THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Developing Model-Based Systems Engineering Pseudo-value Models for Industry Application

RAM 2022 Conference

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Sponsored by the Systems Engineering Technical Discipline Team (SE TDT) Research and Technology (R&T) at NASA

Presentation Outline

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Project overview and research questions

Background 2

What are pseudo-value models?

Methodology 3

Data application process

Results & Discussion 4

Pseudo-value models and implications

Conclusion & Q/A 5

Summary and future work

1. Introduction

MBSE Pseudo-value models

Project Team

MESMER
RESEARCH
GROUP

Thomas Teper
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Industrial & Systems Engineering
Undergraduate Researcher

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Industrial & Systems Engineering
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Associate Professor of Systems Engineering

MBSE Project Timeline

Fall 2020

Phase I: Project Inception

MBSE Source Identification and Preliminary Coding

Spring 2021

Phase I: Data Gathering & Formulation

All sources identified, data extraction and thematic coding performed. Attribute, evidence & metrics aggregation.

Spring 2022

Phase I: Broad MBSE Perceptions

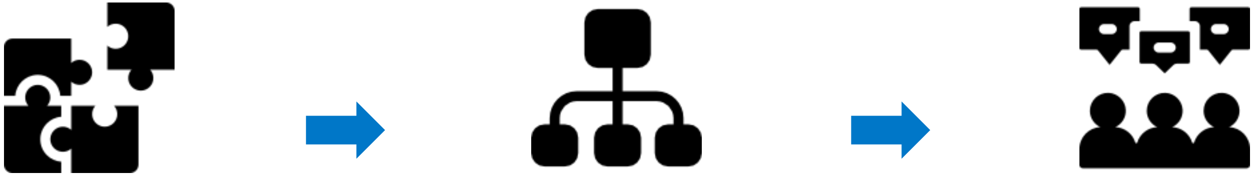
Project results for broad perceptions of MBSE, presentations at RAM 2021 and NASA

Fall 2022

Phase II: Pseudo-value model development

Applying broad project results to specific application types (i.e., government vs. commercial)

Phase II Overview



Broad Perceptions of MBSE → **Pseudo-value Model Development Process** → **Considerations for Industry Application**

Guiding the Research

In guiding the MBSE transition process and considerations, we sought to answer the following research questions:

RQ1: Can we construct categories of MBSE attributes for valuing implementation?

RQ2: Are there differences in the attributes frequently mentioned for valuing MBSE perceived by different sectors as discussed in academic literature?

RQ3: Are there differences in the attributes frequently mentioned for valuing MBSE perceived for system types as discussed in academic literature?

RQ4: Are there commonalities identified in attributes for valuing MBSE implementation across groupings?

2. Background

MBSE Pseudo-value models

Model-Based Systems Engineering

What is MBSE?

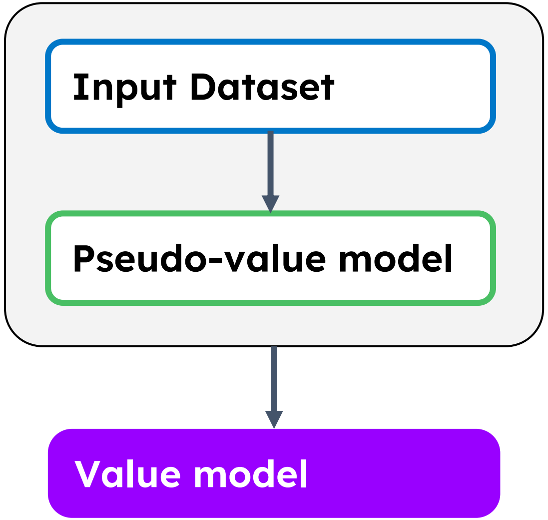
Defined by INCOSE as “formalized application of modeling to support system requirements, design, analysis, verification and validation activities”

In Other Words

MBSE is a system development methodology that is seen as a modern alternative to traditional document-based systems engineering, focused on fully designing, analyzing, and testing systems of interest through the creation of a system model

Capturing value through models

Our Project



Pseudo-value model: A qualitative representation of the preference of a stakeholder

- This representation identifies attributes and their direction of impact in the value model
- Provides the foundation in which to develop a value model

Value model: A mathematical representation of the preference of a stakeholder. This representation is a function of attributes, relating them to the value of the alternatives

V(attributes) = MBSE Value

The *alternatives* for this project are different SE approaches/tools, specifically looking at the alternative of MBSE

Mathematical Expression

A value model could be expressed mathematically as shown below:

benefit conversion factors (a) **disbenefit conversion factors (c)**

$$\text{MBSE Value} = (a_1 b_1 + a_2 b_2 + \ldots + a_n b_n) - (c_1 d_1 + c_2 d_2 + \ldots + c_m d_m)$$

benefits (b) **disbenefits (d)**

b_1: Time
a_1: [x] val/Time

0 val/time **10 val/time**

Why a Pseudo-Value Model?

The data of this study does not provide information on the impact on value by each attribute. Though preferences are not identified or elicited in this study, we have identified the names of the benefits and disbenefits (or b's and d's)

$$\textbf{MBSE Pseudo-value} = \{b_1, b_2, \ldots, b_n\},\{d_1, d_2, \ldots, d_n\}$$

Intended Use for Pseudo-value Models

- Difficult to assign impact on value to MBSE perceived benefits and disbenefits
- We developed several pseudo-value models, identifying *considerations* and *areas of interest* for stakeholders and decision-makers
- Target use case:
  - Workshops on MBSE implementation
  - Brainstorming sessions
  - Considerations when making decisions
- However, we are not intending use for:
  - Determining value as function of any data

"For this specific application, these are things to possibly consider, among others, based on perceptions in literature…"

"For this specific application, these are the only things you should base a decision on… Here are their impacts and importance…"

3. Methodology

MBSE Pseudo-value models

Methodology Overview

1 Source ID & Data Extraction

Identify RQs and relevant sources based on inclusion criteria

2 Coding & Analysis

Extract data from sources into database and apply coding process

3 Data Verification

Verify process properly followed and data meets inclusion criteria, perform statistical tests

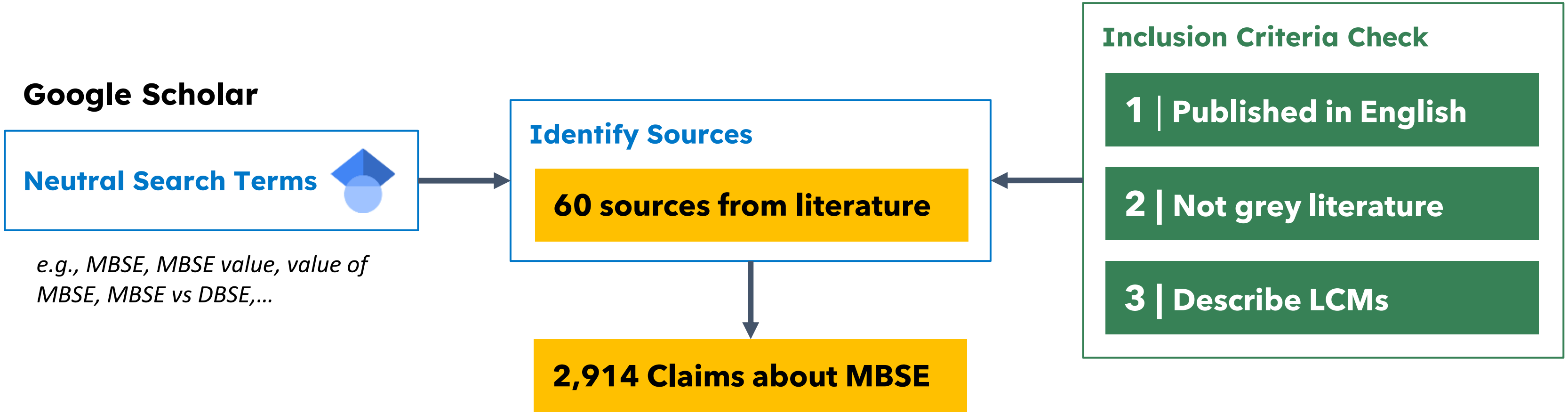
Identifying Research Questions

1

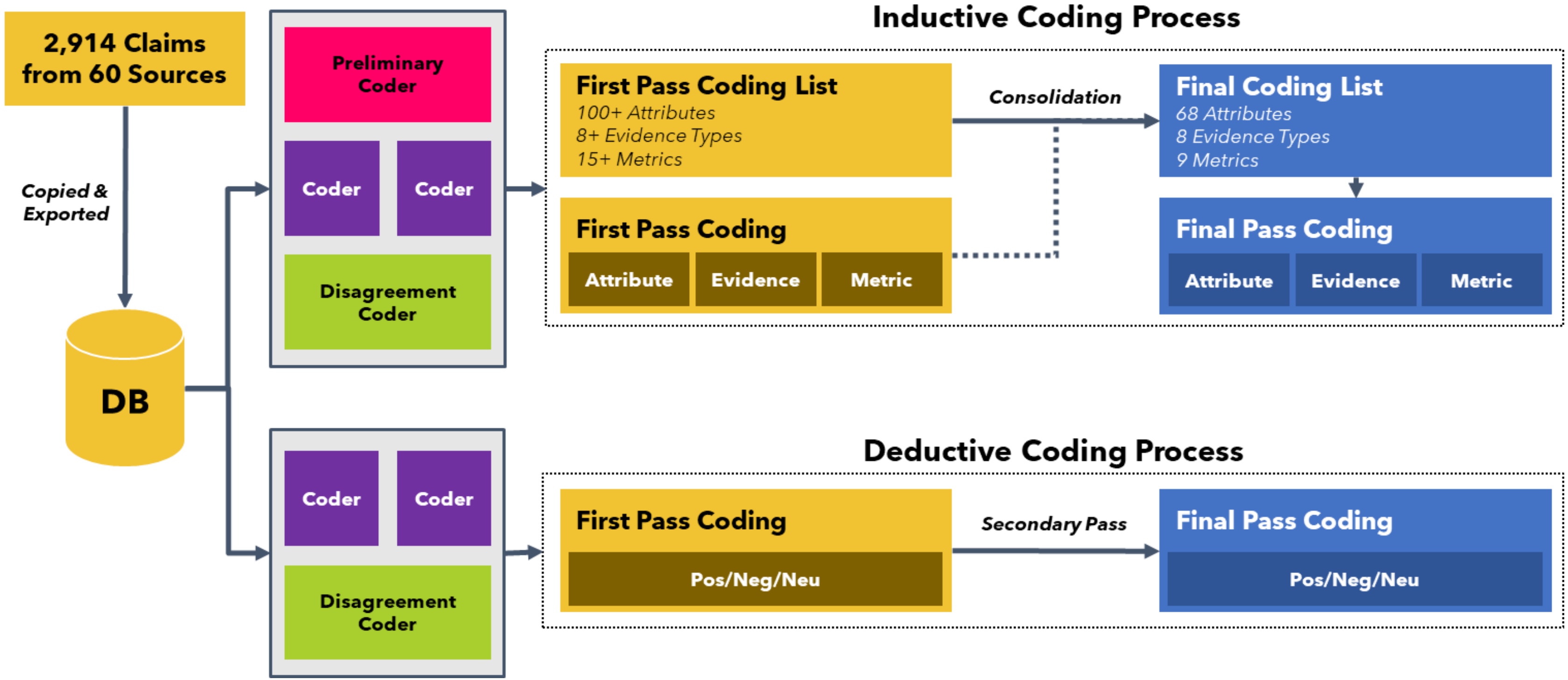
1	Can we construct categories of MBSE attributes for valuing implementation?	What is being said?
2	Are there differences in the attributes frequently mentioned for valuing MBSE perceived by different sectors as discussed in academic literature?	Sector-specific attributes?
3	Are there differences in the attributes frequently mentioned for valuing MBSE perceived for system types as discussed in academic literature?	Systems?
4	Are there commonalities identified in attributes for valuing MBSE implementation across groupings?	What about similarities across the literature?

Source Identification

1



Coding the Data



Coding the Data

2

- Once all quotes were identified, we *coded* each one with an **attribute**, a **positive or negative tag**, and an **evidence type**
- Each code type is defined below:

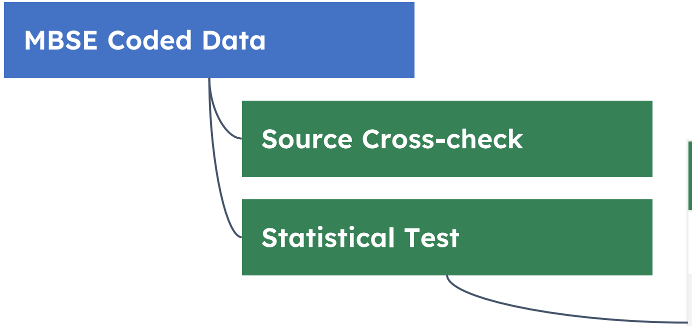
Code Type	Definition	Example Quote
Attribute (ATTR)	A tag that categorizes a *description* (or impact) of MBSE (e.g., Consistency, Maintainability, Robustness, etc.)	"With MBSE, data can be encoded into models, thereby providing an opportunity to **integrate the system model across life cycle process**, and thereby **promote reuse**." [1.30]
Positive and Negative (P/N)	A tag that categorizes whether a quote is positive or negative towards MBSE	
Evidence (EVID)	A tag that categories the level of substantiation an author uses to back up a claim made about MBSE	

ATTR: Integrability
P/N: Positive
EVID: Author Opinion

ATTR: Reusability
P/N: Positive
EVID: Author Opinion

Data Verification

3



Inter-Rater Reliability	
Type	**Cohen's Kappa (κ)**
Attributes	0.845
Positive / Negative	0.862
Evidence	0.744

Inter-Rater Reliability Scale [1]	
Value of κ	**Strength of Agreement**
< 0.20	*Poor*
0.21 - 0.40	*Fair*
0.41 - 0.60	*Moderate*
0.61 - 0.80	*Good*
> 0.80	*Very Good*

[1] Landis, J. R., & Koch, G. G. (1977). The Measurement of Observer Agreement for Categorical Data. *Biometrics*, *33*(1), 159. https://doi.org/10.2307/2529310

Goal of the Pseudo-value models

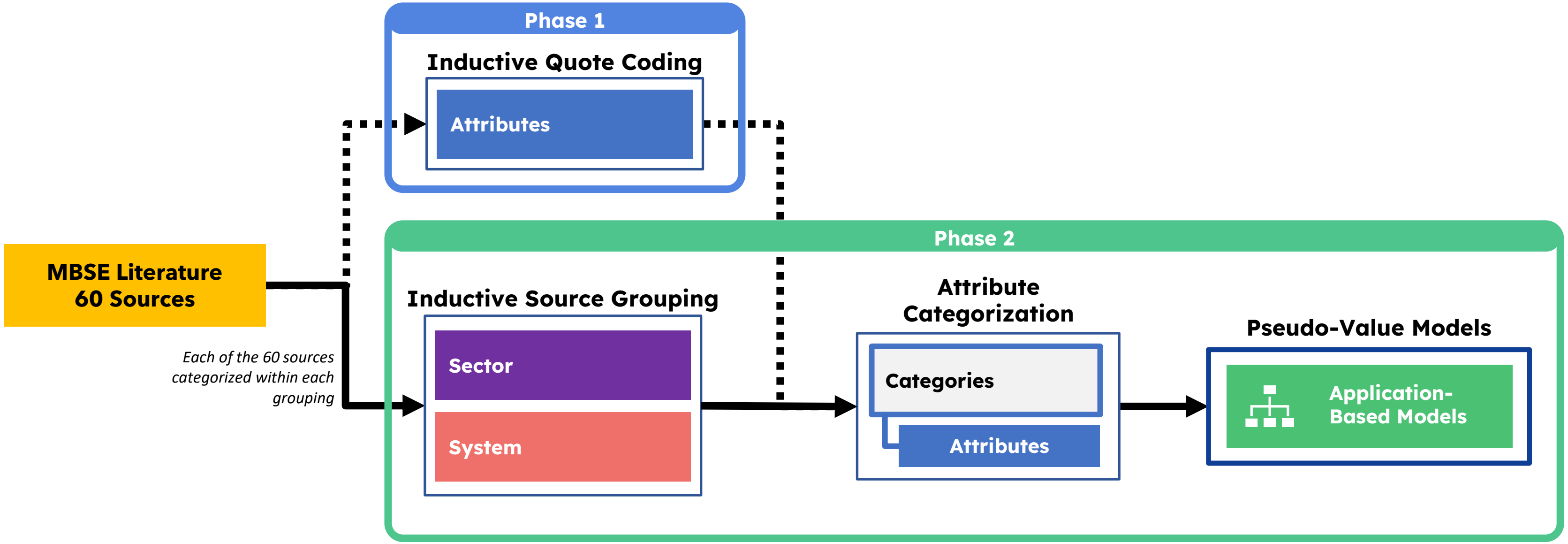
Implementation Considerations

In general, represent the top positive and top negative considerations from each category of attributes

Top Attributes by Sector, System

This is done by selecting the top two positive and top two negative attributes in each category, filtered by application type (i.e., sector or system type)

Pseudo-Value Model Development Process



Literature Source Groupings

Sector

- Government
- Commercial
- Unstated

System Types

- Infrastructure
- Atmospheric system
- Generic
- Space system

System Types

Sectors	Infrastructure	Atmospheric System	Generic	Space System	Total
Commercial	2		2	2	6
Government	2	9	5	19	35
Unstated		4	15		19
Total	4	13	22	21	60

Attribute Categories

Community Perceptions
- Adoption & Emergence
- Applicability
- Approach Substantiation
- Notability
- Desirability
- Effectiveness
- Formality
- Standardization
- Acceptability
- Approach Understanding
- Familiarity

Practical Considerations
- Feasibility
- Implementation Cost

Integrating into Existing Systems
- Integrability
- Compatibility
- Interoperability
- Modernization
- Sclability
- Maintainability
- Reusability

Model Impacts & Capabilities
- Reasoning
- Simplifiability
- Traceability
- Controllability
- Configurability
- Complexity Handling
- Change Manageability
- Comparibility
- Innovativeness
- Verification & Validation Capability
- Reviewability

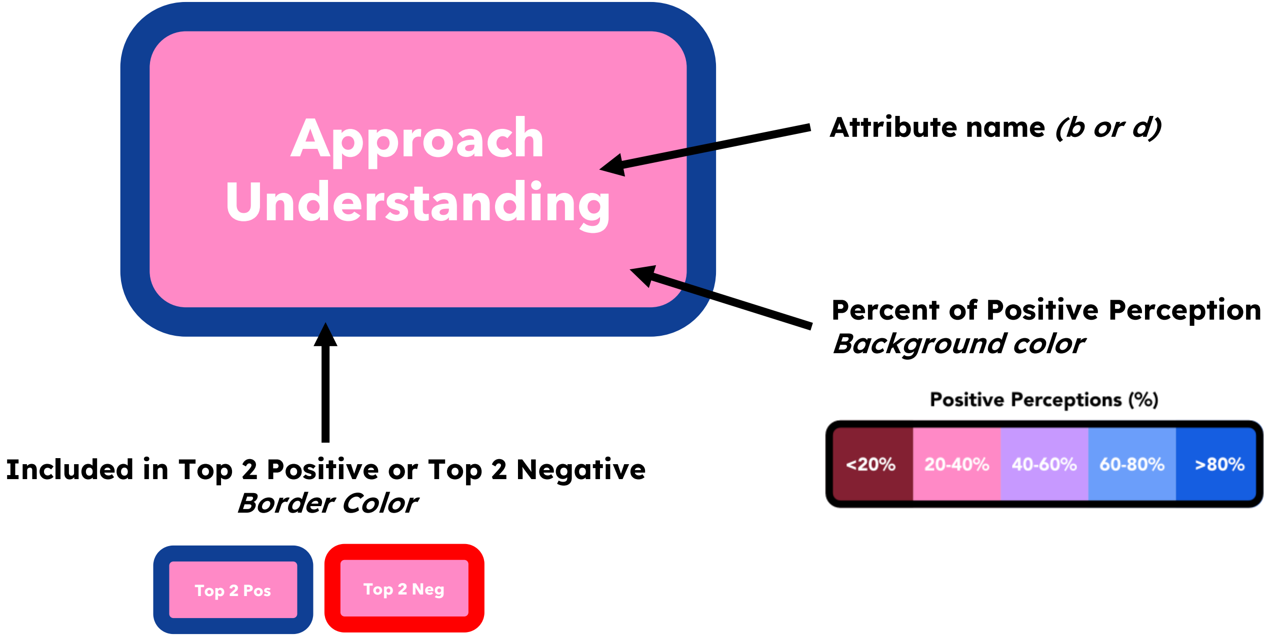
Team Impacts
- Collaborative
- Communication Capability
- Automation Capability
- Workload & Effort
- Approach Complexity & Simplicity
- Ownership
- Documentability

System Representation
- Project/System Understanding
- Clarity
- Informability
- Information Capture Capability
- Representability
- Correctness
- Detailability
- Objectivity

Impacts on Project Processes
- Performance
- Quality
- Project Schedule
- Time
- Cost-effectiveness
- Efficiency
- Approach Flexibility
- Consistency
- Robustness
- Risk & Error Manageability
- Safety
- Misuseability

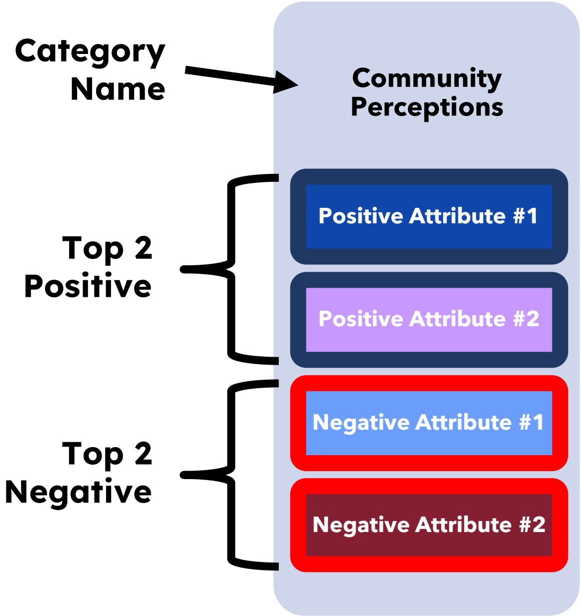
Use/Tool Challenges
- Modularity
- Navigability
- Searchability
- Mathematical Capability
- Maturity
- Capability
- Useability
- Approach Security & Privacy
- System Accessibility

Structuring a Pseudo-value Model
Attributes



Structuring a Pseudo-value Model

Categories



Pseudo-value Model Structure Example

Value

Community Perceptions	Practical Considerations	Integration into Existing Systems	Model Impacts & Capabilities	Team Impacts	System Representation	Impacts on Project Processes	Use/Tool Challenges
Positive Attribute #1	Pos Attribute #1	Pos Attribute #1	Pos Attribute #1	Pos Attribute #1	Pos Attribute #1	Pos Attribute #1	Pos Attribute #1
Positive Attribute #2	Pos Attribute #2	Pos Attribute #2	Pos Attribute #2	Pos Attribute #2	Pos Attribute #2	Pos Attribute #2	Pos Attribute #2
Negative Attribute #1	Neg Attribute #1	Neg Attribute #1	Neg Attribute #1	Neg Attribute #1	Neg Attribute #1	Neg Attribute #1	Neg Attribute #1
Negative Attribute #2	Neg Attribute #2	Neg Attribute #2	Neg Attribute #2	Neg Attribute #2	Neg Attribute #2	Neg Attribute #2	Neg Attribute #2

Attributes for Consideration

New Categories

Label

Top 2 Neg

Top 2 Pos

Positive Perceptions (%)

<20%	20-40%	40-60%	60-80%	>80%

The categories identify considerations for decision makers. Selecting the top two attributes within each category can identify those that may be perceived as critical for specific applications.

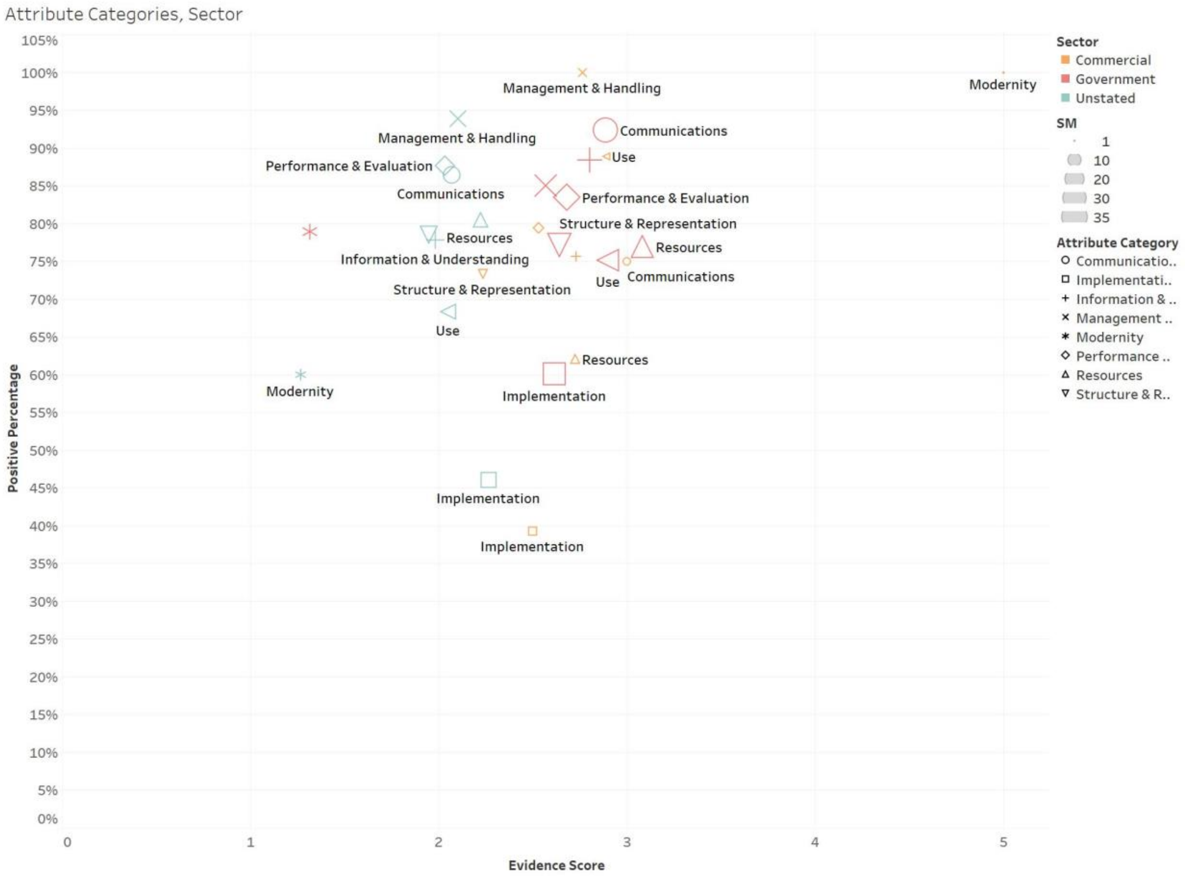
Another way to visualize the data

Plotting percentage of positive uses against a pseudo-evidence scale, with size representing total sources for category/attribute

Positive %: [# positive claims]/[# total claims]*100%

Evidence Score: A range between 1 and 5 representing how "substantiated" the uses for an attribute or category was

- This score is based on *weights* for evidence types (e.g., Author Opinion = 1; Referenced = 3; Case Study/Lit Review = 5) and averaged across all claims for category/attribute
- No conclusions reached by use of evidence score, just for visualizing uses based on dataset



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4. Results & Discussion

MBSE Pseudo-value models

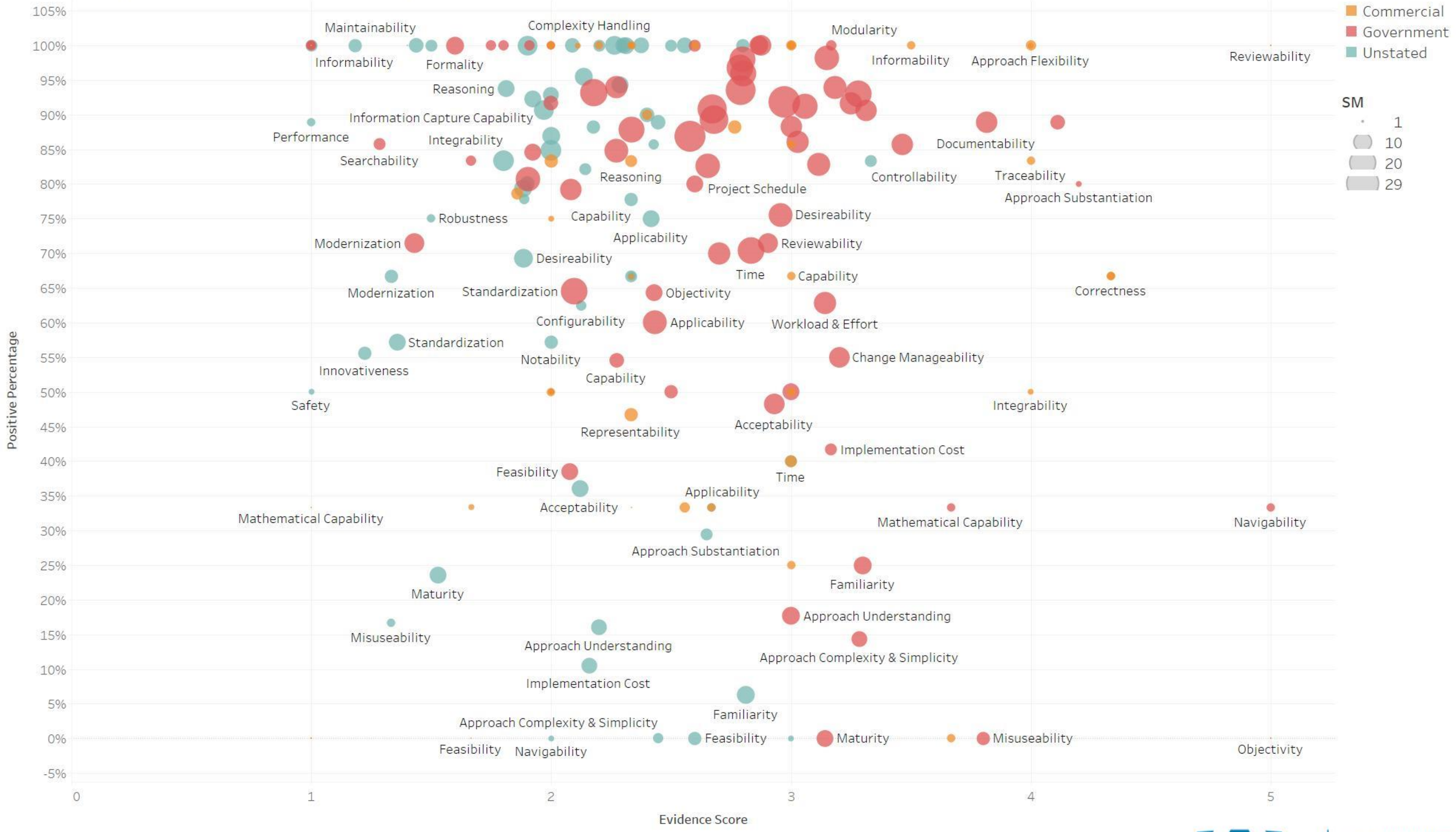
Defining Sector

Commercial: A source targets system(s) that are intended to be **publicly available** (e.g., personal transportation).

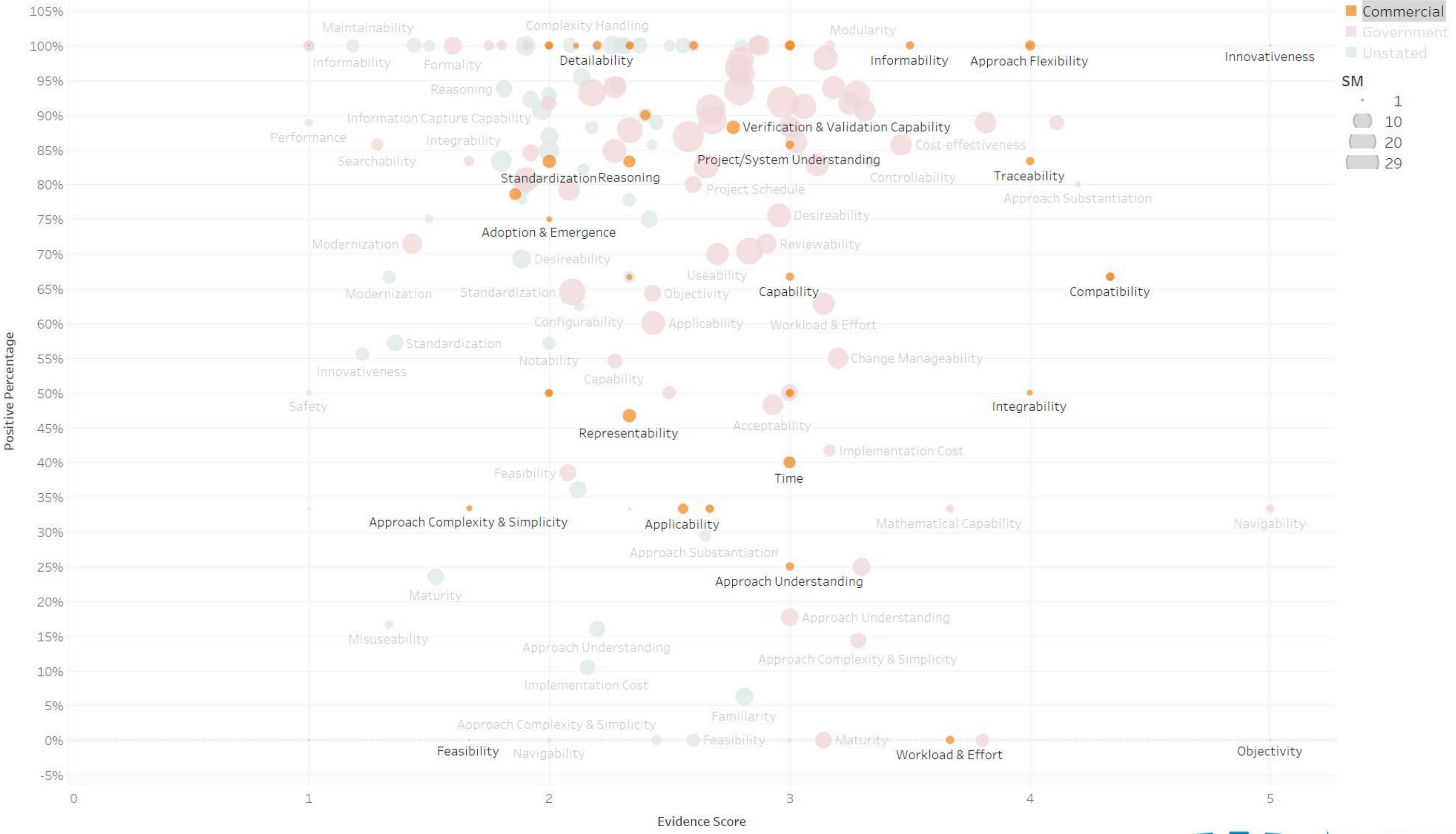
Government: A source targets system(s) that are intended for **primarily government use** (e.g., defense, space exploration).

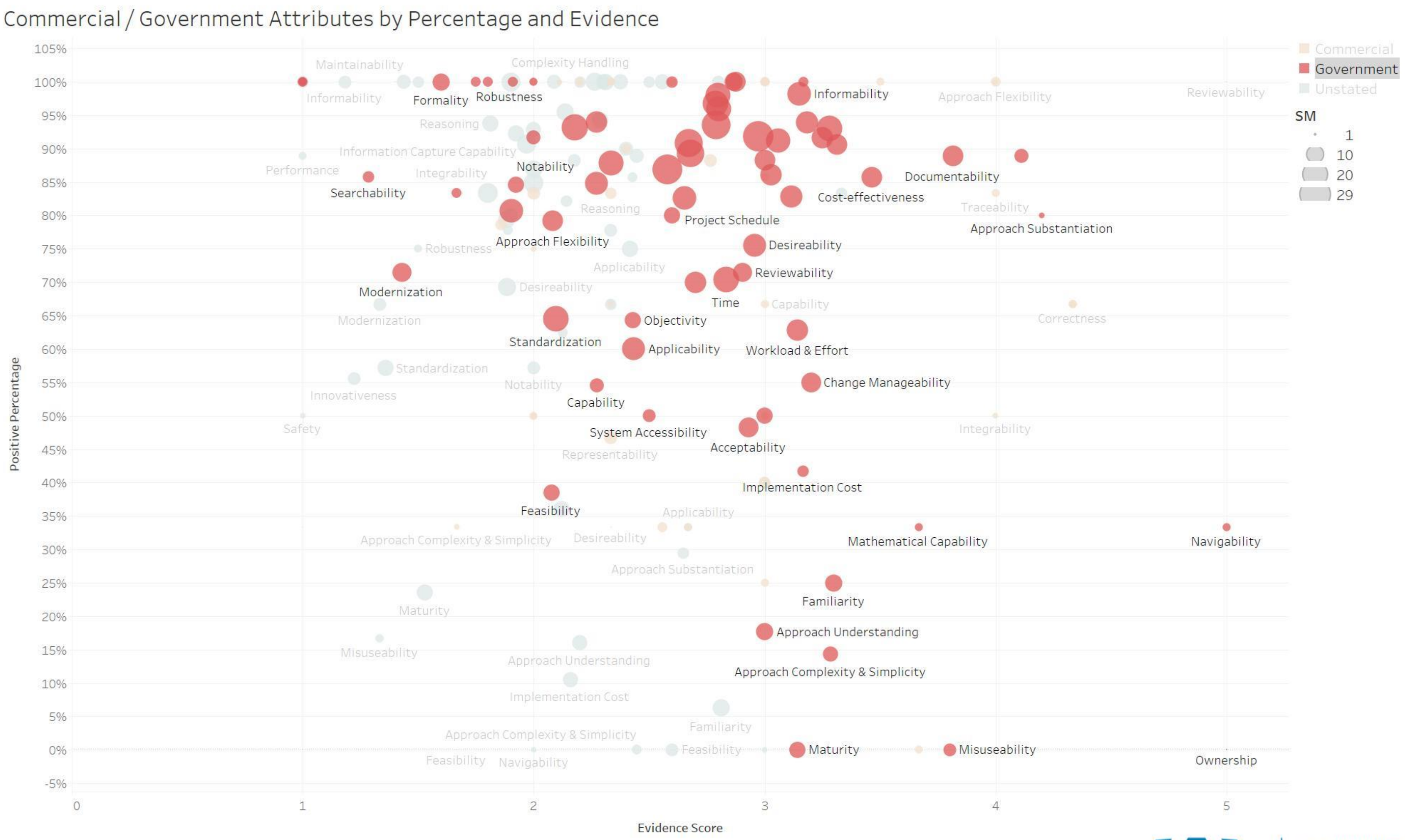
Unstated: A source **does not state** if it targets system(s) that are intended to be publicly available (e.g., personal transportation) AND/OR applications that are intended for primarily government use (e.g., defense, space exploration).

Commercial / Government Attributes by Percentage and Evidence



Commercial / Government Attributes by Percentage and Evidence





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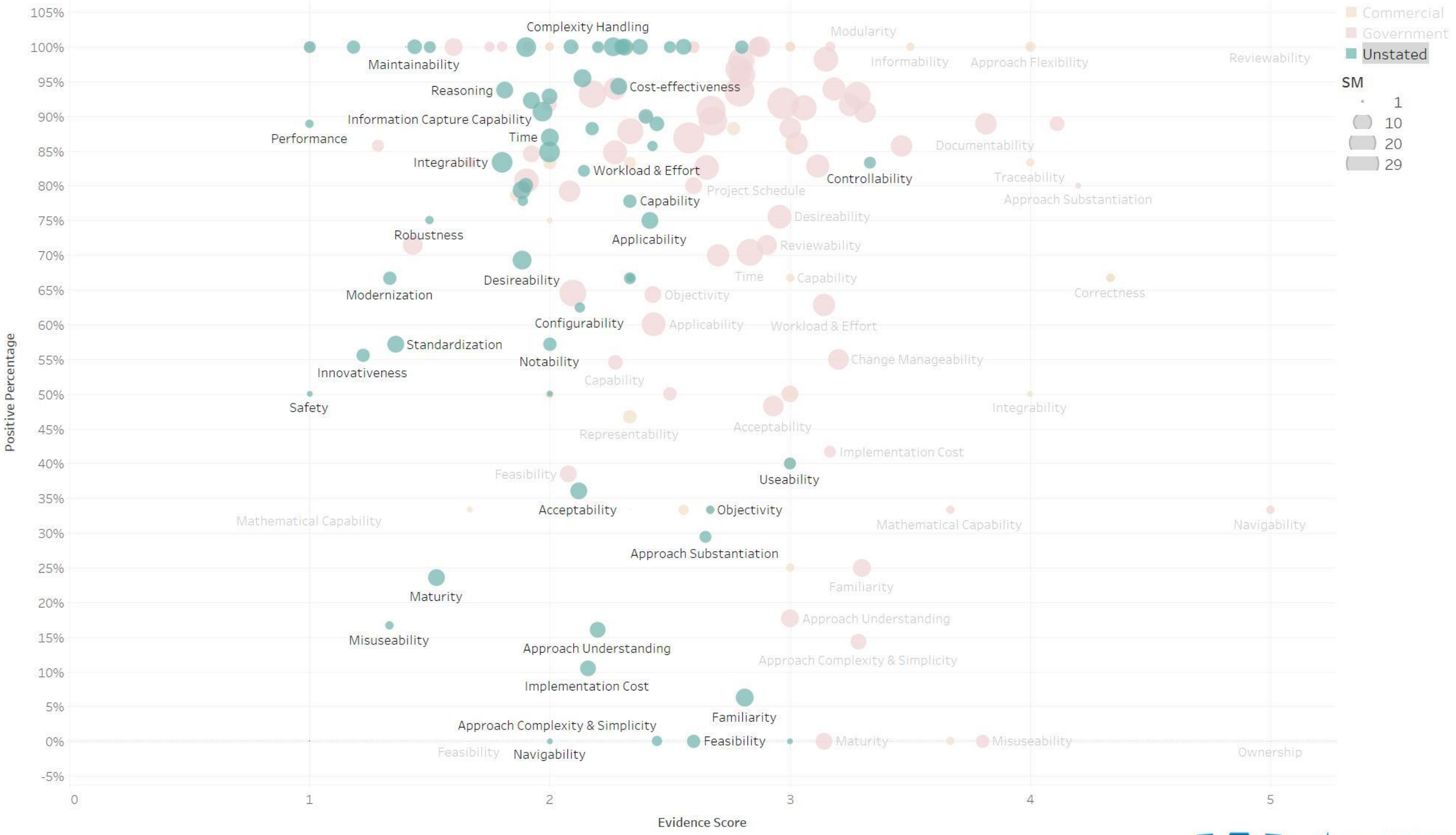
Commercial / Government Attributes by Percentage and Evidence



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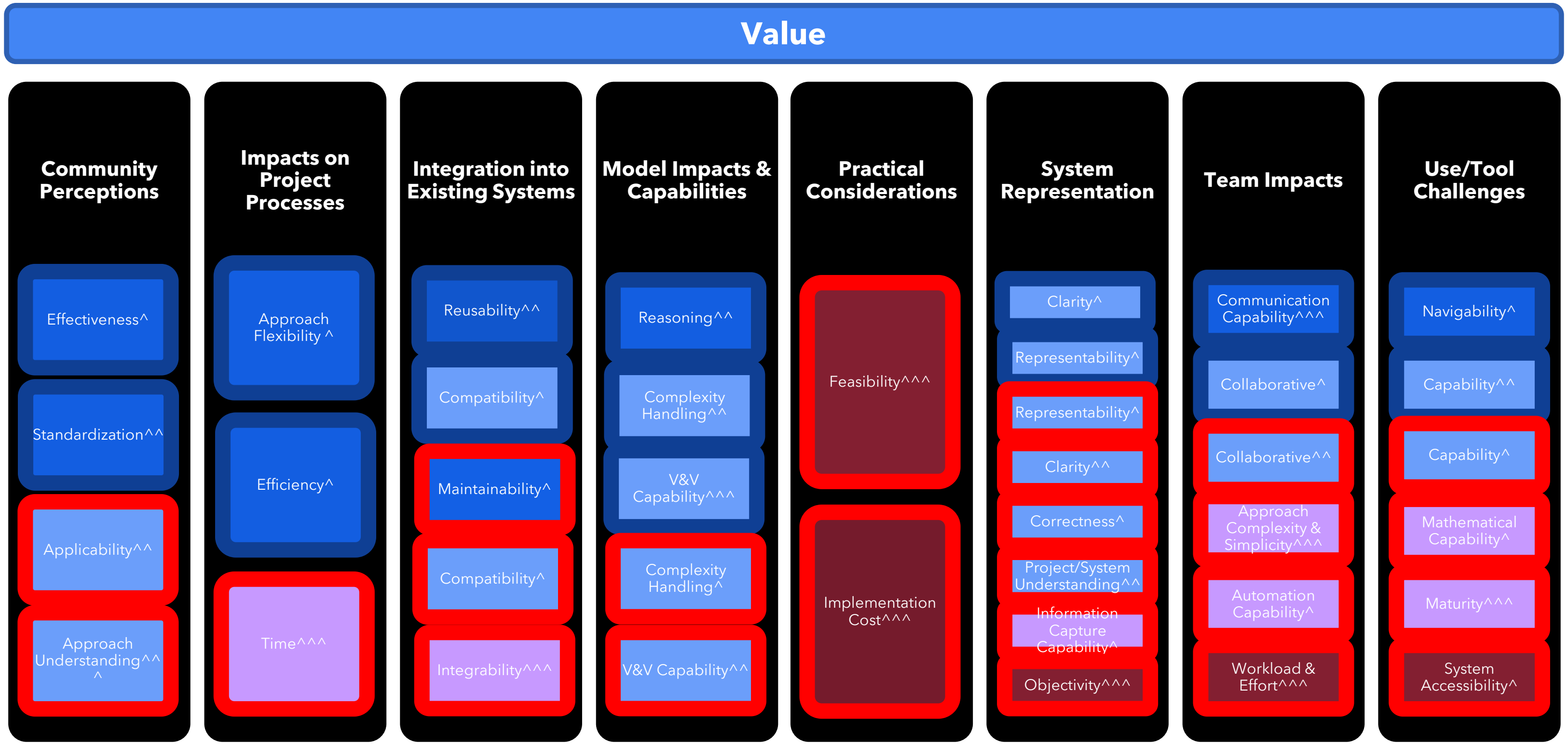
Commercial / Government / Unstated
6/60
35/60
19/60
Categories
Attributes
Commercial
Government
Unstated
Neg
Pos
Community Perceptions
Acceptability
Adoption & Emergence
Applicability
Approach Substantiation
Approach Understanding
Desireability
Effectiveness
Familiarity
Formality
Notability
Standardization
Impacts on Project Processes
Approach Flexibility
Consistency
Cost-effectiveness
Efficiency
Misuseability
Performance
Project Schedule
Quality
Risk & Error Manageability
Robustness
Safety
Time
Integration into Existing Systems
Compatibility
Integrability
Interoperability
Maintainability
Modernization
Reusability
Scalability
Model Impacts & Capabilities
Change Manageability
Comparibility
Complexity Handling
Configurability
Controllability
Innovativeness
Reasoning
Reviewability
Simplifiability
Traceability
Verification & Validation Capability
Practical Considerations
Feasibility
Implementation Cost
System Representation
Clarity
Correctness
Detailability
Informability
Information Capture Capability
Objectivity
Project/System Understanding
Representability
Team Impacts
Approach Complexity & Simplicity
Automation Capability
Collaborative
Communication Capability
Documentability
Ownership
Workload & Effort
Use/Tool Challenges
Approach Security & Privacy
Capability
Mathematical Capability
Maturity
Modularity
Navigability
Searchability
System Accessibility
Useability
0 5 10 15 20 25 30
Source Mentions

Commercial

Label: Top 2 Neg | Top 2 Pos

Positive Perceptions (%): <20% | 20-40% | 40-60% | 60-80% | >80%



*Attributes shown are the Top 2 in each category either positively or negatively

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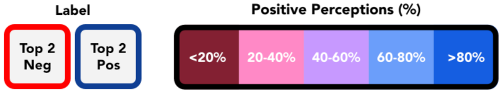
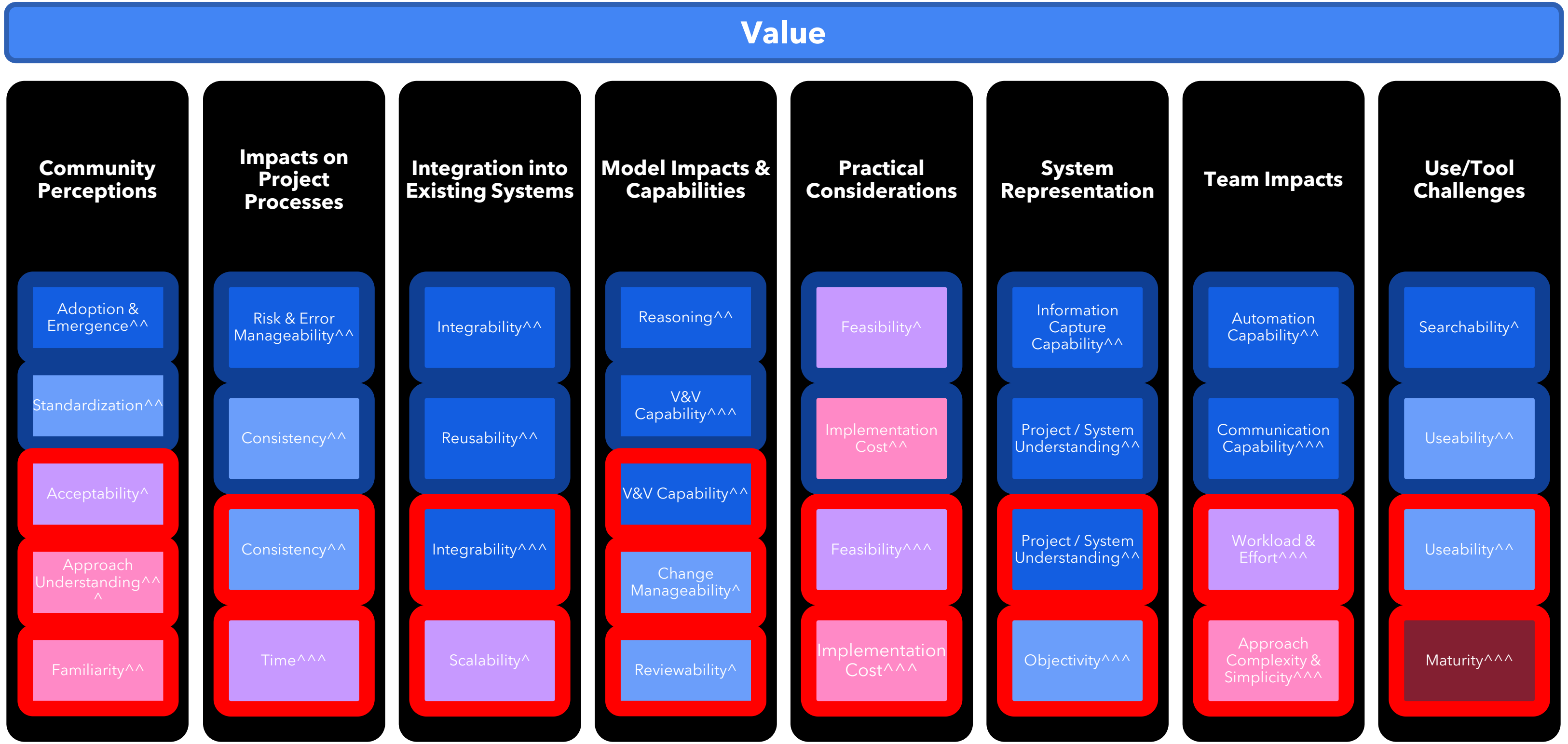
Government





*Attributes shown are the Top 2 in each category either positively or negatively

Unstated

Label: Top 2 Neg | Top 2 Pos

Positive Perceptions (%): <20% | 20-40% | 40-60% | 60-80% | >80%

Value

Community Perceptions
- Adoption & Emergence^^
- Desirability^
- Approach Understanding^^^
- Familiarity^^

Impacts on Project Processes
- Consistency^^
- Risk & Error Manageability^^
- Consistency^^
- Cost-effectiveness^
- Project Schedule^
- Time^^^

Integration into Existing Systems
- Maintainability^
- Integrability^^
- Integrability^^^
- Modernization^

Model Impacts & Capabilities
- Complexity Handling^^
- V&V Capability^^^
- Innovativeness^
- Reasoning^^^

Practical Considerations
- Implementation Cost^^
- Implementation Cost^^^
- Feasibility^^^

System Representation
- Information Capture Capability^^
- Project / System Understanding^^
- Clarity^^
- Objectivity^^^

Team Impacts
- Automation Capability^^
- Communication Capability^^^
- Collaborative^^
- Workload & Effort^^^
- Ownership^
- Approach Complexity & Simplicity^^^

Use/Tool Challenges
- Mathematical Capability^
- Capability^^
- Maturity^^^
- Useability^^

*Attributes shown are the Top 2 in each category either positively or negatively

Appearance in Models

Neg | Pos

Government/Commercial Comparison

Similar Attributes for System Type Pseudo-Value Models (3/3)

Community Perceptions
- Approach Understanding

Impacts on Project Processes
- Time

Integration into Existing Systems
- Integrability

Model Impacts & Capabilities
- V&V Capability

Practical Considerations
- Feasibility
- Implementation Cost

System Representation
- Objectivity

Team Impacts
- Communication Capability
- Approach Complexity & Simplicity
- Workload & Effort

Use/Tool Challenges
- Maturity

*Attributes shown appear in all three of the sector pseudo-value models. The count shown is for the total positive or negative count for each. Shown as either positive or negative based on the majority skew (3/3)

Defining System Type

Atmospheric System: A source targets system(s) whose primary operation is performed inside Earth's atmosphere

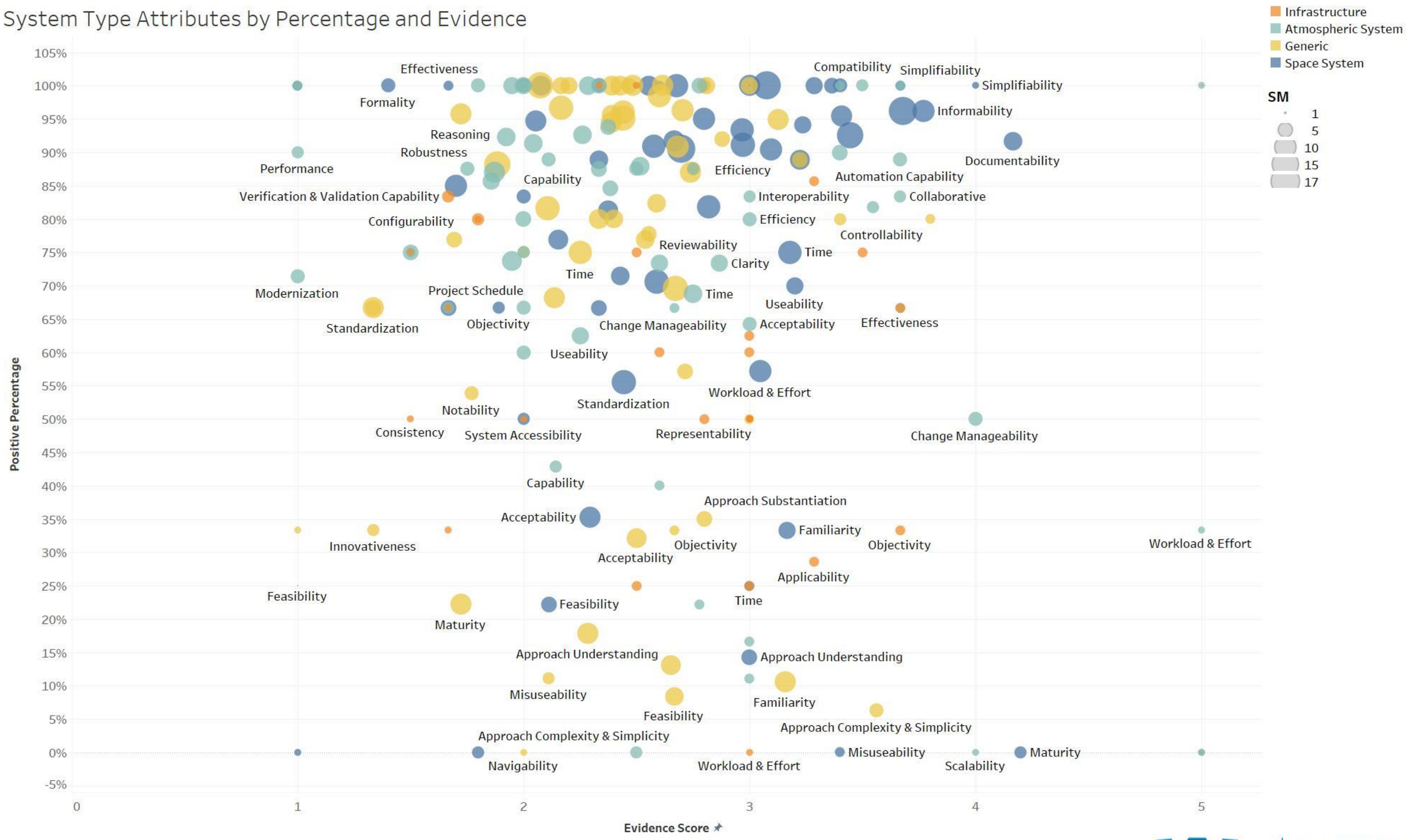
Infrastructure: A source targets system(s) that support physical and organizational community structures and facilities.

Generic: A source does not target a specific system type; targets a system without a specific type of system indicated; or targets a system type other than space vehicle, atmospheric vehicle, ground vehicle, or infrastructure.

Space System: A source targets system(s) whose primary operation is performed outside of the Earth's atmosphere

*Ground systems grouped under *other* for analyses due to low representation (2/60)

System Type Attributes by Percentage and Evidence



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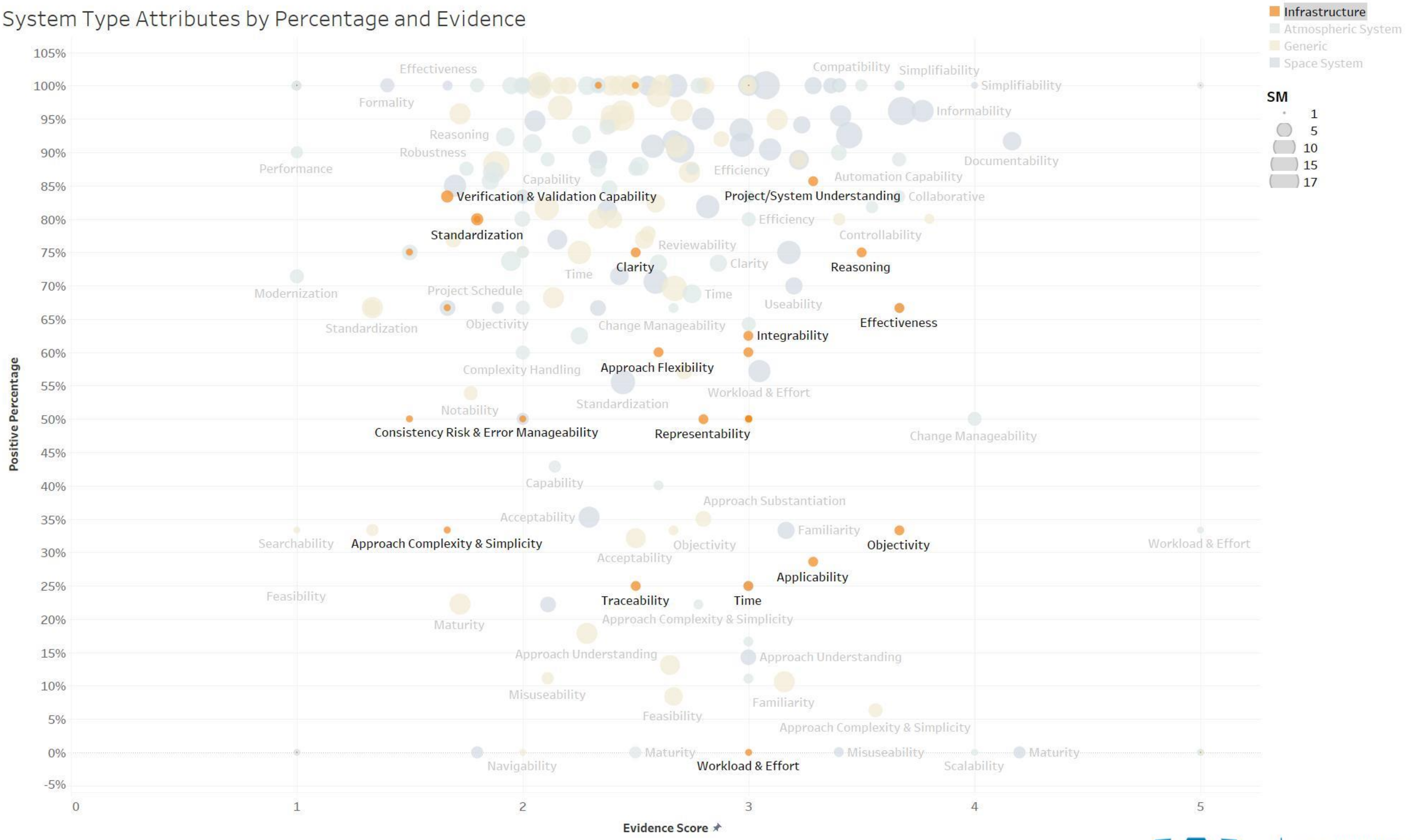
System Type Attributes by Percentage and Evidence



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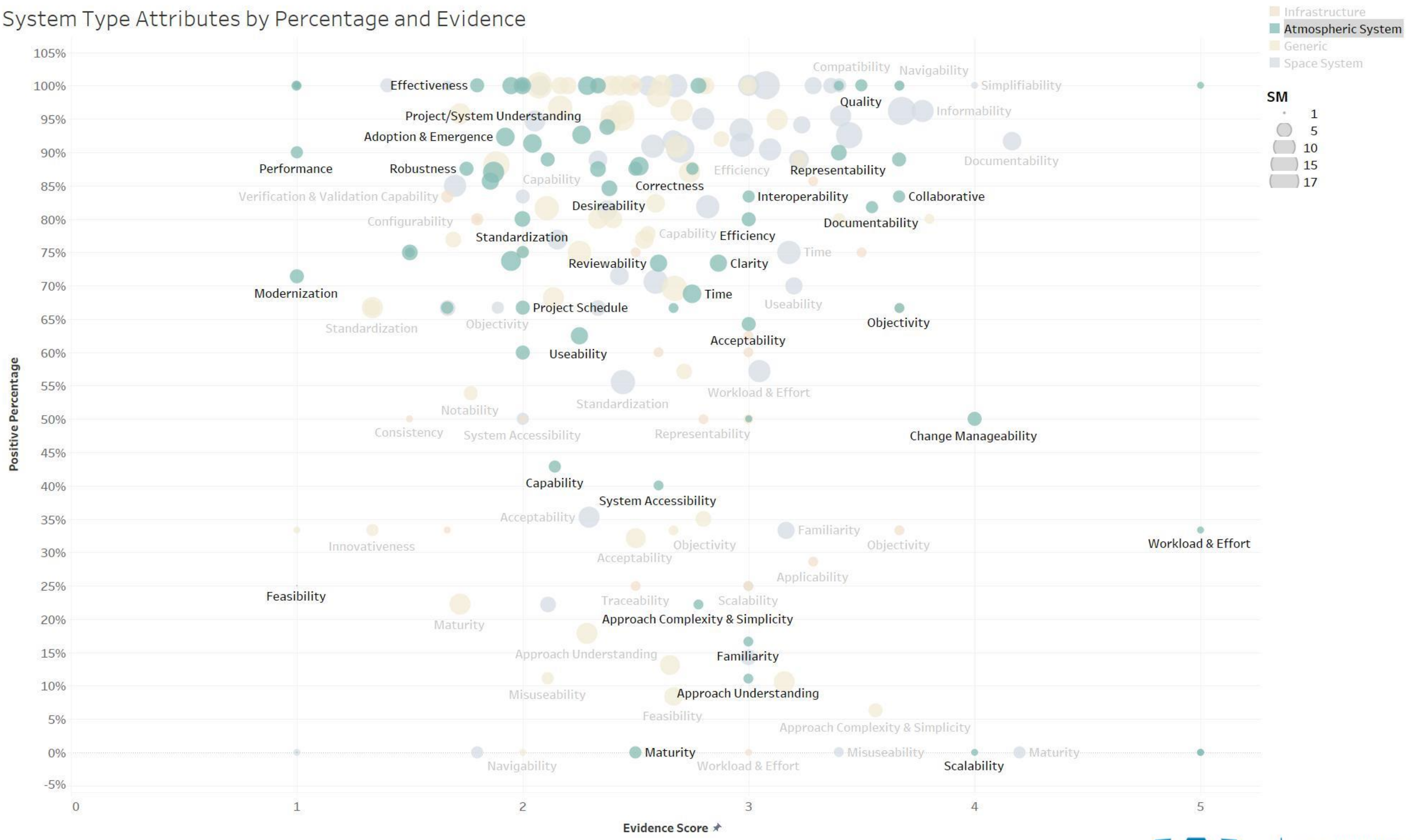
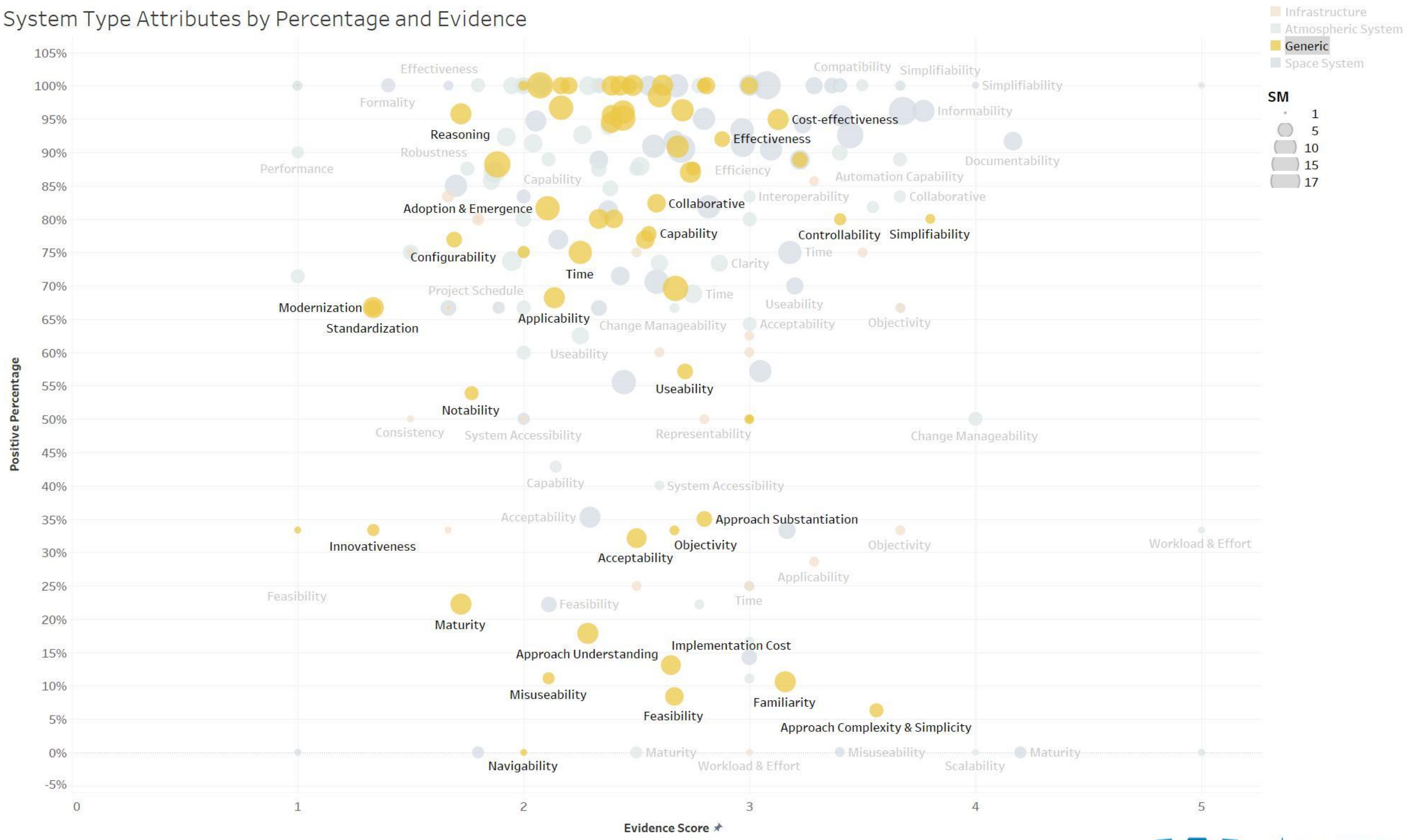


System Type Attributes by Percentage and Evidence



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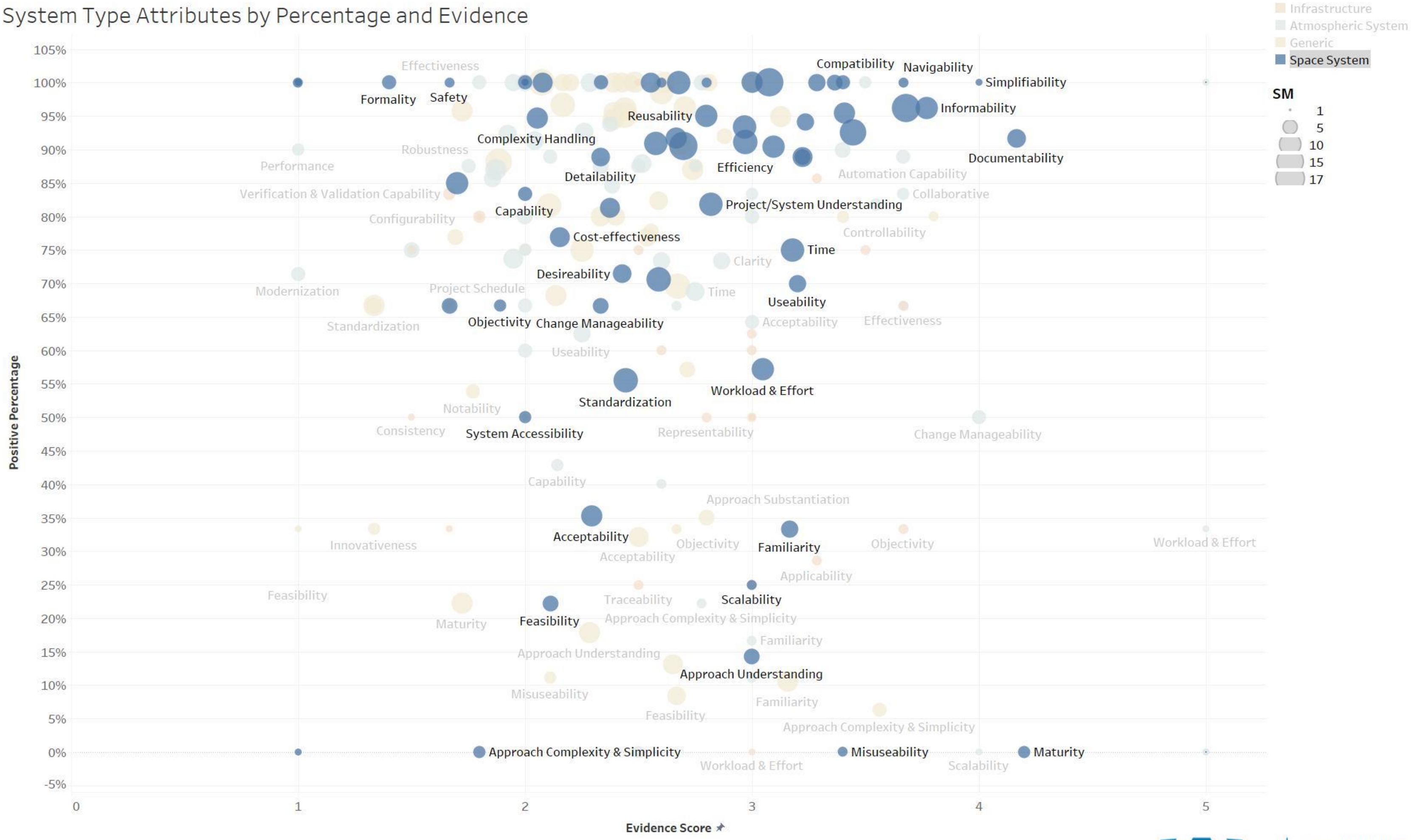
System Type Attributes by Percentage and Evidence



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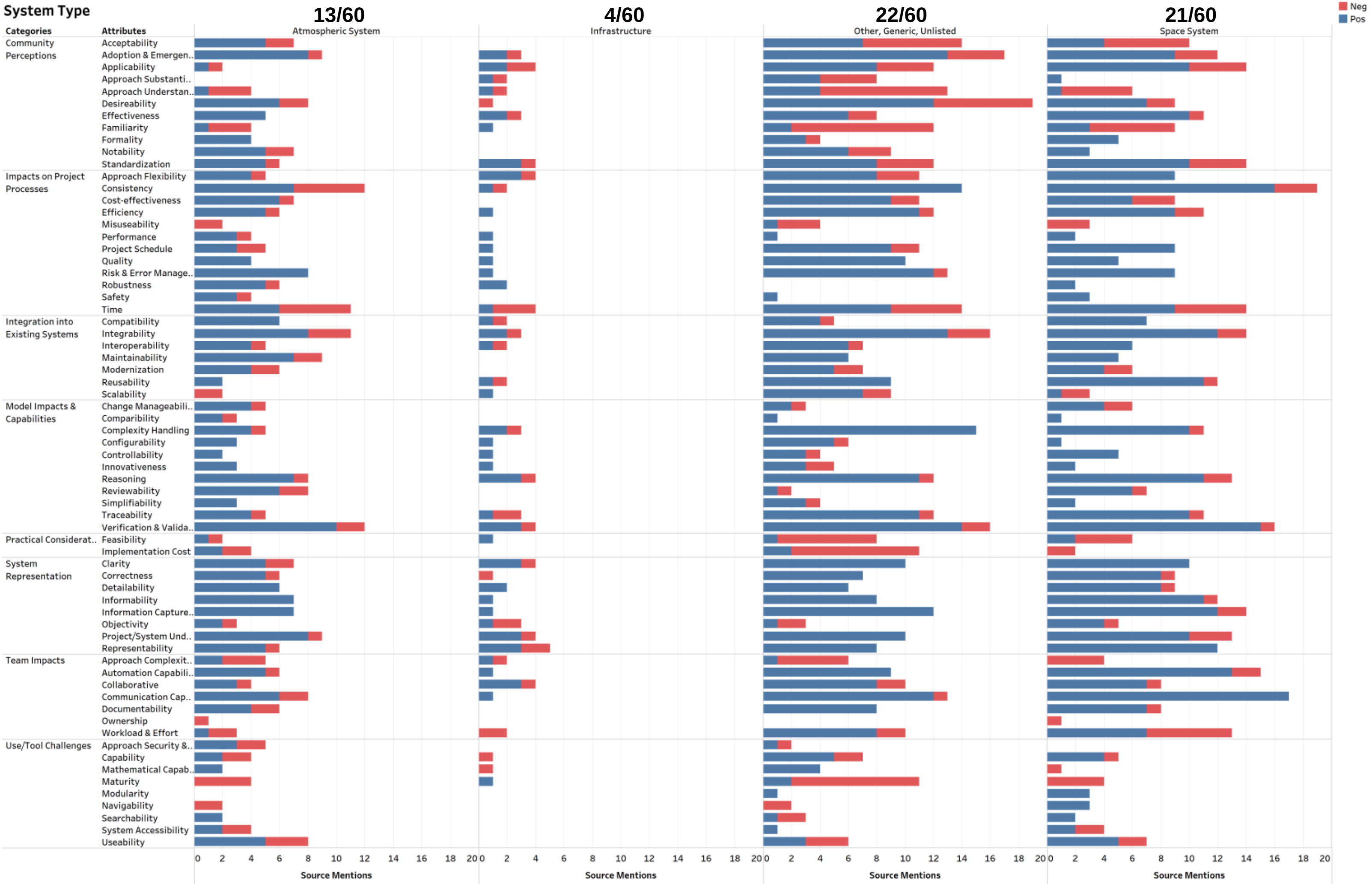
System Type
13/60
Atmospheric System
4/60
Infrastructure
22/60
Other, Generic, Unlisted
21/60
Space System
Neg
Pos
Categories
Attributes
Community Perceptions
Acceptability
Adoption & Emergen..
Applicability
Approach Substanti..
Approach Understan..
Desireability
Effectiveness
Familiarity
Formality
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Objectivity
Project/System Und..
Representability
Team Impacts
Approach Complexit..
Automation Capabili..
Collaborative
Communication Cap..
Documentability
Ownership
Workload & Effort
Use/Tool Challenges
Approach Security &..
Capability
Mathematical Capab..
Maturity
Modularity
Navigability
Searchability
System Accessibility
Useability
0 2 4 6 8 10 12 14 16 18 20
Source Mentions

Space System

Label: Top 2 Neg | Top 2 Pos

Positive Perceptions (%): <20% | 20-40% | 40-60% | 60-80% | >80%

Value

Community Perceptions
- Effectiveness^^
- Applicability
- Familiarity^
- Standardization^^
- Acceptability^
- Familiarity^^^

Impacts on Project Processes
- Approach Flexibility^^
- Consistency^^^
- Efficiency^
- Project Schedule^
- Risk & Error Manageability^^^
- Time^
- Consistency^^^
- Cost-effectiveness^
- Time^^^^
- Misuseability^^

Integration into Existing Systems
- Integrability^^^^
- Reusability
- Integrability^^^^
- Modernization
- Scalability

Model Impacts & Capabilities
- Reasoning^^^
- V&V Capability^^^^
- Reasoning^
- Change Manageability^

Practical Considerations
- Feasibility^^^
- Feasibility^^^^
- Implementation Cost^^^

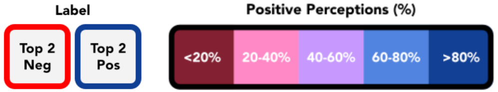
System Representation
- Information Capture Capability^^^
- Representability^^
- Information Capture Capability^
- Project/System Understanding^^^

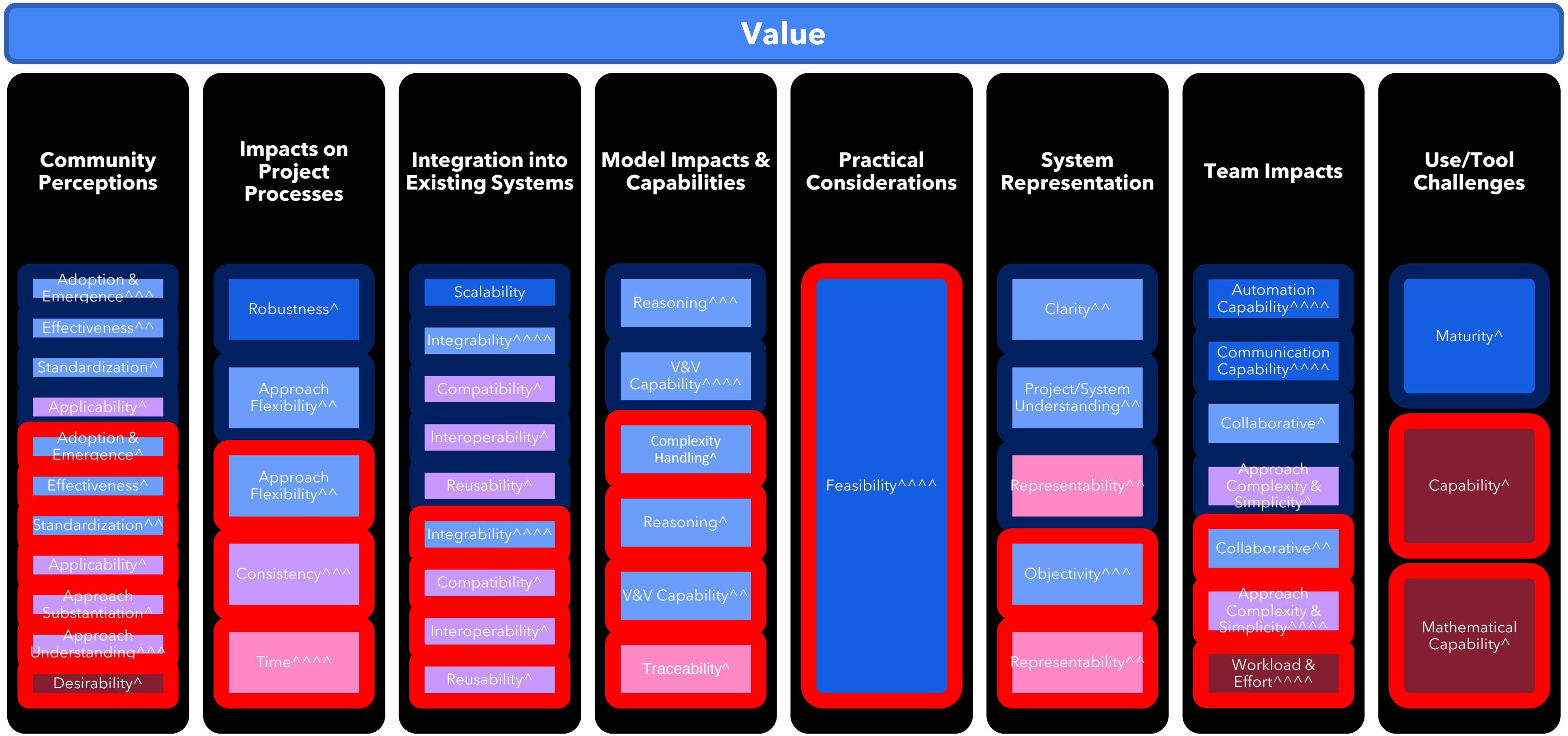
Team Impacts
- Automation Capability^^^^
- Communication Capability^^^^
- Workload & Effort^^^^
- Approach Complexity & Simplicity^^^^

Use/Tool Challenges
- Capability
- Useability^^
- Useability^^^
- System Accessibility^
- Maturity^^^

*Attributes shown are the Top 2 in each category either positively or negatively

Infrastructure





*Attributes shown are the Top 2 in each category either positively or negatively

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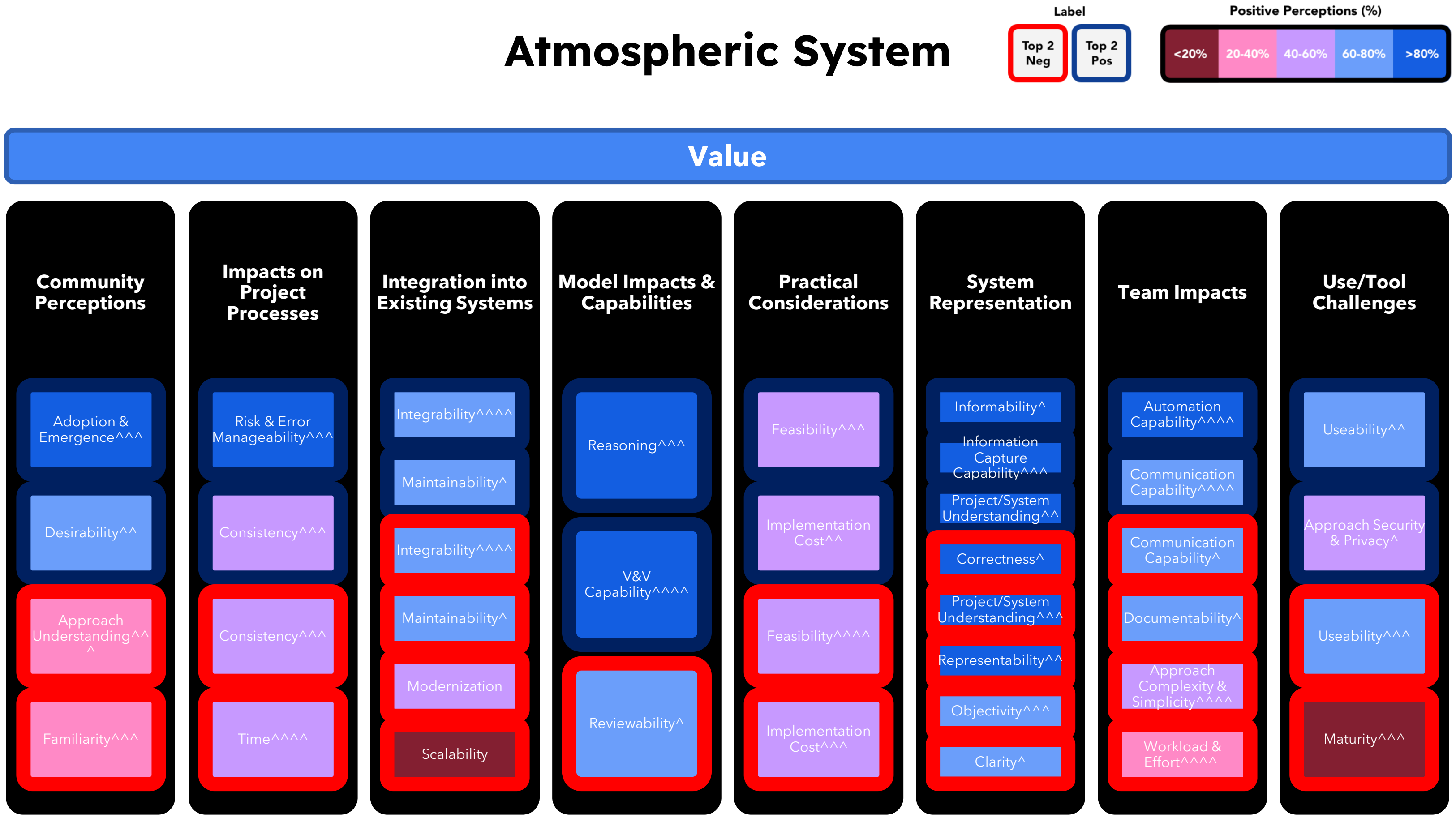
Atmospheric System



*Attributes shown are the Top 2 in each category either positively or negatively

Other, Generic, Unlisted

Label: Top 2 Neg | Top 2 Pos

Positive Perceptions (%): <20% | 20-40% | 40-60% | 60-80% | >80%

Value

Community Perceptions	Impacts on Project Processes	Integration into Existing Systems	Model Impacts & Capabilities	Practical Considerations	System Representation	Team Impacts	Use/Tool Challenges
Adoption & Emergence^^^	Consistency^^^	Reusability	Complexity Handling^	Implementation Cost^^	Clarity^^	Automation Capability^^^^	Mathematical Capability^
Desirability^^	Risk & Error Manageability^^^	Integrability^^^^	V&V Capability^^^^	Feasibility^^^	Information Capture Capability^^^	Communication Capability^^^^	Capability
Approach Understanding^^^	Approach Flexibility^^	Integrability^^^^	V&V Capability^^	Implementation Cost^^^	Project/System Understanding^^^	Collaborative^^	Useability^^^
Familiarity^^^	Time^^^^	Modernization	Innovativeness^	Feasibility^^^^	Objectivity^^^	Workload & Effort^^^^	Maturity^^^
	Misuseability^^	Scalability				Approach Complexity & Simplicity^^^^	

*Attributes shown are the Top 2 in each category either positively or negatively

System Type Comparison

Appearance in Models

Neg | Pos

Similar Attributes for System Type Pseudo-Value Models (3/4)

Community Perceptions
- Approach Understanding (3/4)
- Familiarity (3/4)

Impacts on Project Processes
- Consistency (3/4)
- Time (3/4)

Integration into Existing Systems
- Integrability (4/4)
- Reusability (3/4)
- Integrability (4/4)
- Modernization (3/4)
- Scalability (3/4)

Model Impacts & Capabilities
- Reasoning (3/4)
- V&V Capability (4/4)
- V&V Capability (3/4)

Practical Considerations
- Feasibility (3/4)
- Feasibility (4/4)
- Implementation Cost (3/4)

System Representation
- Information Capture Capability (3/4)
- Project/System Understanding (3/4)
- Objectivity (3/4)

Team Impacts
- Automation Capability (4/4)
- Communication Capability (4/4)
- Approach Complexity & Simplicity (4/4)
- Workload & Effort (4/4)

Use/Tool Challenges
- Useability (3/4)

*Attributes shown appear in at least 3 of the system type pseudo-value models. The count shown is for the total positive or negative count for each.

5. Conclusion

MBSE Pseudo-value models

Impacts

- We are providing an aid for considerations for MBSE implementation through pseudo-value models
- Our research may help decision-makers better understand perceptions about MBSE and its impacts on different system types and applications for different organizations

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