make decisions (e.g., cobots, A/R headset, pick-to-light).
- 5. Technology autonomizes - Machines act and make decisions (e.g., AI-ML, machine vision).

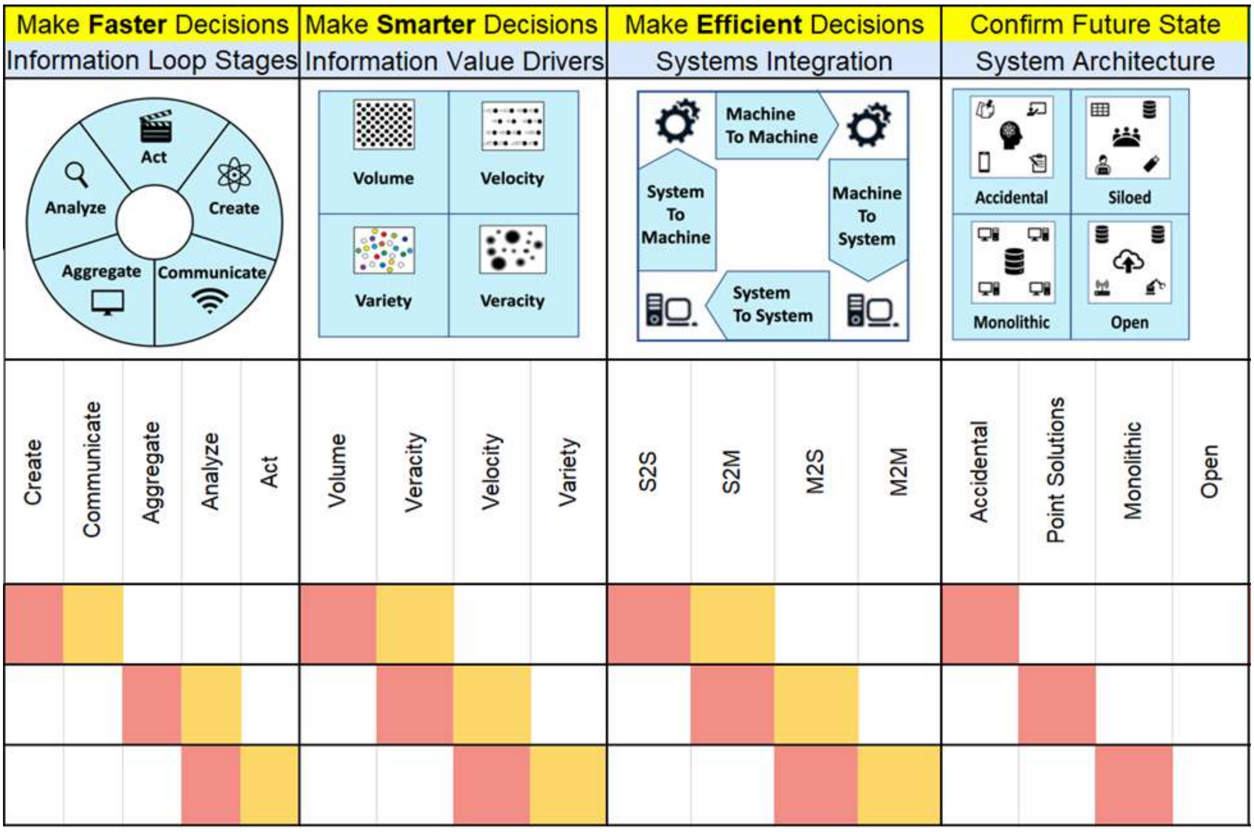
Industry 4.0 involves system integration and modernization of legacy assets to improve interoperability and information flow across the company operating architecture. System Integration opportunities include:

- **Machine-to-Machine (M2M)** - Systems that collect data from machinery with the use of electronic sensors, transmit the received information through a network and utilize software to directly control another machine or process.
- **System-to-System (S2S)** - Information systems integration is the process of linking together various IT systems, services and/or software to enable all of them to work functionally together.
- **System-to-Machine (S2M)** - The use of Computer Aided Manufacturing (CAM) software to automate, program or control a manufacturing process.
- **Machine-to-System (M2S)** - Machine monitoring is any means of connecting machine data feeds to the internet that enables real-time production monitoring and advanced analytics of production data.

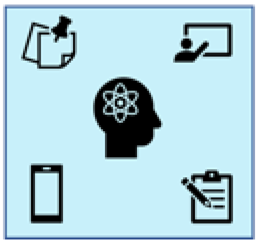
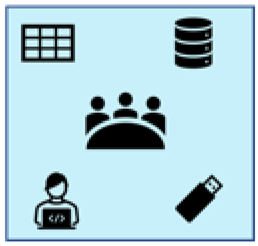
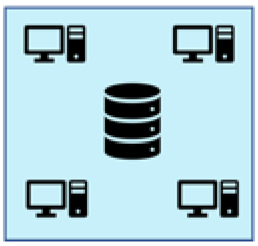
In the family business example, the organization determined that improving the efficiency value of their information to support **more efficient decisions** required improving **System-to-System** integration. Improving the **System-to-Machine** integration was the second highest job step priority. While this small company had only a few software solutions, such as QuickBooks and Excel, they did not have any automated interfaces between them, resulting in duplicate data entry and inefficient use of human resources. They needed to evolve from manual data entry to implementation of API interfaces where possible.

Job Step 4: Confirm Future State Architecture

What is meant by system architecture? Your system architecture is comprised of people, processes, and technology. The way you organize and integrate these three elements has a great bearing on how data flows through your organization in order to make day-to-day decisions. These day-to-day decisions, in aggregate over time, determine whether your organization can overcome business challenges (i.e., flow, variation and flexibility) and achieve business goals (i.e., profitability, on-time delivery and overall equipment effectiveness) on a consistent basis.



At a general level, we can imagine four types of system architectures defined by characteristics related to their level of data-driven maturity.

Accidental: Tribal Knowledge Paper Analysis Verbal Communication Data Silos		**Siloed:** Manage by Meetings Spreadsheet Analysis Redundant Data Entry Islands of Automation	
Monolithic: Infrequent software updates Lack of IT/OT Integration Lack of flexibility Vendor Lock-in		**Open:** Software as a Service Platform as a Service Infrastructure as a Service Adaptive and flexible	

It is critical that organizations assess themselves and align on which future state system architecture is most desirable, given their situation. While the Open architecture best represents the design principles of Industry 4.0 and enables a data-driven system architecture, it may not be realistic given limits on management bandwidth, capital resources and organizational capabilities. It is also important to benchmark an organization versus the competition. Living with an Accidental or Siloed architecture can lead to lack of competitiveness if your competitors have already evolved to a Monolithic or Open architecture. The point is to make system architecture an explicit strategic conversation during the road-mapping process.

In the example provided here, the organization chose the Monolithic architecture as their future-state technology informed by the previous job steps and organizational constraints.

Previous Step Results	Future-State Architecture Chosen
Improve the information **Creation** stage	Monolithic architecture
Increase the **Volume** of information created	
Improve the integration of information flow from **Systems-to-System**	

Job Step 5: Develop Organizational Capabilities

The identification of which organizational capabilities to develop internally is a function of the results from the first four job steps.

- 1. Improve the information creation stage
- 2. Increase the volume of information created
- 3. Improve the integration of information flow from systems to system
- 4. Migrate to a monolithic system architecture

In this example, the organization identified the three People Capabilities of Leadership, Workforce Development and Strategy Deployment as keys to success. The rationale was that the migration from the accidental architecture embedded in the company culture for 60 years would be hard to move on from without a concerted effort on change and change management associated with the People Capabilities.

Job Step 6: Identify Strategic Partners

Implementation partners can fill internal organizational capability gaps and help ensure successful Digital Transformation. Implementation partners can be broken down based upon the current needs of an organization as follows:

- Need information — Educators
- Need a plan — Consultant
- Need a system — System Integrators
- Need a solution — Solution Providers
- Need a service — Managed Service Providers

Educators - Provide information to individuals and companies on Digital Transformation principles, solutions and benefits. Examples include:

- Associations - Manufacturing, industry specific, professional, industry consortia
- Government - Standards, regulatory, economic development, innovation & technology
- Academia - Universities, community colleges, vocational schools
- Media - Publications, websites, webinars, conferences, research

Consultants - Advise companies on Digital Transformation strategies including:

- Management Consultants - Strategy, organization, product, operations
- Business Advisors - CPA firms, independent board, peer groups
- Information Technology - Enterprise architecture, network infrastructure
- Operating Technology - Industrial networking, process automation, floor plan layout

System Integrators - Provide integrated systems as part of a Digital Transformation. Examples include:

- Automation Integrators - Work cell automation, assembly line automation, material handling

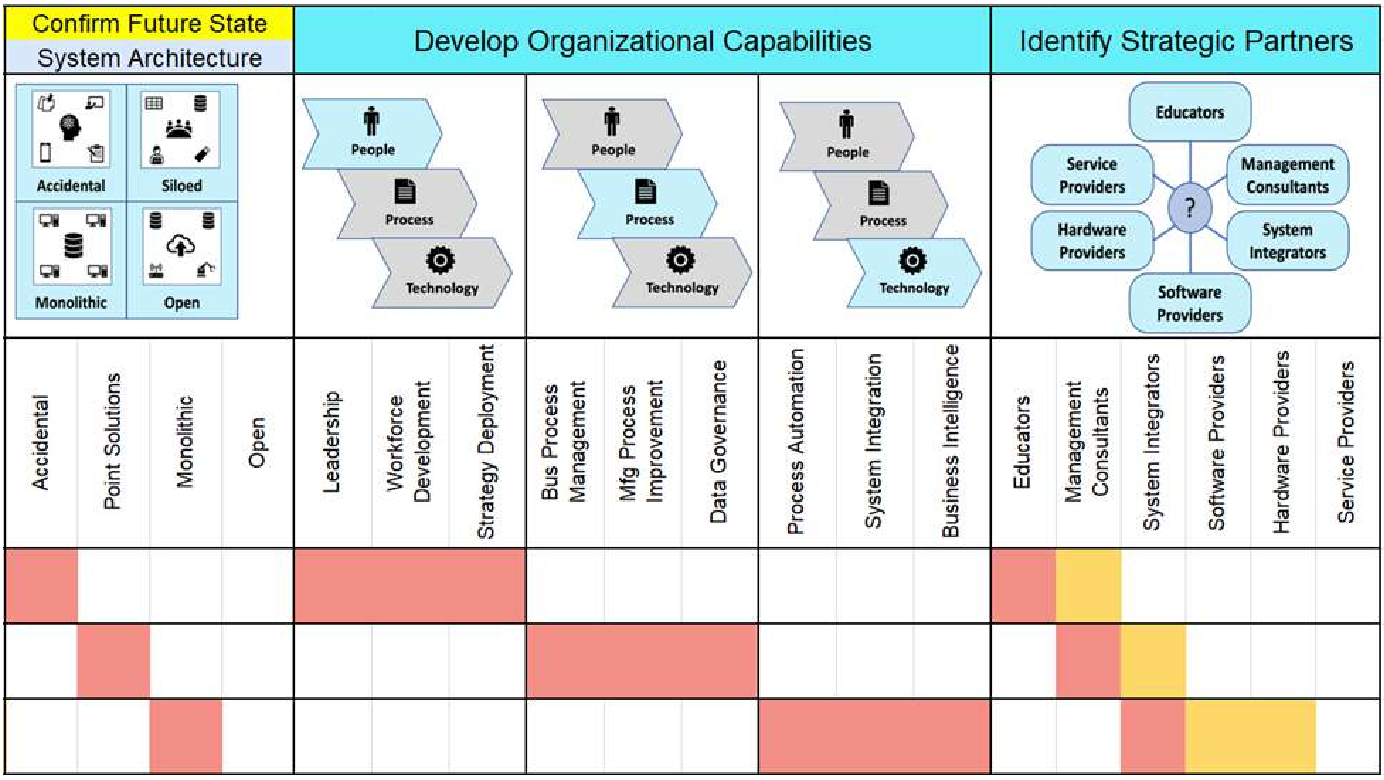
- Control System Integrators - Panel design, controls programming, drive systems
- Hardware Integrators - Machine vision systems, machine monitoring
- Software Integrators - Enterprise software, IoT Platform, custom applications

Solution Providers - Provide hardware, software and other solutions as part of an integrated system. Examples include:

- Hardware - Sensors, controls, cameras, actuators, industrial computers, PLCs
- Equipment - Robots, machines, conveyance, metrology
- Software - Database, operating systems, device drivers, middleware, applications
- Integrated Solutions - Computer vision, machine monitoring, geospatial, etc.

Managed Service Providers - Provide management of systems and solutions as a service. Examples include:

- Infrastructure-as-a-Service - Cloud computing service that offers compute, storage, and networking resources on demand (e.g., Azure, AWS)
- Platform-as-a-Service - Cloud based development and deployment environment for simple cloud-based apps to enterprise applications (e.g., Thingworx)
- Managed IT Services - Managed services for connectivity and bandwidth, network monitoring, security, virtualization and disaster recovery.



In the family business example, given the capability gaps relative to Leadership, Workforce Development and Strategy Deployment, the organization identified educators and management consultants as the initial strategic partners to engage. This was particularly important because there was little to no separation in the multiple hats worn by the family owners, four of which were still active in operational leadership roles. It was not clear to other employees as to when a family member was acting in their role as owner, board member or day-to-day supervisor. It was agreed that a management consultant would be required to help develop the People Capabilities prior to investment in processes and technologies.

Concurrent Engineering

Although our primary focus is on the Digital Transformation of the manufacturing enterprise, one of the greatest promises of Industry 4.0 is the seamless, concurrent engineering of products and the enabling lifecycle systems that design, manufacture, test, deploy, sustain and eventually dispose of (e.g. recycle) these products. The capability architecture and methods described herein may be applied to the Digital Transformation of the rest of the enterprise.

Conclusions

The i4score Digital Transformation roadmap model was designed to accelerate value delivery and reduce decision risks by presenting seven key decisions to an organization in a way that triggered discussions that would not otherwise normally be had.

- Jobs-to-Be-Done (improvement priorities)
- Information Value Loop Stages
- Information Value Drivers
- Systems Integration Approach
- System Architecture Style
- Organizational Capabilities
- Strategic Implementation Partners

The impact of gathering input from a broad group within the company brings in diverse perspectives, independent opinions, and decentralized knowledge. This Wisdom-of-the-Crowd [8] approach results in better decisions and higher odds of successful implementation. Of the seven key decisions, getting broad input and alignment on the Organizational Capability gaps is the most crucial.

Future Research

The Industry 4.0/Digital Transformation organizational capability architecture is largely based upon the author's personal experience consulting with small- to medium-sized discreet manufacturing firms in the United States. The organizational capability architecture is currently one component of a larger Industry 4.0 Roadmapping Tool (i4Score.com) that only recently has become available as a free, online tool for companies to access for their own benefit.

Readers of this article and others are encouraged to visit i4Score.com and consider becoming a facilitator for the development of their organization's Industry 4.0 Roadmap. Benchmarking data will be made available to all companies who participate. One of the research objectives of i4Score is to see how broadly the organizational capability model applies across multiple types and sizes of industrial organizations located in different regions and participating in different market segments (e.g., automotive vs pharmaceutical vs food & beverage).

Readers are also encouraged to provide direct feedback to the author on your thoughts and questions regarding the organizational capability model. The author can be reached at sphillips@i4score.com.

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About the Author:

Scott Phillips is the founder of i4Score, which helps manufacturers become more data-driven, efficient and profitable by creating Industry 4.0 Roadmaps. Prior to starting i4Score, Scott held leadership positions with Whirlpool Corporation, Therma-Tru Doors, Burger King Corporation and Comerica Bank. Scott earned a Master of Business Administration from Wayne State University and a Bachelor of Arts in Business from Michigan State University. Scott and his wife currently reside in Ann Arbor, Michigan.

"

A definition of architecture that I find of great practical use is "the conceptual design (noun) of an item, structurally and/or logically.

ROBERT HALLIGAN

Decision Modeling

by James Taylor, Decision Management Solutions

Email: james@decisionmanagementsolutions.com

Introduction

Organizations make many different kinds of decisions. They make strategic, one-off decisions about direction or intent. They make tactical decisions with broad impact about products and about how to run the business. And they make day-to-day operational decisions about specific customers, transactions or interactions. While some decisions are open-ended, with an infinite continuum of possible options, most decision-making is about using the data available at the moment to pick an option from a set of defined (or at least definable) options.

Some of these decisions are made once and only once. But many, especially the more structured ones, must be made over and over with new data each time. Ideally, an organization would always apply the best possible decision-making approach to the data every time. In practice, the decision-making approach probably changes each time. Each of the people making the decision likely has their own way of making the decision. Plus, people struggle to be consistent and use the same decision-making approach reliably. This creates inconsistency or noise in the system and means the decision is not made accurately and consistently each time.

Decision modeling focuses on the repeatable, operational decisions made every day by organizations. Decision modeling creates a visual blueprint of the decision-making approach you're going to use. It shows everyone how the decision should be made. It creates a shared understanding of the best, most legal and most appropriate approach available. Decision modeling also decomposes the decision into its component parts, breaking down a complex decision into a network of simpler decisions, such that the results of simpler decisions are combined to enable the more complex decision to be made. Decision modeling lets you capture how a decision will be made before you make it, so you can get everyone on the same page, decide consistently, ensure best practice, and apply data-driven analytics effectively.

Various approaches to building decision models are available, but the best and most widely used is the Decision Model and Notation standard from the Object Management Group or OMG. The OMG is a standards development organization dedicated to bringing together its international membership of end-users, vendors, government agencies, universities and research institutions to develop and revise technology standards as technologies change throughout the years.

The Decision Model and Notation Standard

About ten years ago, the OMG requested submissions for a standard to address the ad hoc nature of the specification of decision-making logic for process and system designs. The intent was to develop a technology-agnostic and standardized way to model decisions. In particular, the standard was expected to make decision models communicable among people and machines and to support both decision automation (digital decisioning or decision management as it is often called) and decision support scenarios. The standard was to focus primarily on capturing the logic, the business rules, of a decision, but was to be open to other decision-making approaches such as predictive analytics or constraint-based optimization models. Companies including Decision Management Solutions, IBM, Oracle, FICO and Tibco responded with proposals. The first version of the Decision Model and Notation (DMN) standard [1] was published in 2015, since then it has been regularly updated – v 1.4 has just been approved and will soon be published.

The Elements of DMN

DMN has three perspectives that combine to create a complete decision model.

- A decision requirements model defined using a series of decision requirements diagrams, that shows how decisions are decomposed into their component pieces, the data each piece requires and where the knowledge for making a decision comes from.
- A set of decision logic definitions, mostly decision tables, that define how each decision in the decision requirements model can be made.
- A set of business context relationships that tie decisions into organizations, processes and Key Process Indicator (KPI)/measurement frameworks.

A DMN Example

The example below shows these various perspectives.

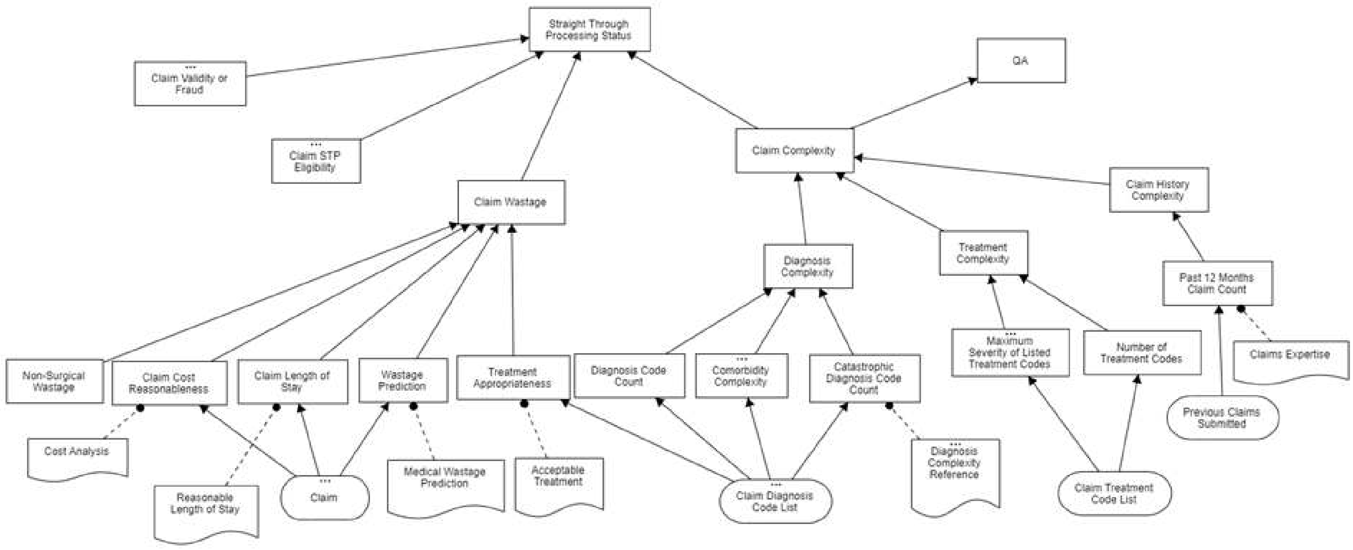

Figure 1: A decision requirements model

Figure 1 shows how an insurance company might decide how to pay a claim while Figures 2a and 2b shows the same decision model using several simpler views. The more complex decision requirements diagram shows all the sub-decisions that make up the wastage and complexity parts of the claims handling decision. The two simpler diagrams are views that show only part of the model – a high level decision summary and the sub-decisions of the decision about claim complexity. Support for views is a key element of DMN, making it usable for even the most complex decision-making problems.

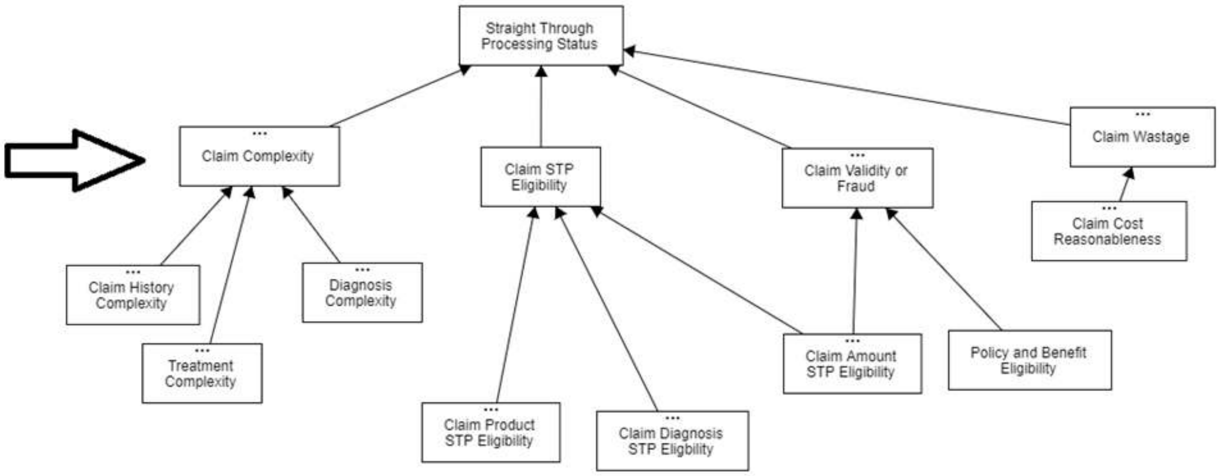

Figure 2a: Summary decisions-only view of the same decision requirements model

Using the diagrams in Figures 2a and 2b, we can see that to decide on the Straight Through Processing Status of a claim, we must decide how complex the claim is (Claim Complexity), if it is eligible for straight through processing (Claim STP Eligibility), if there are fraud or validity concerns (Claim Validity or Fraud) and if there are any concerns about wastage (Claim Wastage). Only after these four sub-decisions have been made can we decide how to process the claim.

Behind the model is a set of definitions of these decisions, specifically the questions that must be answered in each case and the possible answers. For instance, the Straight Through Processing Status decision assigns a status to each claim – Auto Approve, Auto Decline, Review or Investigate. If we know the answers to the four sub-decisions, then we can determine the right option from this set.

The Claim Complexity decision is also shown in the second diagram view – it is the same decision in both diagrams. This view shows how Claim Complexity requires an assessment of Treatment Complexity, Claim History Complexity and Diagnosis Complexity. Each of these decisions is similarly broken down into its component sub-decisions.

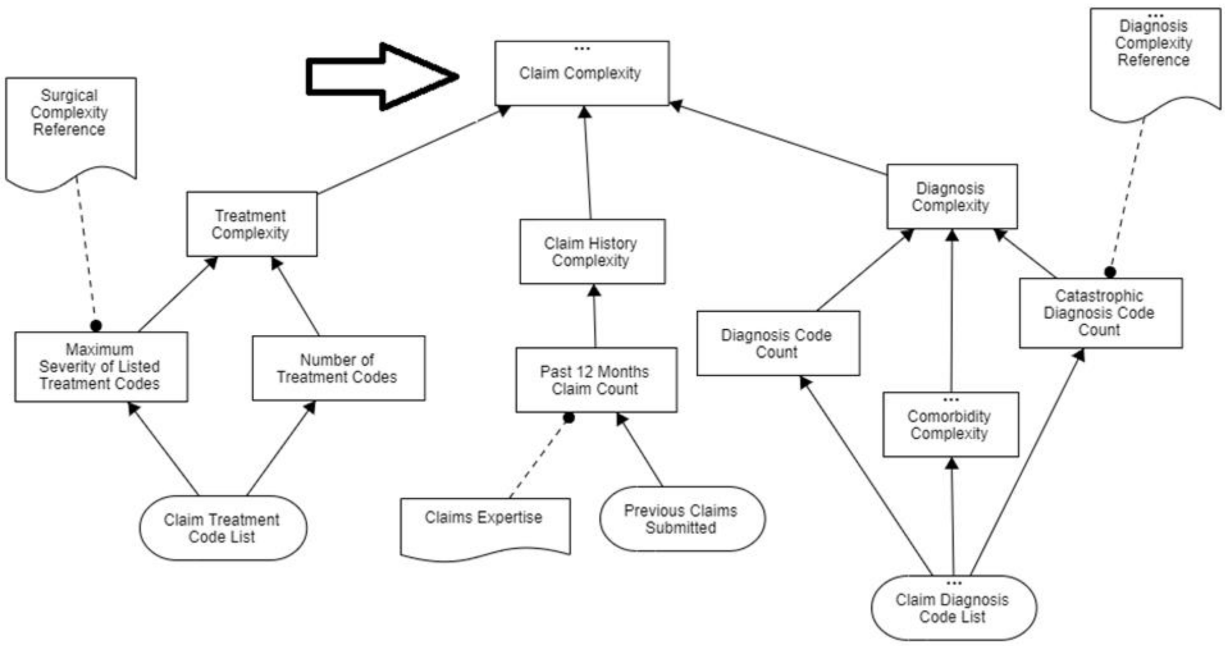

Figure 2b: Sub-decision details of the same decision requirements model

These diagrams also show the Input Data (shown as ovals) such as Previous Claims Submitted and the Claim itself as well as Knowledge Sources that can be referenced to understand how a particular decision should be made such as the Surgical Complexity Reference. Input Data are data structures with individual fields or items and the Knowledge Sources are typically documents or regulations.

Claim Complexity

Unique	Diagnosis Complexity	Claim History Complexity	Treatment Complexity	Claim Complexity	Messages
	Low, Moderate, High	Low, Moderate, High	Low, Moderate, High	Low, Moderate, High	
1	Low	Low	Low	Low	
2	-	-	High	High	
3	-	High	-	High	
4	High	-	-	High	
5	Low, Moderate	Low, Moderate	Moderate	Moderate	
6	Low, Moderate	Moderate	Low, Moderate	Moderate	
7	Moderate	Low, Moderate	Low, Moderate	Moderate	

Figure 3: A decision table

Figure 3 shows a decision table containing the logic for the Claim Complexity decision. Decision tables like this one build on the requirements model to show exactly how the various sub-decisions and data elements combine to select options. Each row can be considered a single rule and the columns are all ANDed together – ORs result in additional rows. So, for instance, if the Diagnosis Complexity is Low and the Claim History Complexity is Low and the Treatment Complexity is Low then the Claim Complexity is also Low.

The columns correspond to the requirements shown on the diagram – in this case each represents a sub-decision though they can also represent pieces of Input Data.

Figure 4 shows how some of the decisions in the model impact various metrics. The decisions in the table are the main sub-decisions and while all of them impact the Straight Through Processing rate, likely a key metric, some have side effects that must be considered. For instance, loosening the fraud checks will increase the rate of straight through processing but only at the expense of increased fraud.

KPI / Decision	Claims STP Rate	Fraud Losses	Customer Appeals
Claim Complexity	X		
Claim STP Eligibility	X		
Claim Validity or Fraud	X	X	X
Claim Wastage	X		X

Figure 4: A decision to KPI/Organization grid

Key Principles of DMN

In an introductory article like this one, only the briefest summary of the approach can be provided; however, additional sources abound. [2], [3], [4], [5], [6] Several key principles underlie the decision modeling approach enabled by DMN.

First and foremost, DMN manages complexity. It allows you to break a decision-making problem down into pieces that are orchestrated into a complete solution. This simplifies the problem, creates a visual blueprint, and allows the logic to be written for each piece, keeping it simpler and easier to manage – thus avoiding many of the pitfalls of more traditional rules-based approaches. For instance, a complex decision about auto-approving auto loans involved more than 100 sub-decisions but no complex rules.

Second, this approach lends itself to business ownership of the model and a business-focused creation process. Technical teams can create a decision model and a decision model can be reverse-engineered from existing logic and built bottom-up, but the top-down decomposition allows for a business-led project. Business experts can describe how they would break down a decision-making problem and this leads naturally to a decision model that matches the way they think. This makes the model a better fit for reality and helps ensures business engagement in the ongoing management of the model. For instance, one insurance claims team uses the decision model as part of weekly updates to their claims handling system.

Thirdly, DMN scales to extremely complex problems. Decision requirements diagrams are views on an underlying model or graph. This allows multiple diagrams to be built for the same problem, showing different perspectives or layers of detail. Even when a decision might involve hundreds of sub-decisions, there is no requirement to show them on a single diagram. Tooling that implements this approach allows teams to easily manage large, complex models while still presenting consumable, easily verifiable views to business experts. For instance, in both the claims and auto loan approval decisions, a dozen or so diagrams were created so that each was focused, clear and usable.

Finally, the approach is remarkably flexible. A focus on automation is not required - decision models are useful even when the decisions are manual. The same notation and approach can be used to document manual decision-making, to design decision support tools and to automate all or part of a decision. This allows decision models to be built as part of determining the appropriate level of automation. The notation also does not require that you write declarative logic for a decision in the model. This is the most common approach, but decisions can be defined as being automated using constraint-based optimization, predictive analytics, or machine learning models also. For instance, a decision to specify a custom manufacturing design involved a model that included manual decisions on the viability of some options, rules-based decisions on where parts could fit, an optimization model to identify a set of plausible layouts, a predictive analytic to predict maintainability of each such layout, and a set of rules to use all this information to pick the best design. All coordinated in a single decision model.

Decisions and Business Processes: BPMN and DMN

Many people first come across DMN because they are familiar with the Business Process Model and Notation or BPMN [7] . The two standards are highly complementary. Experience is that decision models are often used standalone, but they can also be used very effectively alongside BPMN models.

In Figure 5a, for instance, a BPMN process model shows how to determine the next task for an applicant for medical insurance. It determines if the next task is to automatically approve them, automatically reject them or arrange for them to have a medical examination. Despite only simple logic being added to this process model, it is already complex.

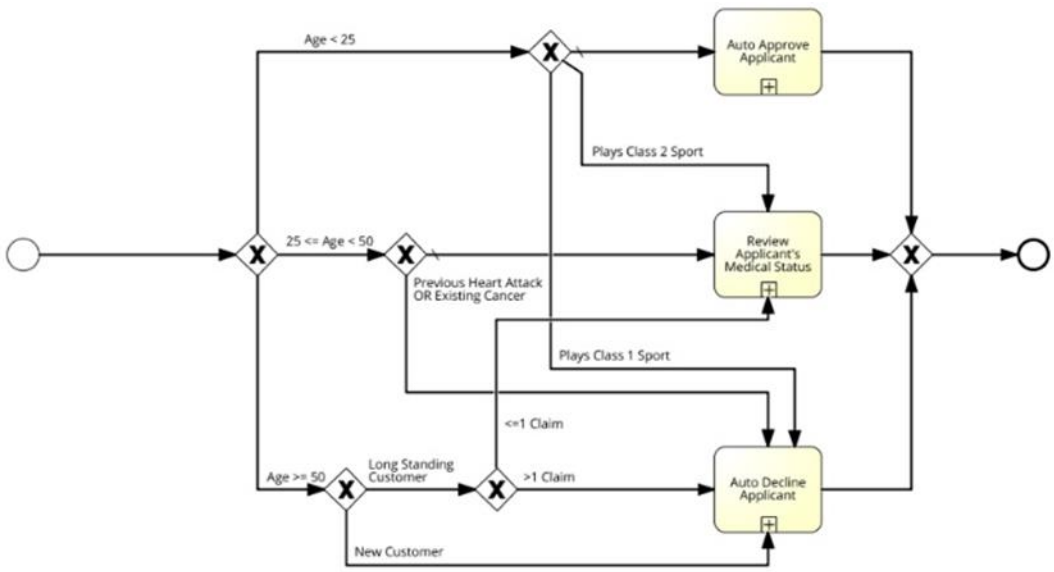

Figure 5a: Process model

When a DMN decision model is added, as shown on in Figure 5b, the process becomes much clearer. A decision must be made as to the riskiness of the applicant and, based on that, the appropriate task can be executed. The logic of the decision is then represented by a decision requirements diagram and a decision table. The set of diagrams contains the same information, but the use of both DMN and BPMN separates concerns and simplifies the problem.

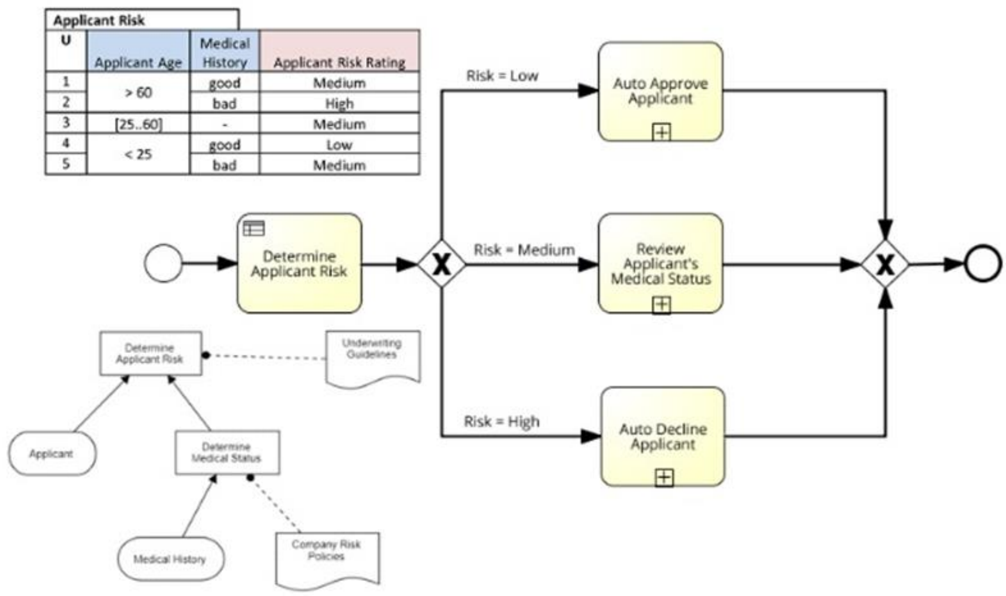

Figure 5b: Process model with a decision model

When both approaches are used at the same time it is important to treat them as independent, complementary models. If compromises are made regarding what goes in the decision model and what goes in the process model, then value will be destroyed not added. BPMN users who add proper DMN models to their approach see three main benefits – their processes are simpler, smarter and more agile.

Simpler: Embedding decision-making in a process makes it complex. Layers of gateways being used to represent logic or complex conditions associated with those gateways makes processes hard to read and overly complex. Removing all this logic from the process and instead representing it as a decision model greatly reduces the complexity of the process. A Business Rules Task can be linked to the Decision being made or, at implementation time, a Decision Service can be defined to show the decision logic being automated and this service can be called from the process.

Smarter: Many processes rely on complex calculations being made as they are executed. It is extremely difficult to show the logic of such calculations in a process model. Defining a decision model for these calculations is a perfect solution. Similarly, it is often difficult to identify how to apply artificial intelligence (AI) and machine learning (ML) to a process to make it smarter. Identifying the decisions in the process, and modeling those decisions, clearly identifies the possible ML and AI pressure points (they will all be decision-making ones) and so makes it possible to effectively apply these powerful technologies.

More Agile: Externalizing decision-making in a decision model makes it much easier to change the behavior of a process. This is partly thanks to the simplification of the process that modeling decisions produces, but mostly it comes from the separation of concerns. Experience shows that decision-making changes much more often than process, as court rulings, policy changes or the behavior of competitors directly impact it. Embedding decision-making in a process requires that the process change each time. Separating it out allows the decision model to be changed while keeping a stable process.

Lessons Learned Applying DMN

The team at Decision Management Solutions has modeled more than 5,000 decisions across more than 70 projects for 40 customers over the years. We have used the resulting decision models to drive automated decisions, train people to make decisions manually, design decision support environments, orchestrate multiple decisioning technologies and document official decision-making approaches. We have learned many lessons but three show up again and again.

The first and most important is to apply Decisions-First Design Thinking. The principles of design thinking – user-centricity, empathy, collaboration, ideation, experimentation and iteration – are a great fit for decision modeling. Applying these principles while building a top-down, business-led decision model results in the highest quality models and the most engagement. Wherever possible, build decision models top-down working directly with the business. Use the model to capture how people really make the decision today, including all the things that make it difficult. And use this model to discuss new ideas, try out new approaches and iterate toward a successful outcome.

Second, recognize that decision-making involves many kinds of technology. While “AI” is all the rage, this is an overused and often vaguely applied term. Making a machine artificially intelligent is almost always about enabling it to make decisions the way that a human would – or better. This might include documenting explicit logic – business rules – to capture how a regulation must be applied, using machine learning or other analytic models to capture what historical data says will work, or using constraint-based optimization to pick between viable options. A decision model provides an ideal framework for mixing and matching these technologies and delivering a successful outcome.

Finally, think always about continuous improvement. Decision-making is not static. Regulations change, competitors adapt, markets move, and people change their minds. Building decision models and implementing decisioning systems based on those models requires that this change be allowed for. Capturing data about how decisions were made and the business outcomes of each decision is critical. A regular update cycle is essential too – outcome data must be reviewed, new and changed policies and regulations assessed and the decision-making improved.

How DMN drives AI Adoption

Given the investments being made in AI today, it's worth considering the role of decision modeling and DMN in realizing the potential of AI-enabled systems and products. After all, study after study shows a high rate of failure in AI projects and many "successful" ones remain in limited or pilot deployment [8], [9], [10]

Broad, deep use of AI to solve real business problems remains the exception not the rule. A better approach is possible.

The broad definition of AI introduced above – any technology that can be used to make a machine decide like a human – is an important first step. Once we recognize that AI is not just deep learning and neural networks our odds of success start to rise. Successful AI efforts combined explicit decision-making logic with analytical techniques based on historical data and mathematical models of reality to make decisions.

To apply these technologies effectively, though, we need to know when to use each of them and how to orchestrate them into a solution. A decision model meets both of these needs. By breaking the problem down into many sub-decisions, it becomes clear which technology will work where: This decision is constrained by regulations, so rules will be required. This one involves a tradeoff between options, so perhaps optimization will work better. A third might need to be based on patterns that have shown up historically.

Because a decision model is a clear, visual blueprint that can be understood by everyone, starting with one means that the discussion is focused on the business problem to be solved by AI not on AI technology. It applies everyone's expertise – business experts, data experts, mathematicians, programmers – maximizing the chance of success. A decision model allows for incremental delivery, perhaps starting with those elements that require the least new technology or that don't require lots of high-quality data. As the solution evolves, new technology and better data can be applied to improve the quality of decisions being made. Value can be created sooner and technology risks can be mitigated.

For many decisions, decision models offer one last advantage: They allow the role of human decision-makers to be clearly articulated. It's often impractical for a human to review an automated decision in the time available, so making the decision a "recommendation" and asking a human to press the button is just pretending to have a human engaged. A decision model allows for those elements of the decision that should be made by a human to be made by a human and then integrated into an overall decision. Sometimes this means the human makes the final call, but more often it means the human provides a critical piece of judgment or expertise that will ensure that the automated decision is the right one.

What's Next

The DMN standard continues to evolve, with the committee making small incremental improvements as more experience is gained with implementations and use cases around the world. More importantly, adoption is growing with more companies standardizing on decision modeling as a key requirements and design approach for their decision-making systems. This adoption is being supported by new organizations such as DecisionAutomation.Org, dedicated to helping companies adopt and succeed with decision modeling. Both alongside process models and independently, decision models are showing their value in traditional rules-based systems and more complex machine learning and AI-based environments.

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About the Author

James Taylor is the CEO of Decision Management Solutions and a leading expert in digital decisioning and using advanced analytics, business rules and AI to improve business results. He provides strategic consulting to companies in the Fortune 100 and top 100 companies globally, working with clients in all sectors to adopt decision-making technology.

James is a faculty member of the International Institute for Analytics (IIA), an IBM Champion and is the author of numerous books including "Digital Decisioning: Using Decision Management to Deliver Business Impact from AI" (MK Press, 2019) and "Real-World Decision Modeling with DMN" (2016, Meghan-Kiffer) with Jan Purchase. He writes a regular blog at JT on EDM, contributes to standards and delivers webinars, workshops and training. He is a regular keynote speaker at conferences around the world.

James was previously a Vice President at FICO where he developed and refined the concept of Decision Management. The best-known proponent of the approach, James helped create the emerging Decision Management market and is a passionate advocate of decision management. He understands how companies buy and use these technologies, and he has helped companies successfully adopt these technologies and apply them in the context of Business Process Management and Business Intelligence initiatives.

SYSTEMS ENGINEERING RESOURCES

Useful artifacts to improve your SE effectiveness

Free-to-Read INCOSE Papers Available through Wiley

Wiley Online Library

The Wiley online library, on behalf of INCOSE, has "unlocked" three sets of "Free to Read" papers from INCOSE journals. The first set of papers titled, "Featured Papers of 2020" include a diverse range of topics:

- Business process improvement using Object-Process Methodology
- A stakeholder framework for evaluating the -ilities of autonomous behaviors in complex adaptive systems
- Exploring and managing the complexity of large infrastructure projects with network theory and model-based systems engineering - The example of radioactive waste disposal.
- Operationalizing digital twins through model-based systems engineering methods

The second set of papers, Model-Based Systems Engineering and Design Approaches, includes the latter two papers, plus four additional topics:

- Unified design approach for systems engineering by integrating model-based systems design with axiomatic design
- Model-based design of project systems, modes, and states
- Toward a better integration of requirements and model-based specifications
- Synergizing model-based systems engineering, modularity, and software container concepts to manage obsolescence

The most recent set of papers, Systems Modeling Language (SysML) in Model-Based Systems Engineering, published on 6 January (and available until 15 April 2022) adds:

- Employing SysML to model and explore levels-of-service: The case of passenger comfort in railway transportation systems
- Verifying SysML activity diagrams using formal transformation to Petri nets
- Systems modeling language extension to support modeling of human-agent teams
- Model-driven architecture based security analysis
- Comparative analysis of a model-based systems engineering approach to a traditional systems engineering approach for architecting a robotic space system through knowledge categorization

INCOSE members in good standing may access all Systems Engineering Journal content without time-out concerns through their INCOSE Connect login.

All other SyEN readers are encouraged to check periodically for new releases of free-to-read papers from the Virtual Issues section of the Wiley Online Library. Please note that all such issues have an expiration date. Don't delay.

Infrastructure Architecture Framework (IAF)

Infrastructure Architecture Framework

A multi-sector approach to enterprise systems engineering and management

November 2021

In November, 2021, a trans-disciplinary team led by the New York Academy of Sciences, funded by the United Engineering Foundation, with support from Mott MacDonald, ASCE, ASME, AIChE, IEEE, and INCOSE, released a 68-page report, titled Infrastructure Architecture Framework: A multi-sector approach to enterprise systems engineering and management.

The purpose of the IAF is to address the need to align different standards for managing physical civil infrastructure in a holistic, integrative manner with an overall systems view. The team sought to demonstrate the feasibility of establishing a common specification for an architectural framework that could support the transformation of civil infrastructure as complex socioeconomic systems. The project included the establishment of a functioning trans-disciplinary engineering partnership and the delivery of draft framework that will facilitate communication between management, operational, engineering, and information systems.

The project focused on the modeling and integration of four domains:

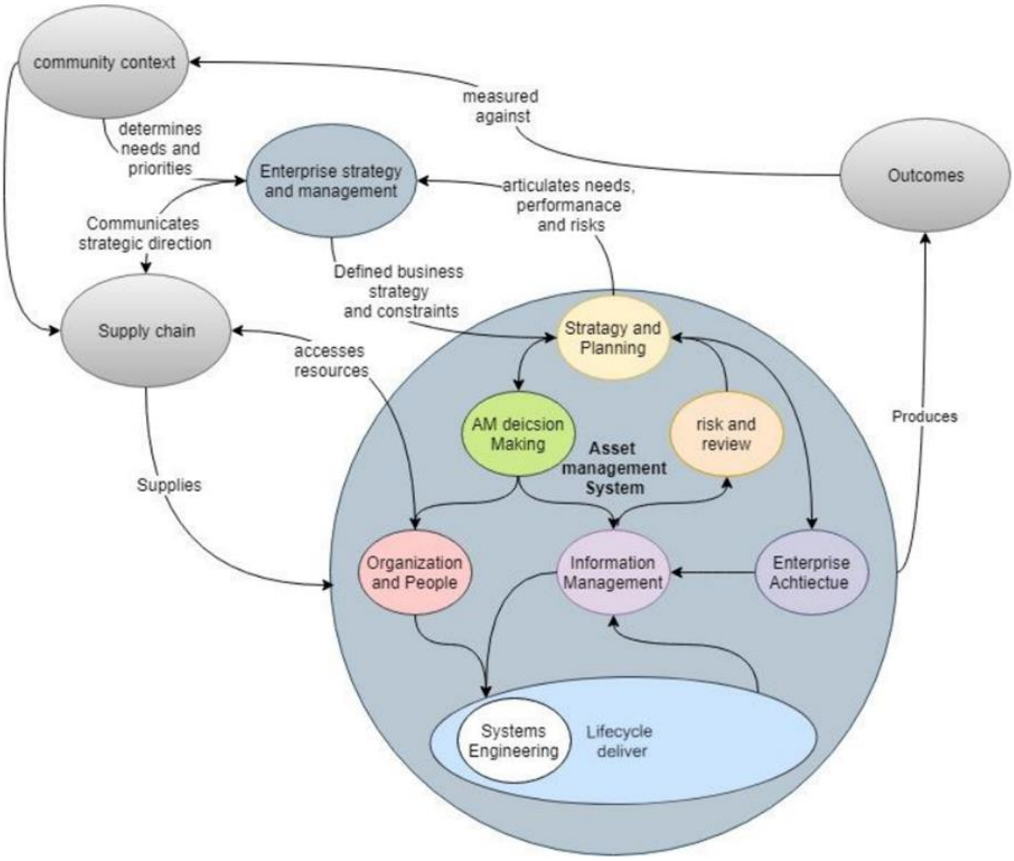
- Asset management
- Systems engineering
- Enterprise architecture
- Information management

The project sought to answer four key questions:

- What are the business models, capabilities, processes, and functions necessary for infrastructure systems lifecycle management?
- What are the data and information management models, capabilities, processes, and functions necessary for infrastructure systems lifecycle management?
- How should the integration of management, information, and engineering systems be addressed within the Infrastructure Architecture Framework?
- What are the models, capabilities, processes, and functions necessary for the management of change (MoC) of infrastructure systems?

The System of Interest (SOI) addressed by the IAF includes the public and private infrastructure enterprises provisioning the energy, transportation, clean water, and waste management services that sustain the social and economic activities of a city, using the New York metropolitan area as the demonstration example.

Beginning with a May, 2021 workshop, facilitators used the SystemiTool, developed by the Systems Engineering Research Center (SERC) and Stevens Institute of Technology, to drill into the business models, capabilities, and functions necessary for infrastructure lifecycle management and examined the data and information management models and systems engineering techniques necessary for the design and management of cyber-physical infrastructure system. These integrated and visual system models, known as Systemigrams, are featured through the report.



Simplified IAF Systemigram

The report ends with consideration on how to take the IAF from theory into practice and identifies areas for future research, including Sustainability, Incident Management, Geographic Information System (GIS), Human Dimension, Management of Change, Risk Management, Legal and Procurement Framework and Maturity Models.

Download the report.

Complexity Primer for Systems Engineers

INCOSE has published an updated version of the Complexity Primer for Systems Engineers. This 20-page whitepaper is a product of the INCOSE Complex Systems Working Group, with the support of numerous additional contributors.

The Primer is available through INCOSE Connect. It is free for INCOSE members.

Topics include:

- What is complexity? (Characteristics of complexity, Identifying the right level of complexity)
- Solutions for complexity (Complexity thinking; guiding principles, Specific methods)

Of particular note are the fifteen guiding principles that represent a shift in thinking that is needed for systems engineering practitioners to successfully engage with ever-increasing complexity in both problem and solution domains.

NIST AI Risk Management Framework Concept Paper

The U.S. National Institute of Standards and Technology (NIST) has published an 8-page concept paper summarizing its evolving Artificial Intelligence (AI) Risk Management Framework.

The concept paper incorporates input from the Notice of Request for Information (RFI) released by NIST on 29 July and discussions during the workshop, "Kicking off NIST AI Risk Management Framework," held 19-21 October.

NIST Is seeking feedback as inputs prior to issuing an initial draft of the framework for public comment in early 2022. Specifically, NIST requests input on the following questions:

- Is the approach described in this concept paper generally on the right track for the eventual AI RMF?
- Are the scope and audience (users) of the AI RMF described appropriately?
- Are AI risks framed appropriately?
- Will the structure – consisting of Core (with functions, categories, and subcategories), Profiles, and Tiers – enable users to appropriately manage AI risks?
- Will the proposed functions (Map, Measure, Manage, Govern) enable users to appropriately manage AI risks?
- What, if anything, is missing?

Download the AI Risk Management Framework Concept Paper here.

PDMA Classic Article on Steve Jobs and Innovation

The Product Development Management Association (PDMA) maintains a Knowledge Hub (kHUB) that contains a rich library of resources to assist the product development and innovation community. PDMA recently highlighted one of their most read articles: Steve Jobs: A Product Developer's Perspective.

First published in 2012, the article evaluates Job's "Think different" legacy using Will Strobel's 2007 definition of innovation:

"Innovation is the process of successfully identifying, developing and implementing new ideas which create new value".

Addressing the reproducibility of Job's success in other individuals and organizations, the article goes on to compare Job's approach to innovation against seven skills that drive innovation success, including:

- Connecting the unconnected;
- Respectfully challenging the status quo;
- Flipping perspective;
- Embracing constraints;
- Studying customers like a scientist;
- Experimenting; and
- Networking.

Read the full article here.

SYSTEMS ENGINEERING IN SOCIETY

Expanding applications of SE across the globe

INCOSE 2021 Annual Impact Statement

INCOSE has published its Annual Impact Statement for 2021. The 6-page Impact Statement highlights the wide range of INCOSE programs and outreach initiatives that seek to realize "A better world through a systems approach". Easy to reach and rich in graphics, the Impact Statement summarizes 2021 accomplishments and how these accomplishments deliver value to INCOSE members and the world at large.

Download the Impact Statement

Teaching Positions at Stevens Institute of Technology

Stevens Institute of Technology (Hoboken, New Jersey, USA) is seeking applicants for three open teaching positions within the School of Systems and Enterprises (SSE). The two Teaching-track Faculty positions and one Lecturer position require a doctoral degree in a related science or engineering discipline, plus relevant industry experience.

Learn more through the INCOSE career website.

“

Architecture is design but not all design is architecture.

GRADY BOOCH

FINAL THOUGHTS BY SYENNA

Dear Reader,

Whilst on holiday I read the autobiography of Captain Sir Tom Moore. He became famous worldwide during March/April 2020 for completing 100 laps of his garden (with a walking aid) in time for his 100th birthday. He set out to raise £1000 for a good cause but went on to raise £30M in the first 26 days. He also achieved two entries in the Guinness Book of Records: one for the highest amount raised from an individual charity walk, and the other for being the oldest person to achieve a No. 1 track in the UK Charts. He received over 150,000 cards on his 100th birthday, including one from Queen Elizabeth II.

I can recommend the book – it took me just 2 days to read about 100 years well-lived – but for now I'd like to share some thoughts around its title ("Tomorrow Will Be a Good Day"). When you read further, it becomes clear that the fuller meaning is "Tomorrow will be a better day".

Part of the attraction is the inherent riddle in the title. Do you think Captain Tom means:

a) That he reviewed 100 years' worth of personal diaries to find that each of his c. 36,500 days was better than the previous one, and that, by induction, it is reasonable to expect tomorrow to be better than today?

b) That continuous improvement is inherent in mother nature regardless of the merely human decisions that we individually make?

c) That we don't know if we will be here tomorrow, so surviving to a new day is a good thing?

d) That there is great power in having a positive mindset?

e) Something else?

Option c) is explicitly confirmed at the end of the book. I would now like to develop option d), which is strongly inferred throughout.

The question arises: what is the reference value model for determining if an outcome is "good" or "better"? Whether something is "good" depends on who you talk to, when you talk to them, and how you talk to them.

I'm sure that for Captain Tom, "good" meant both that he would be content in life, and that he would have a positive effect on those around him.

As human beings, we aren't just units meandering inconsequentially through the Universe; the interaction with our environment is bidirectional. Does the Moon dance around the Earth? Does the Earth dance around the Moon? Answer: no and no; they perform a pas-de-deux around a common point, and the same is true in our human relationships. The words of Captain Tom's favourite song ("You'll never walk alone") can be seen in a new light.

Talk to any doctor or nurse and they will generally confirm that a positive mindset helps people to recover from illness and accidents. In Engineering, our decisions are supposed to be driven by a balance between seeking opportunity and mitigating against risks. Would you rather work in a culture that promotes opportunity or one that pours excessive resource into risk management? Is your lessons learnt database clogged up with things that went wrong, or does it motivate you to build on past successes?

Using data-driven research, Marcus Buckingham shows that people and organizations that build on their strengths outperform those that focus on weaknesses. As he says, the opposite of "bad" is "not bad", which just isn't the same thing as "good".

People who choose to be content have more headspace to empathize and collaborate with others, making them feel more positive. John Maxwell argues that "we attract who we are", so if we cultivate a positive mindset, we will tend to be surrounded by like-minded people.

Captain Tom inspired millions by what he did, how he did it, what he said, and how he said it. He never really understood what happened, saying that "I was knighted for walking round my garden".

Sadly he is no longer with us, so I can't ask his permission to tailor his catchphrase. Nevertheless, dear Reader, in the spirit of Captain Tom, I would like to tell you that 2022 will be a better year.