34th Annual INCOSE international symposium

hybrid event

Dublin, Ireland
July 2 - 6, 2024

Sponsored by the INCOSE Decision Analysis Working Group

Enhancing Data-Driven Decision Making through MBSE

Presented by: Greg Parnell (University of Arkansas)

Co-authors: C. Robert Kenley (Purdue University) - Devon Clark (Deloitte Consulting) - Frank Salvatore (SAIC) - Jared Smith (Deloitte Consulting)

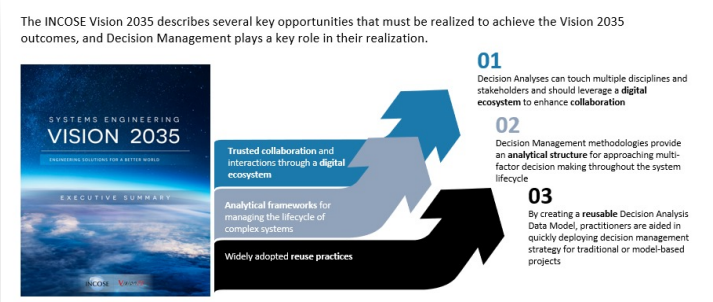
Thursday 4 July
10:00 IST

Convention Center Dublin
Dublin, Ireland

Decision Analysis Data Model (DADM) - BLUF

The Decision Analysis Working Group (DAWG) is developing a Decision Analysis Data Model (DADM) to help realize INCOSE Vision 2035 objectives for analytical frameworks, data-centricity, model re-use by doing the following:

1. Develop a reusable Decision Analysis Data Model to support SE Vision 2035
2. Integrate Decision Management Life Cycle Process in MBSE
3. Enhance Data Driven Decision Making with Models



The DADM is an INCOSE product that will be **available on SE Lab** for INCOSE members to use

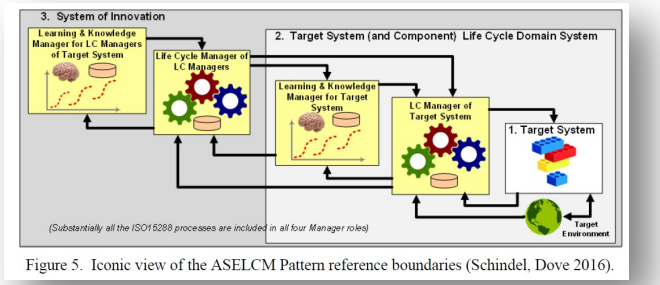
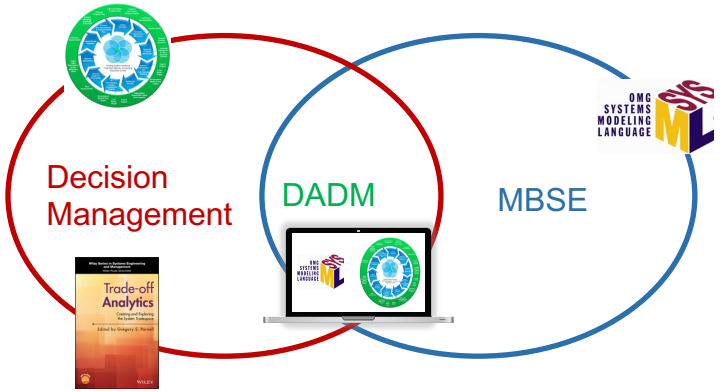


Figure 5. Iconic view of the ASELCM Pattern reference boundaries (Schindel, Dove 2016).

The DADM is a data model validated against a **Decision Analysis Process Model** flexible to multiple domains and lifecycle stages



The DADM enhances pre-existing SE literature by **incorporating system modeling and data architecture practices** into decision analysis.

The Decision Analysis Working Group (DAWG)

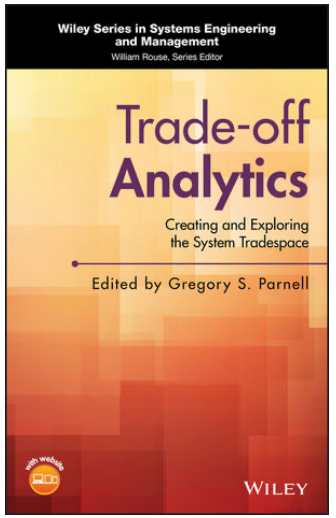
- **Established:** 2012 **Members: ~** 164
- **Leadership Team:**

Frank Salvatore, SAIC	Chair	frank.salvatore@saic.com
Dr. Greg Parnell, University of Arkansas	Co-Chair	gparnell@uark.edu
Jared Smith, Deloitte	Co-Chair	jarsmith@deloitte.com
Dr. Bob Kenley , Purdue University		kenley@purdue.edu
Devon Clark , Deloitte		devclark@deloitte.com
Dr. Eric Specking, University of Arkansas		especki@uark.edu

- **Purpose:** The purpose of the Decision Analysis Working Group is to advance the state of practice, education and theory of Decision Analysis and its relationship to other systems engineering disciplines.
- **Outcomes:**
  - Updated INCOSE Decision Management Section of SE Handbook, and SeBoK
  - Created "Trade-off Analytics: Creating and Exploring the System Tradespace"
  - Delivered tutorial on Decision Analysis and Trade Studies at previous IS
  - Working on Decision Analysis Data Model

Editor/authors funds from Wiley go to INCOSE Foundation

Parnell, G. S., Editor, Trade-off Analytics: Creating and Evaluating the Tradespace, Wiley Series in Systems Engineering and Management, Wiley & Sons, 2017



Community

DAWG

DADM Team

2-6 July 2024

Devon Clark
Specialist Leader
Deloitte Consulting LLP

Dr. C. Robert Kenley, ESEP, FINCOSE
Chair INCOSE Fellows
Professor of Practice
Purdue University

Jeremy Doerr, CSEP and OCSMP-MBF
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Research Engineer
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Drake Nwobodo,TOGAF-EA
Senior Consultant
Deloitte Consulting LLP

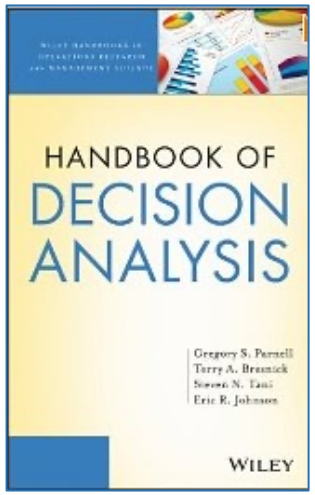
Jared Smith
Manager
Deloitte Consulting LLP

Dr. Gregory S. Parnell, CSEP, FINCOSE
Professor of Practice
University of Arkansas

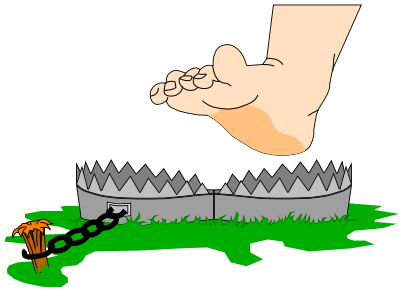
Frank Salvatore, ESEP, OCSMP
Chair, Decision Analysis WG
Senior Systems Engineer, Technical Fellow
SAIC

Decision Analysis

- **Decision:** An irrevocable allocation of resources.
- **Decision Analysis:** Decision analysis is a philosophy and a social-technical process to *create value for decision makers and stakeholders* facing difficult decisions involving multiple stakeholders, multiple (possibly conflicting) objectives, complex alternatives, important uncertainties, and significant consequences
  - **Foundation:** Decision analysis is founded on an axiomatic decision theory and uses insights from the behavioral study of decision making.
  - **Purpose:** Provide insight to decision-makers faced with hard problems.



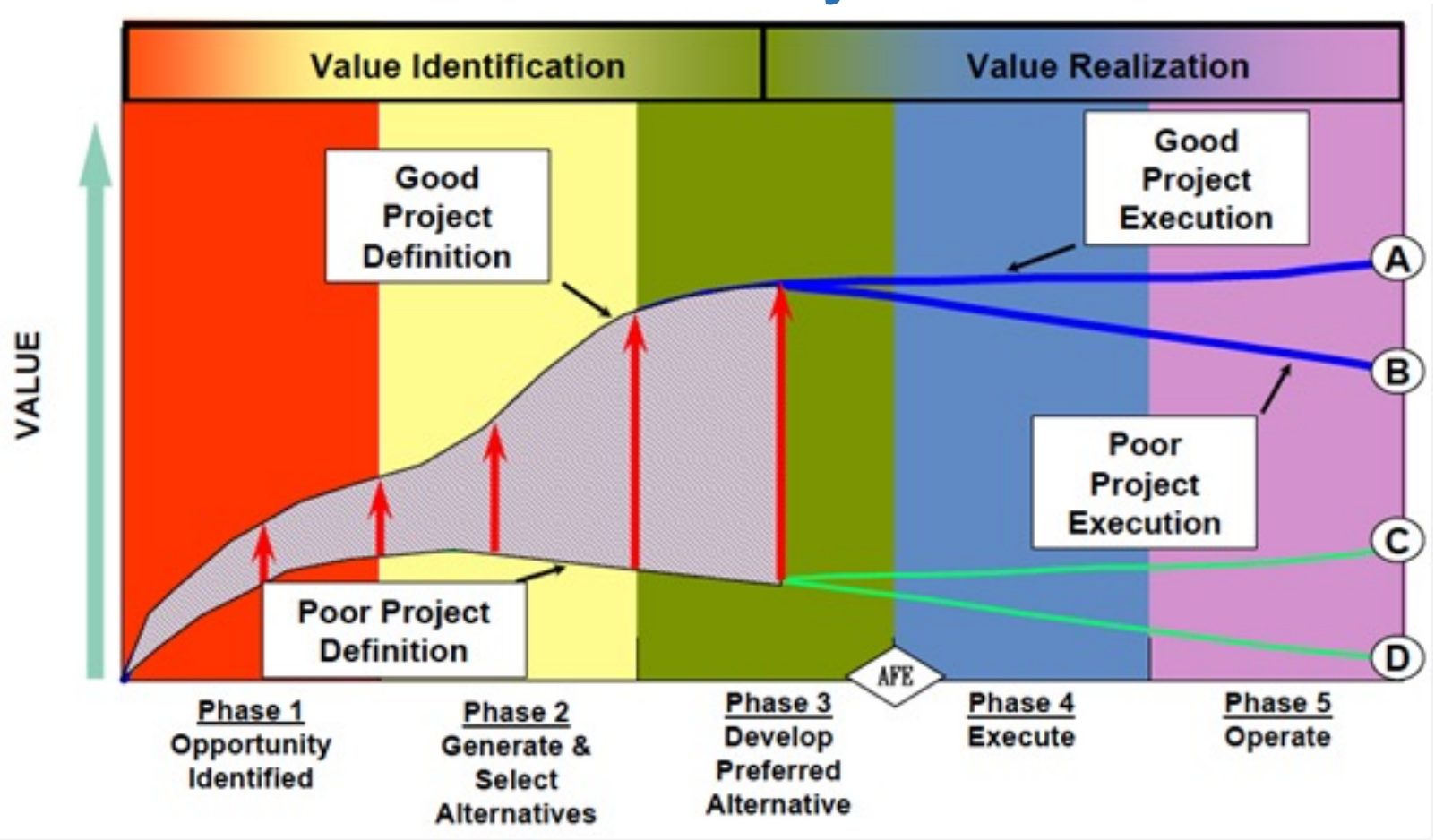
Parnell, G., Bresnick, T., Tani, S., & Johnson, E., *Handbook of Decision Analysis*, Wiley & Sons, 2013



Good SE requires good decisions.

Vision for Systems Engineering and Project Management

Why



What

- Create a reusable model to develop an **integrated*** digital system model to inform decision-making in Phase 1 thru Phase 5 of the engineered system.
- Use the initial integrated model to support Phase 1 system analysis/ trade-off analysis and to **continue to improve the model** (with new designs, better data, models, simulations, test data, and operational data).
- **Every** time a requirement changes, a design changes, or new data is obtained, the systems analysis will be **automatically** updated to support timely decision-making.

Lavingia, N. J. (n.d.). *Business Success Through Excellence in Project Management.* Retrieved December 28, 2014, from Critical Facilities Roundtable: http://www.cfroundtable.org/ldc/040706/excellence.pdf

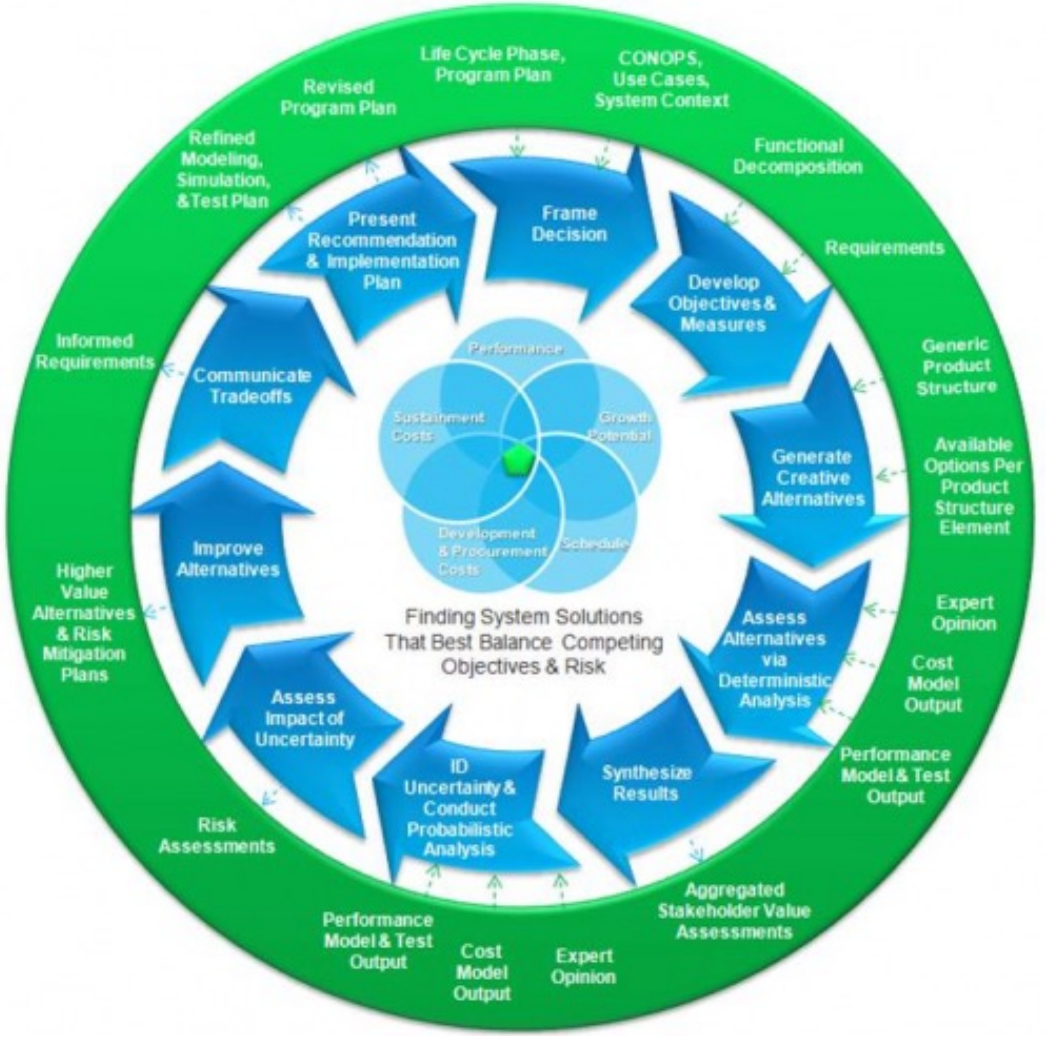
Parnell, G. S., Shallcross, N. J., Specking, E., Pohl, E., and Phillips, M., "Role of Decision Analysis in MBSE", Handbook of Model-Based Systems Engineering, Springer, Madni, A. and Augustine, N. Editors, 2023

*Integrated=system design drives the cost, schedule, performance, and value models.

Decision Management – Process (Conceptual)

The purpose of the decision management process is "…to provide a structured, analytical framework for objectively identifying, characterizing and evaluating a set of alternatives for a decision at any point in the life cycle and select the most beneficial course of action."(*ISO/IEC/IEEE 15288*)

DADM uses the Decision Management Process in the SEBoK. This process was developed to align with ISO/IEC/IEEE 15288 and the INCOSE SE Handbook)



https://sebokwiki.org/wiki/Decision_Management

Integrate Decision Management Life Cycle Process in MBSE

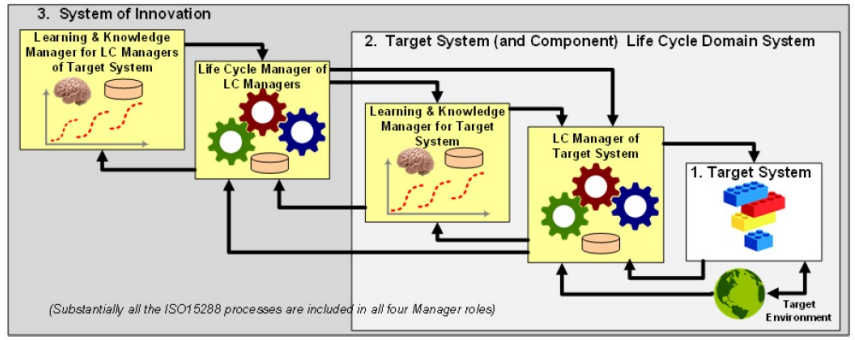
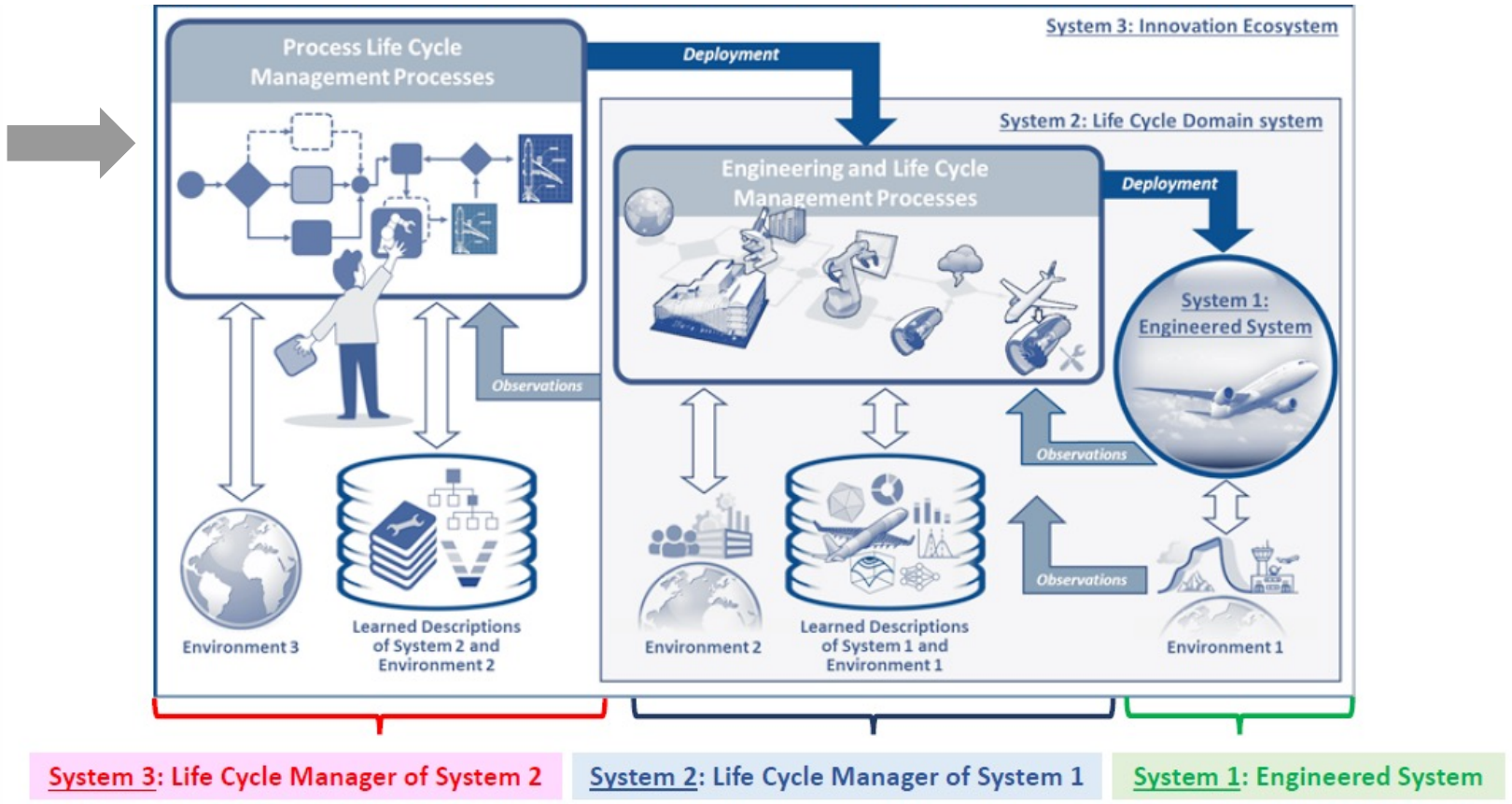


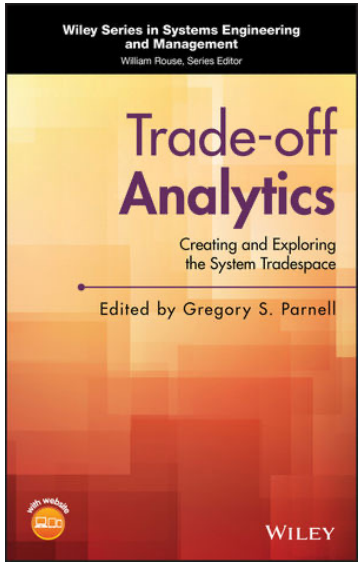
Figure 5. Iconic view of the ASELCM Pattern reference boundaries (Schindel, Dove 2016).

DADM will be INCOSE-provided MBSE software available for System 2 Decision Management process owners to use for Decisions Management for their System 1 Engineered System in different life cycle stages.



Schindel, W., R. Dove. 2016. Introduction to the Agile Systems Engineering Life Cycle MBSE Pattern. Proceedings International Symposium. International Council on Systems Engineering. Edinburgh, Scotland, 18-21 July.

Decision Management in the System Life Cycle



Parnell, G. S., Editor, Trade-off Analytics: Creating and Evaluating the Tradespace, Wiley Series in Systems Engineering and Management, Wiley & Sons, 2017

Foundations

1. Introduction to Trade-off Analysis
2. Using Decision Analysis to Identify Value and Risk
3. Quantifying Uncertainty
4. Analyzing Resources

Process, Principles and Techniques

5. Understanding Decision Management
6. Identifying Opportunities
7. Identifying Objectives and Value Measures
8. Generating and Evaluating Alternatives
9. Integrating Value and Risk Trade-off Analyses

Illustrative Life Cycle Issues and Examples

10. Exploring Concept Trade-offs
11. Architecture Evaluation
12. Performing Design Trade-offs
13. Performing Sustainment Trade-offs
14. Performing Programmatic Trade-offs
15. Summary and Future Opportunities

The foundations, the process, the principles and the data types are the same. However, the decisions, data quality, methods, and models change in each life cycle stage.

The Road to Integrated Decision Analysis

CURRENT STATE

DEVELOPING ADOPTION FOR MBSE AND DE
Many initiatives exist in government and industry to accelerate adoption of MBSE and DE; however many engineering organizations remain manual and document-based

MATURITY OF DECISION MANAGEMENT AND ANALYSIS
Many quality trade-off studies \make good use of data; however, decision processes are not captured and must be redefined with each “new” decision.

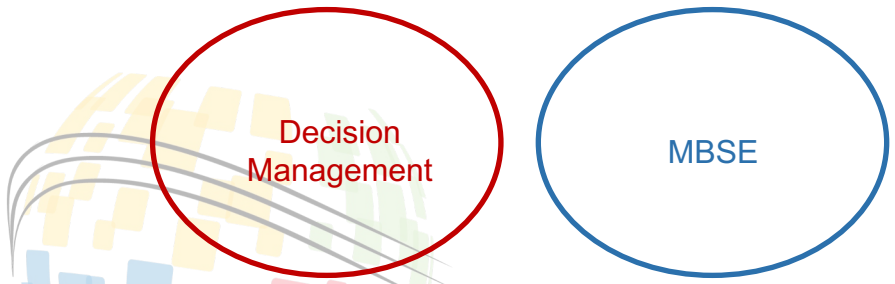
DISCONNECTED DATA AND MODELS
MBSE models are largely isolated to system models and not integrated. Decision analyses are often disconnected from technical processes and data.

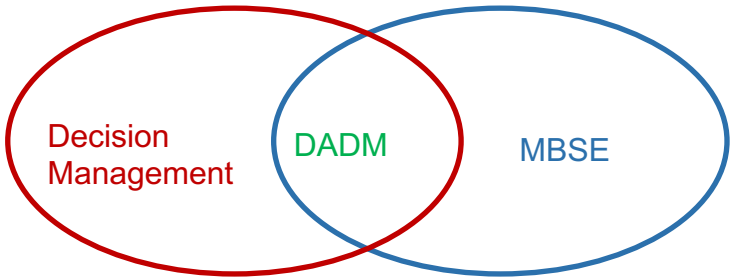
NEW WORLD

“BORN DIGITAL” ENGINEERS
System Engineers work predominantly in models and are tightly integrated with data and software activities. Systems Engineers actively exchange and integrate models (including process models)

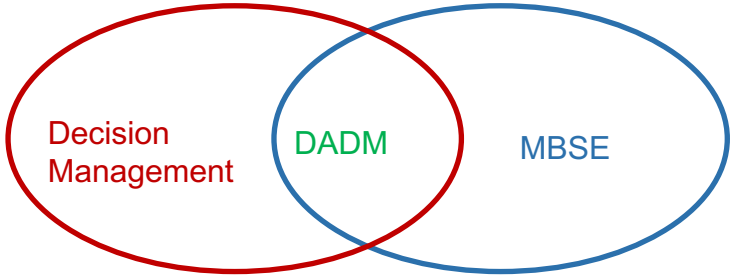
ARTIFICIAL INTELLIGENCE ACCELERATES DECISION MAKING
Advanced analytics, machine learning, and AI solutions increase repeatability, scalability and quality of decision processes. Data is required for all critical decisions.

SCALABILITY THROUGH COMMON DATA MODELS
Open systems are software-enabled and aligned to common data models. Decision Analysis systems and processes are aligned to a common **Decision Analysis Data Model**





Why is a DADM important?



Challenge	Solution	Value
Identify the use case	Understand Schindel's patterns research: System 3 is innovation ecosystem System 2 is life cycle management processes System 1 is the system of interest	DADM will be INCOSE provided MBSE software available for System 2 Decision Management process owners to use for Decision Management of System 1 Engineered Systems.
Lack of common decision analysis experience and vocabulary	Use ISO 15288, SE Handbook (Decision Management and Systems Analysis), SEBoK (Decision Management) and Trade-Off Analytics Textbook as the foundation.	Developed, documented, and used decision analysis and MBSE standard terms.
Lack of common MBSE experience and vocabulary.	Used Cameo based on recommendation of the MBSE experienced team members	Developed an integrated process and data model using a common vocabulary.
Converting conceptual to logical models	Convert the SEBoK Decision Management conceptual cycle model to a logical model. Use life cycle independent terms.	Developed implementable decision management processes not well documented in the SE literature.
Make results available to INCOSE members	Develop DADM for use in INCOSE SE Lab https://www.incose.org/learn/se-laboratory	Accessible in INCOSE SE Lab and at the INCOSE store.

Value was provided to newer members and experts to better understand and develop new insights. Result is a better integrated understanding. Will drive change.

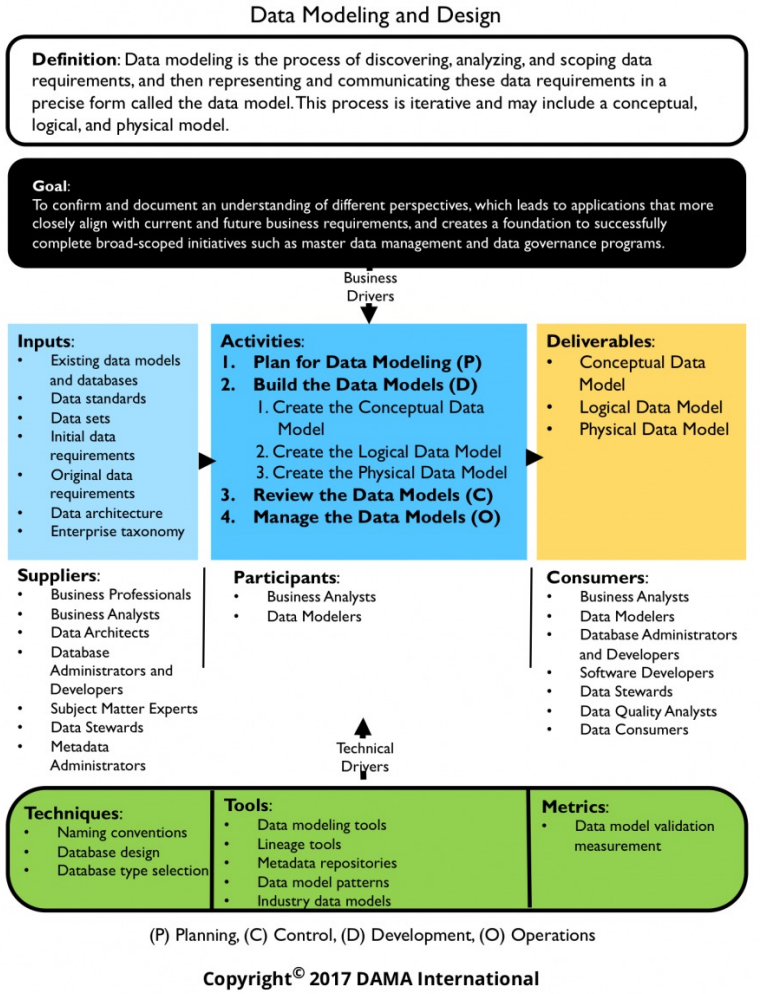
Information and Data Centricity

Data Models are intended to drive consistency and interoperability across disparate developers and teams by aligning data definitions to the information and concepts necessary to support the organization's mission and operations. A good reference architecture should be…

- **CONCEPTUAL DATA MODEL -** A conceptual data model is a high-level representation of the most critical concepts that apply to a given problem. A Conceptual Data Model is…
  - Simple
  - Strategic
  - Foundation for Design

- **LOGICAL DATA MODEL -** A logical data model elaborates on the conceptual data model to identify information needs without being tied to any specific database or technology. The logical data model identifies all entities, relationships, key attributes, and non-key attributes that are necessary for development. A Logical Data Model is…
  - Detailed
  - Technology-Agnostic
  - Normalized
  - Foundation for Integration and Development

- **PHYSICAL DATA MODEL**
- The physical data model is a complete representation of the data structure, business rules, and specific database for an information system. The physical data model includes all of the management system (DBMS) parameters and relationships necessary to create a database.
  - Structured
  - Technology-Specific
  - Optimized
  - Foundation for Implementation



The DADM will include Conceptual and Logical Data Models, and (some) Physical Data Model examples

What Makes a Good Data Model for Decision Analysis

Data Models are intended to drive consistency and interoperability across disparate developers and teams by aligning data definitions to the information and concepts necessary to support the organization's mission and operations. A good reference architecture should be…

Information and Data Centric

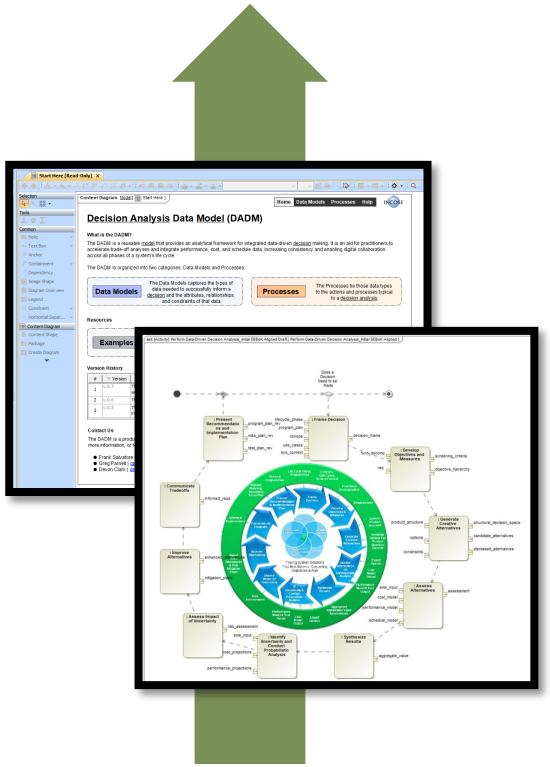
- Current state processes **map inputs and outputs** to complete conceptual information model
- Logical processes are nested in conceptual model to **transform conceptual information model into logical data model**
- **Physical metamodel and metadata** is defined for aligning systems, software, and data analysis (e.g., AI) solutions.

Flexible to Domain and Lifecycle Stages

- Capture processes and patterns in **domain-agnostic analysis pattern**
- *Note, to avoid "boiling the ocean", the DAWG started at the Engineered System level while including engineering management (i.e., "programmatic") decisions*
- Focus on providing **useful information** for a junior or mid-tier engineer in **any industry or government sector**

Validated Against Decision Analysis Best Practices

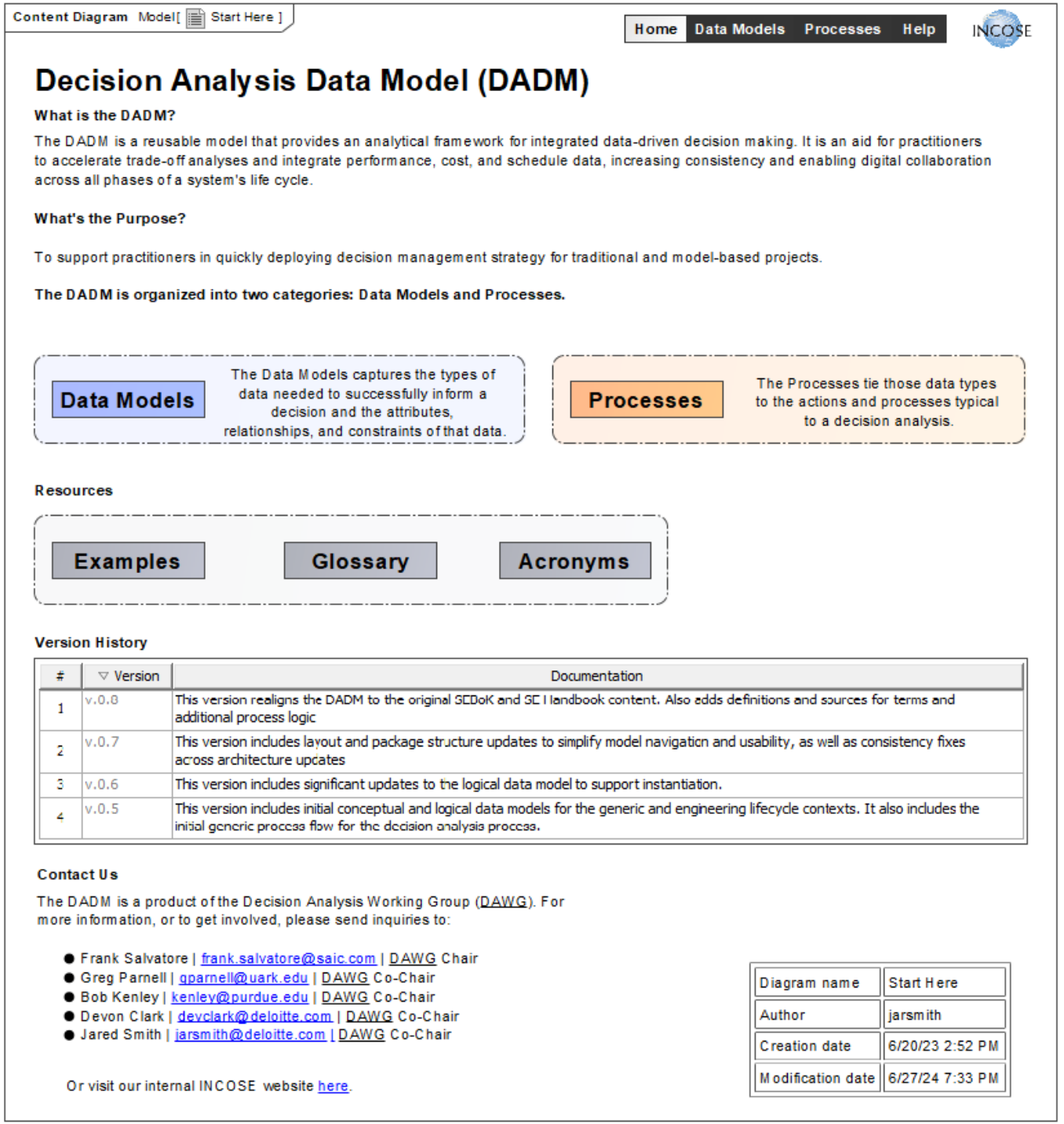
- Starts with **industry standards and literature**, such as the SEBoK and "Trade-Off Analytics" handbook, for alignment to established best practice
- Current state processes are modeled to **identify critical concepts and associated information exchanges** for data-driven decision analysis



Increased Decision Analysis Maturity and Consistency

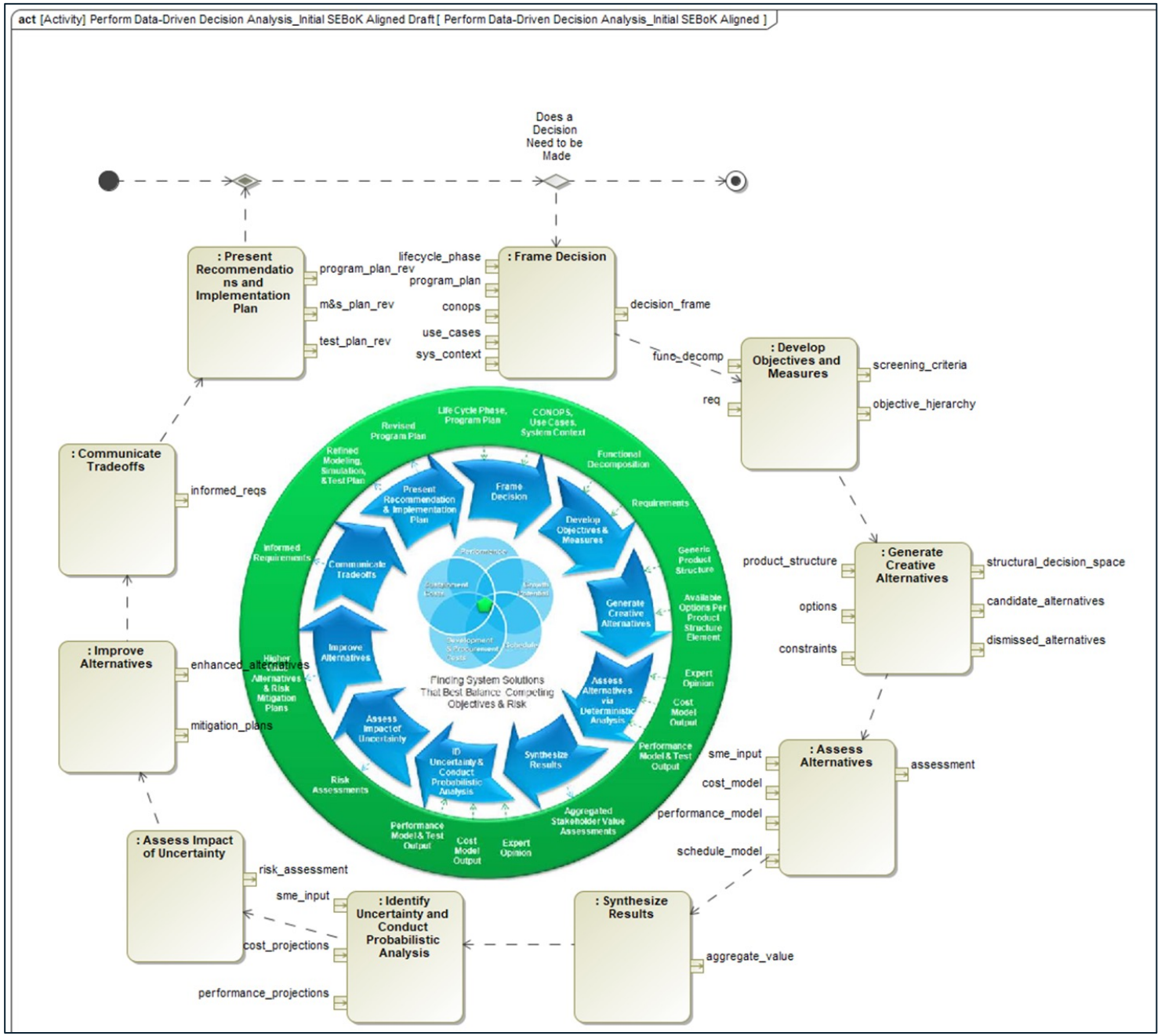
Content Diagram

DADM Demo starts here



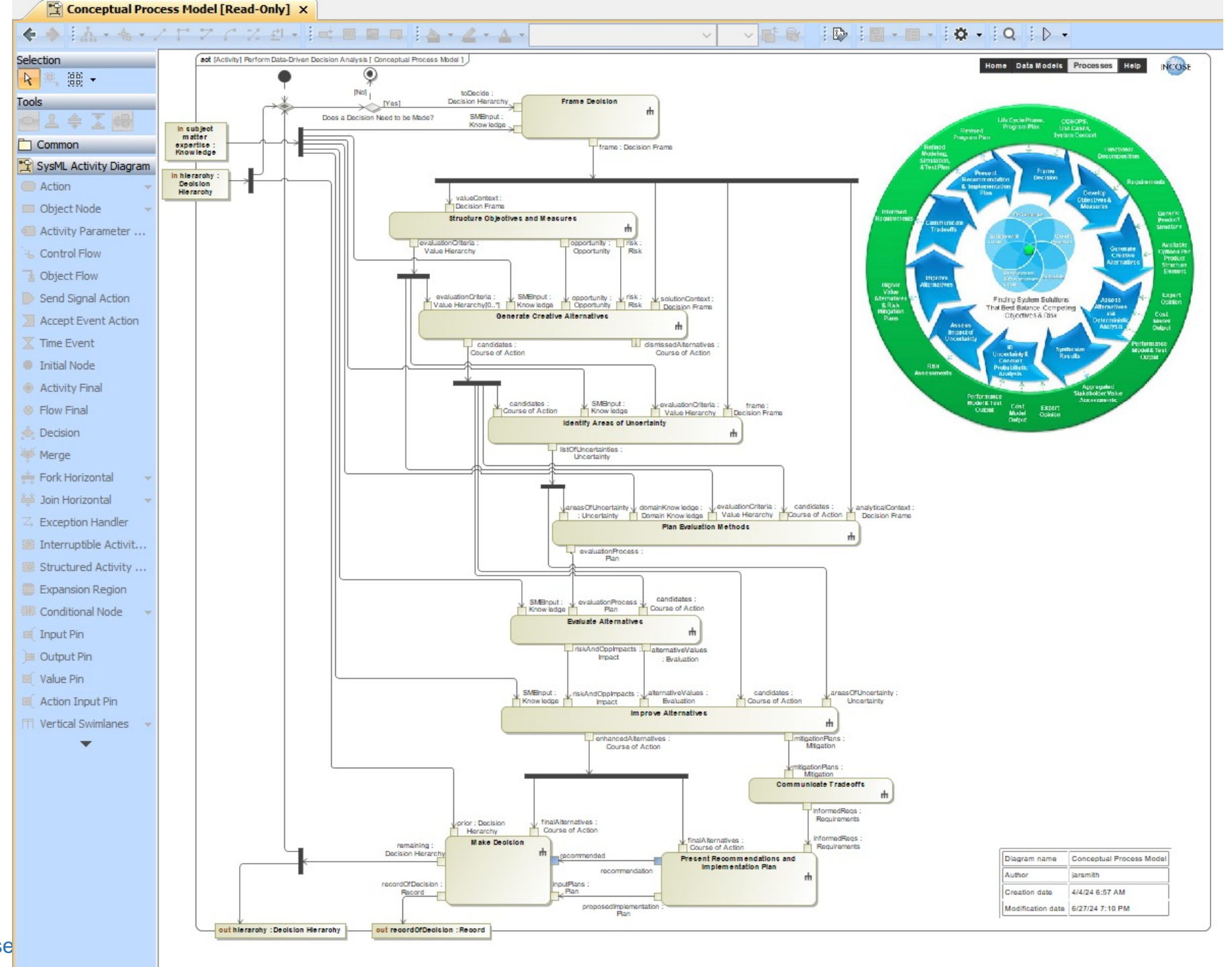
Activity Diagram

The SEBok Decision Management conceptual diagram (expanded in the Trade-Analytics Textbook) provided the foundation for the conceptual model.

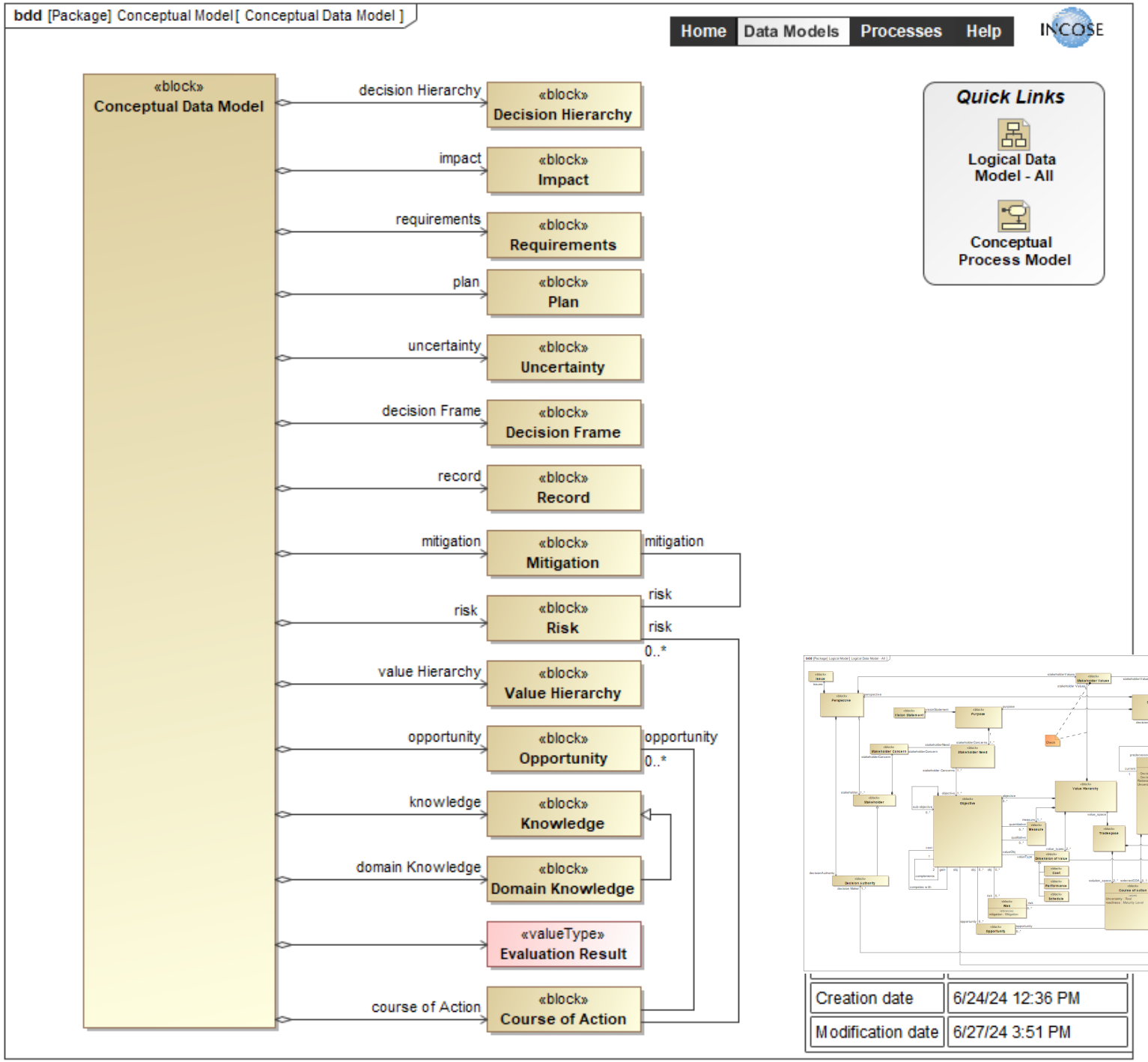


Conceptual Process Model

The SEBok Decision Management conceptual diagram (expanded in the Trade-Analytics Textbook) also provided the foundation for the more complex logical model but more information was required to complete the model.

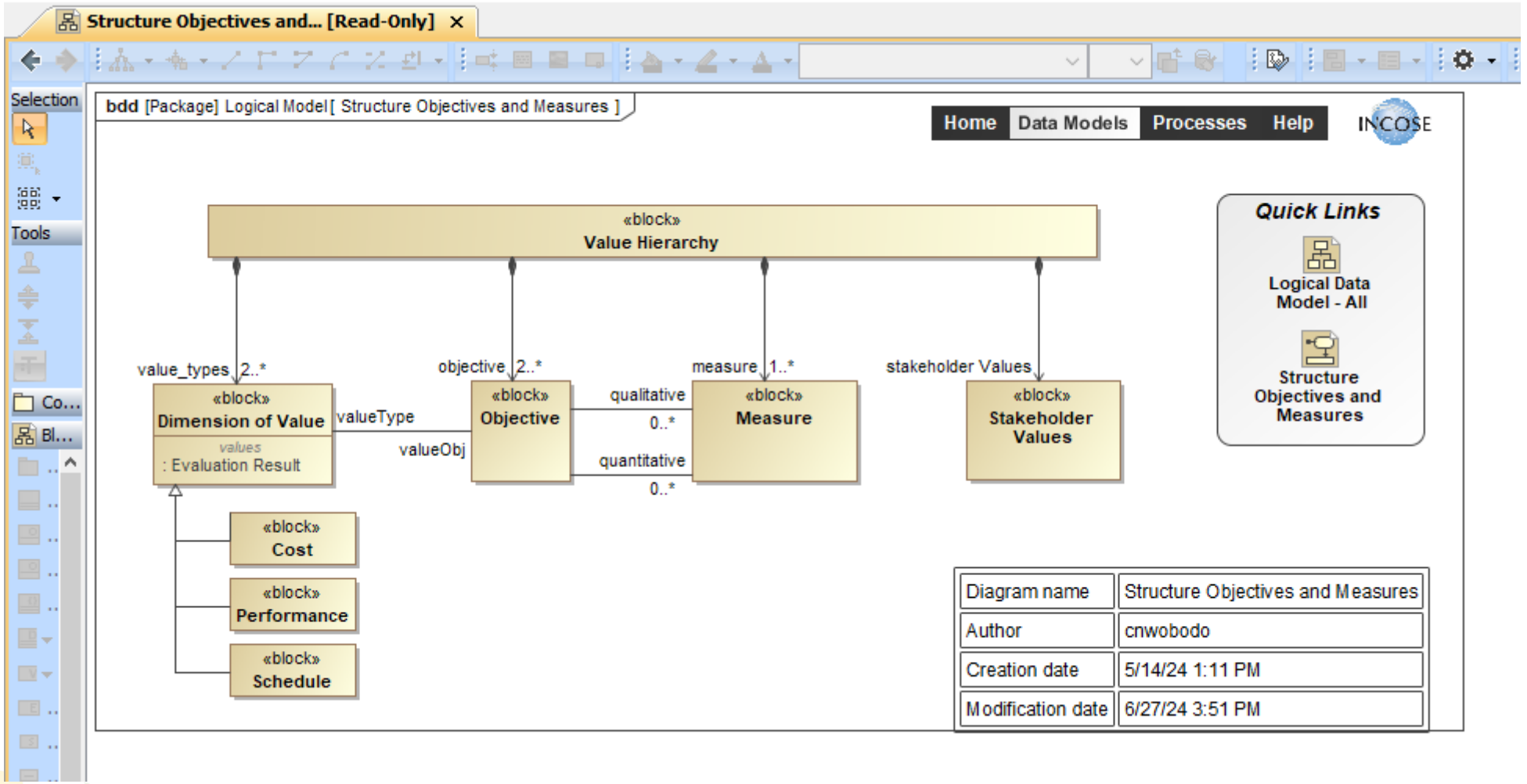


Conceptual Data Model

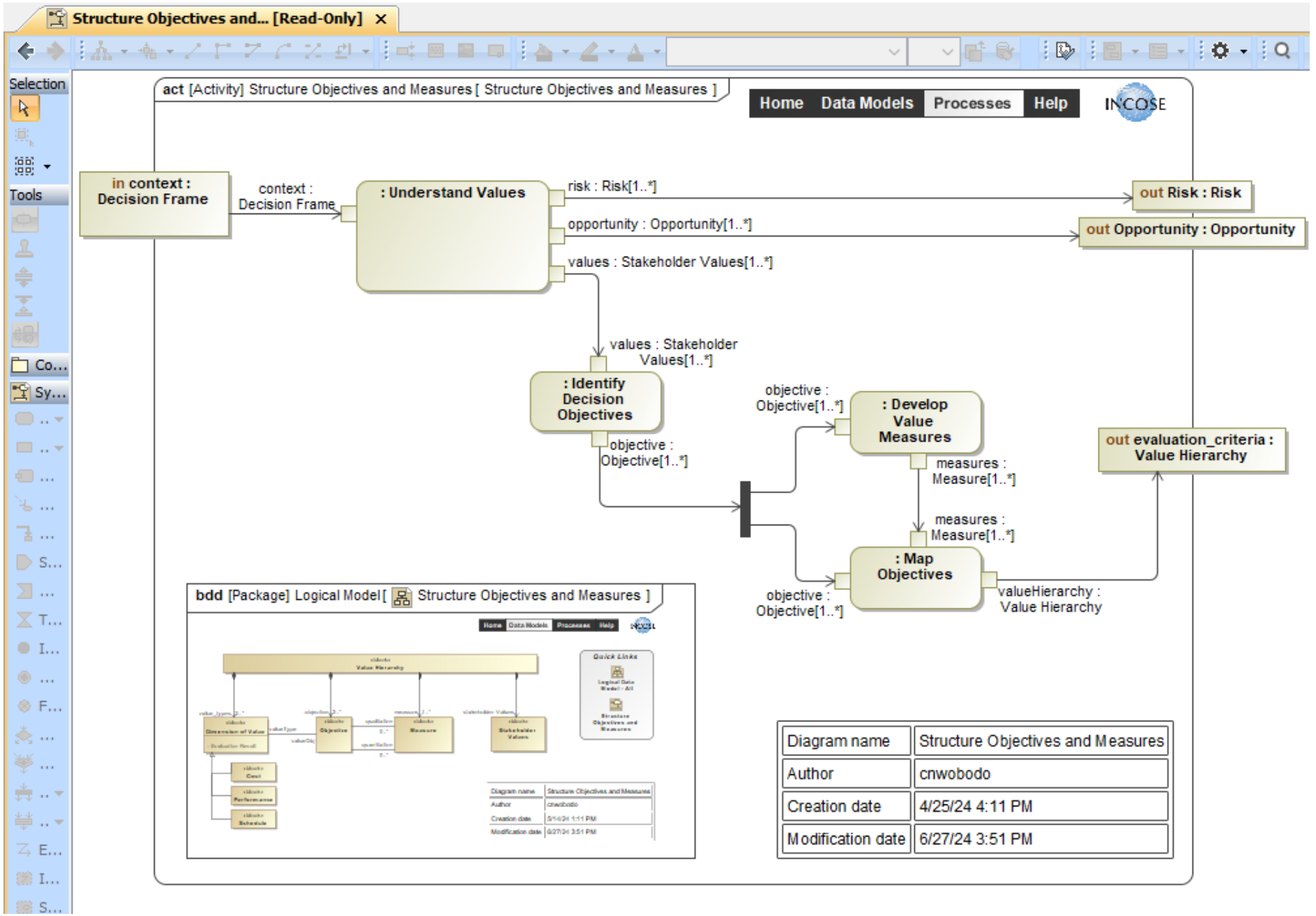


Alternative

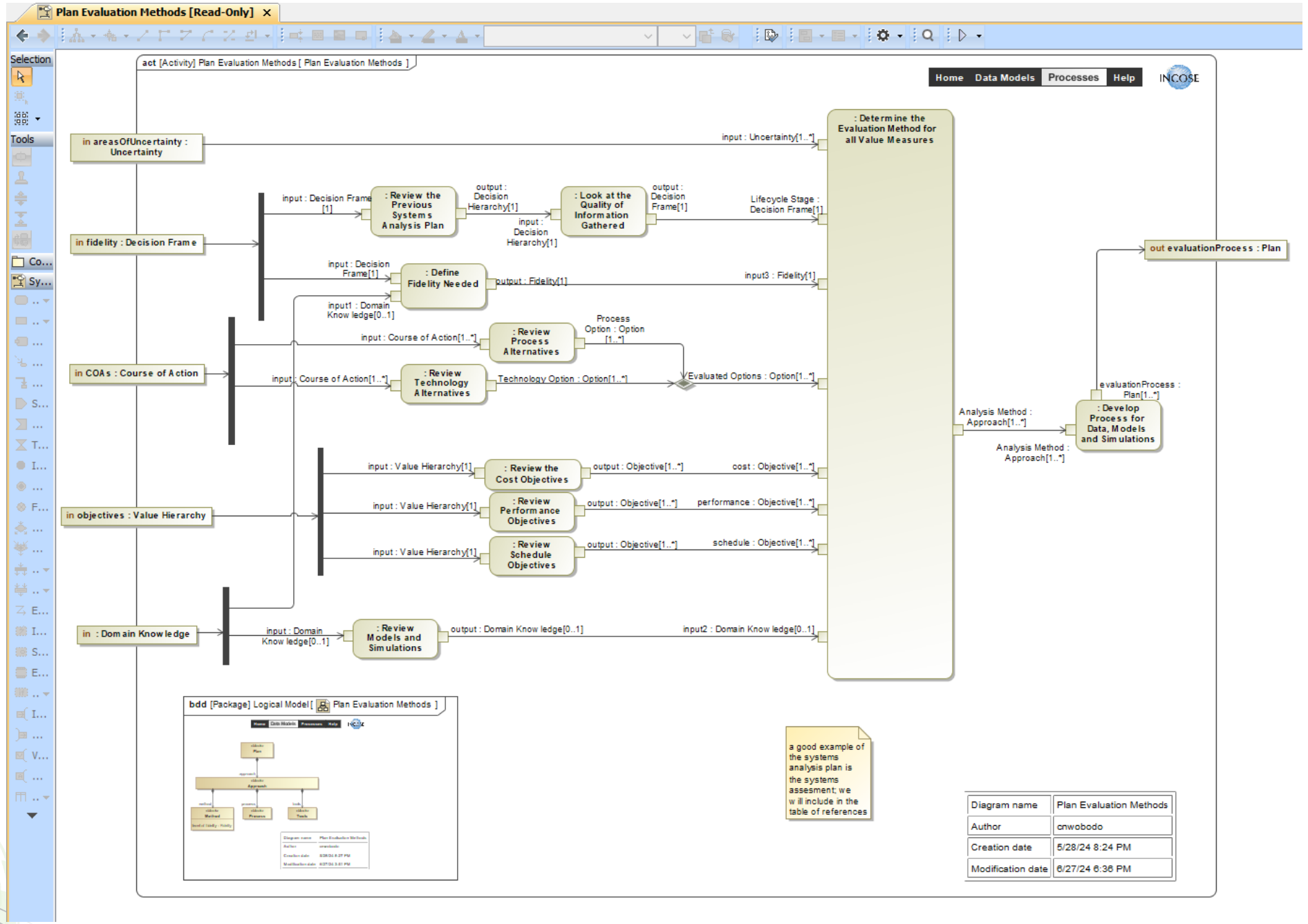
Logical Data Model



Logical Process Model (and Data Model)



Activity Diagram: Assessment Flow Diagram



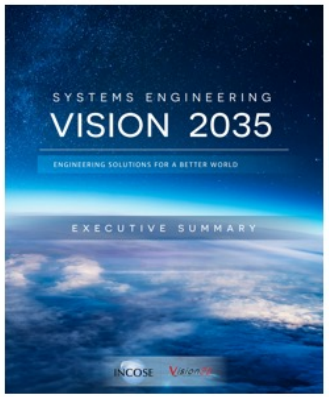
DADM Next Steps

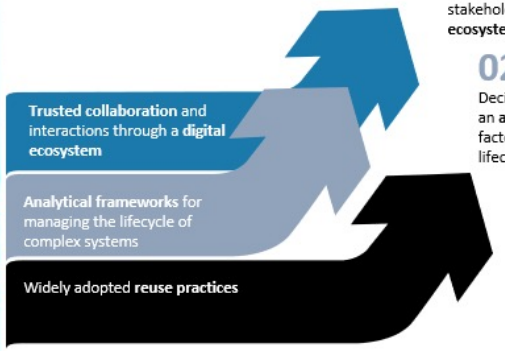
- Approved INCOSE TTP (25 Jun 24)
- Deploy prior to IW
- Update INCOSE Handbook and SEBoK
- Create a user guide
- Seek pilot implementations
- Make improvements based on user feedback
- Demonstrate interoperability with other tools
- Implement data model as a new/existing ontology
- Compare with Decision Modeling Notation (OMG Standard)
- Compare with SysML v2 specification

Decision Analysis Data Model – Summary

Develop a reusable Decision Analysis Data Model to support SE Vision 2025

The INCOSE Vision 2035 describes several key opportunities that must be realized to achieve the Vision 2035 outcomes, and Decision Management plays a key role in their realization.





01
Decision Analyses can touch multiple disciplines and stakeholders and should leverage a **digital ecosystem** to enhance **collaboration**

02
Decision Management methodologies provide an **analytical structure** for approaching multi-factor decision making throughout the system lifecycle

03
By creating a **reusable** Decision Analysis Data Model, practitioners are aided in quickly deploying decision management strategy for traditional or model-based projects

Integrate Decision Management Life Cycle Process in MBSE

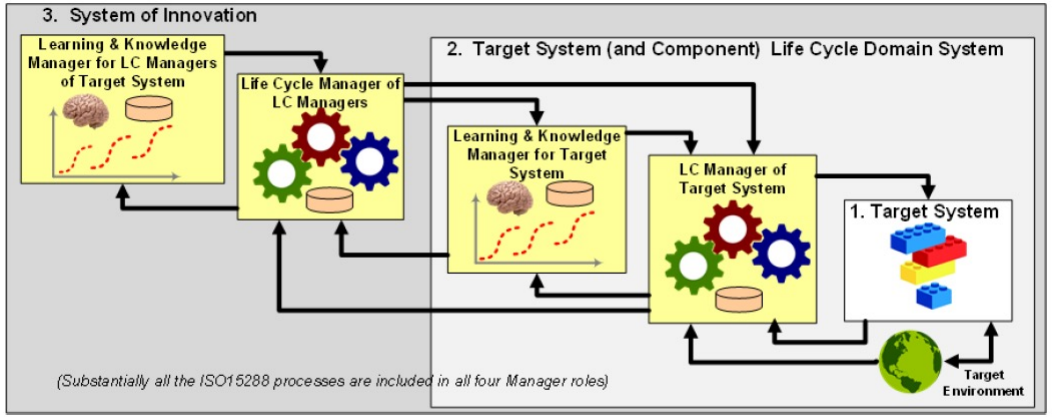
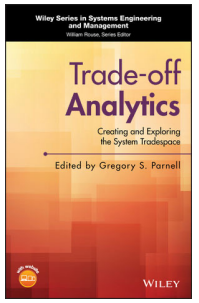
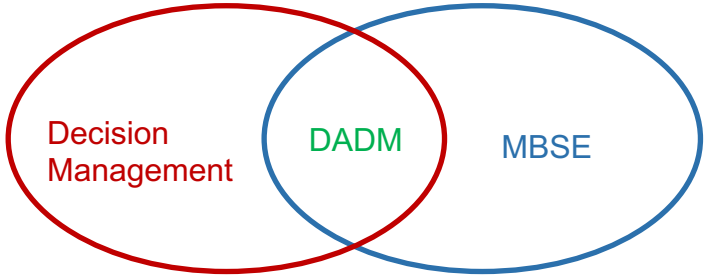


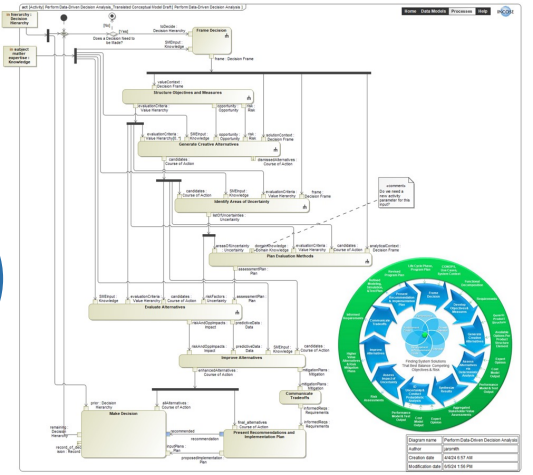
Figure 5. Iconic view of the ASELCM Pattern reference boundaries (Schindel, Dove 2016).

Use Decision Management Process (ISO/IEC/IEEE 15288, SE Handbook, SEBoK)

Enable Decision Management best practices in each system life cycle stage







How can you participate?

Join the DAWG

decision-analysis@incose.net

Attend our meetings at INCOSE IS (2) and IW (2)