THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

Model-Based Systems Engineering: Investigating the Perceptions of Reliability and Maintainability

2021 RAM Student Competition

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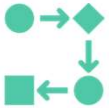
Presentation Outline

Background

What is MBSE?



Methodology

Rigorous Literature Review Process

Results & Discussion

Conclusion & Impacts

MBSE for RAM Engineers

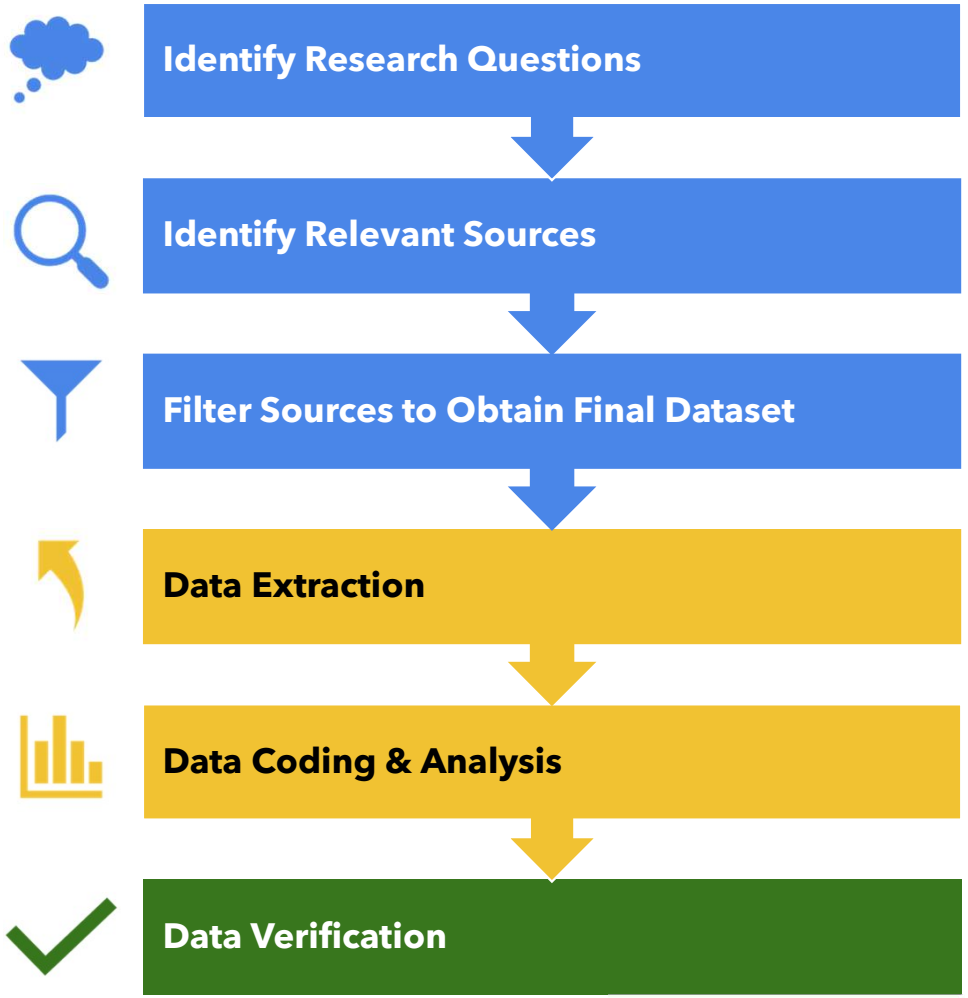
Q/A

Background

Model-Based Systems Engineering (MBSE) is defined as "the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases" (Hart, 2015).

- MBSE is an emerging approach in the field of Systems Engineering
- A potential application of MBSE is for complex systems that often experience challenges in reliability and maintainability

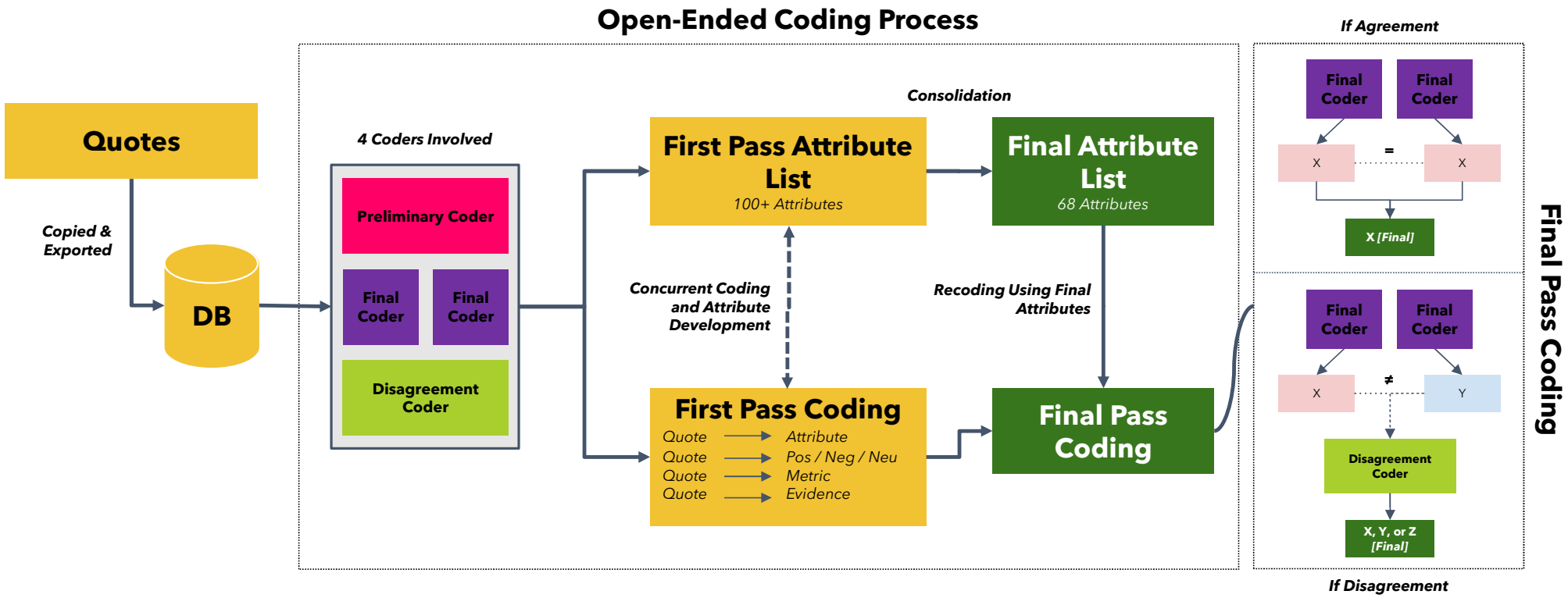
Overview of Methodology



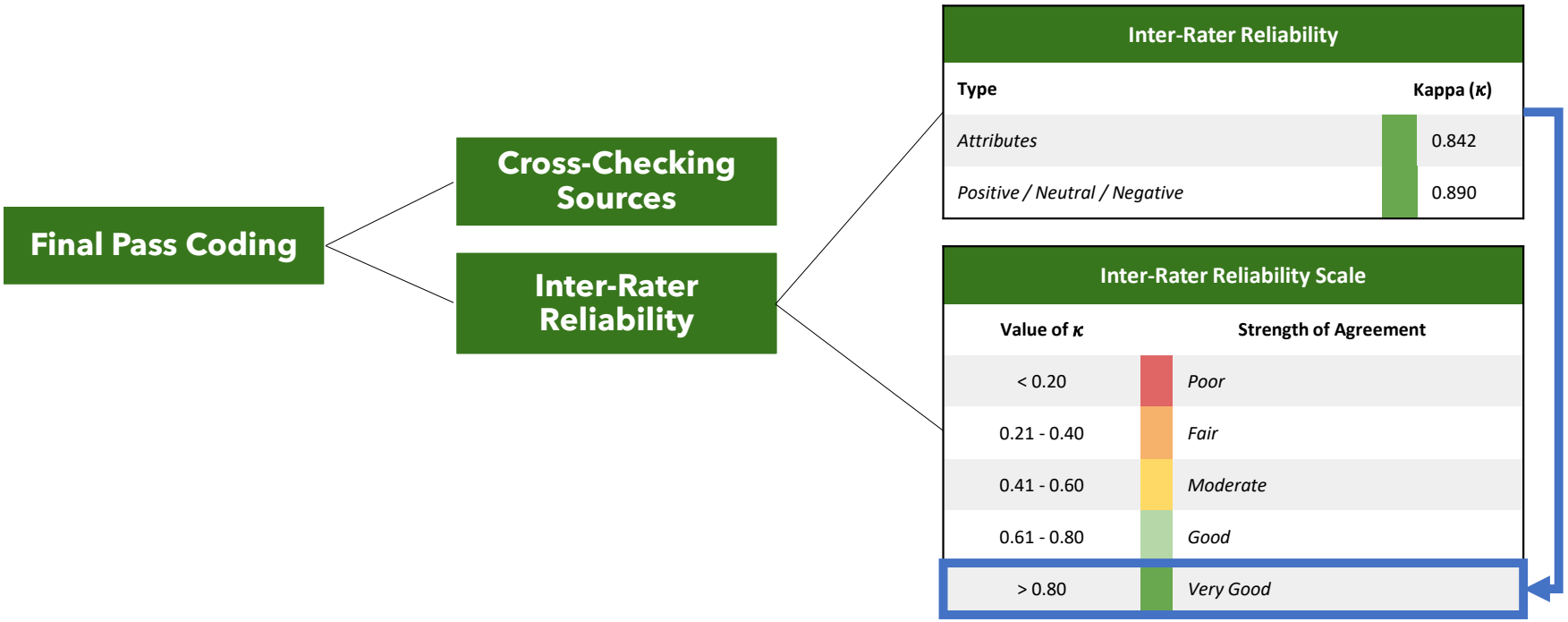
Steps 1-3: Source Identification

* Google, Public domain, via Wikimedia Commons

Steps 4-5: Coding & Analysis



Step 6: Data Verification



Positive, Negative, or Neutral

All quotes were labeled Positive, Negative, or Neutral based on how the attribute describes MBSE or its impact

Code	Example
Positive	MBSE is more efficient than DBSE
Negative	MBSE tools are not mature functionally
Neutral	MBSE will likely be an effective approach for handling complex systems in the future

Attributes

- An ***attribute*** is a quote about MBSE that captures both description and impact
  - A ***description*** is a quote that makes a claim about MBSE
  - An ***impact*** is a quote that makes a claim about the effect of using or implementing MBSE

Attribute	Definition	Description Ex.	Impact Ex.
Maintainability	ability of MBSE to allow for maintenance of the system, including isolating defects or their cause, correct defects or their cause, meet new requirements, make future maintenance easier, or cope with a changing environment, preventing obsoletion	Proactive maintenance	Enhances predictive maintenance, easier to maintain
Consistency	the degree of consistency and dependability present in MBSE methodology and elements	Single source of truth	Consistent system models
Robust	the ability of MBSE to respond to errors, inconsistencies, and mistakes in project and system implementation to continue operation at a constant level or to return to pre-change levels	Robust SysML model	Enabling a robust system, developing a robust analysis capability
Risk & Error Manageability	the ability of MBSE to successfully manage and mitigate risks, and therefore reduce errors	Ability to manage risk	Reduce risk

Evidence

- Type of substantiation used by authors for MBSE quotes
- Code Requirements:
  - Stated in the text what kind of evidence was used
  - Able to infer from context

Evidence	Claims and Results…
Case Study	From a case / pilot study
Referenced	Referenced from one source
Interview	From studies that utilized interviews
Survey	From studies that utilized surveys
Literature Review	Derived from a literature review of sources
Community Viewpoint	Based on widely-held community beliefs
Author Opinion	That are unsubstantiated or stem from author experience and beliefs

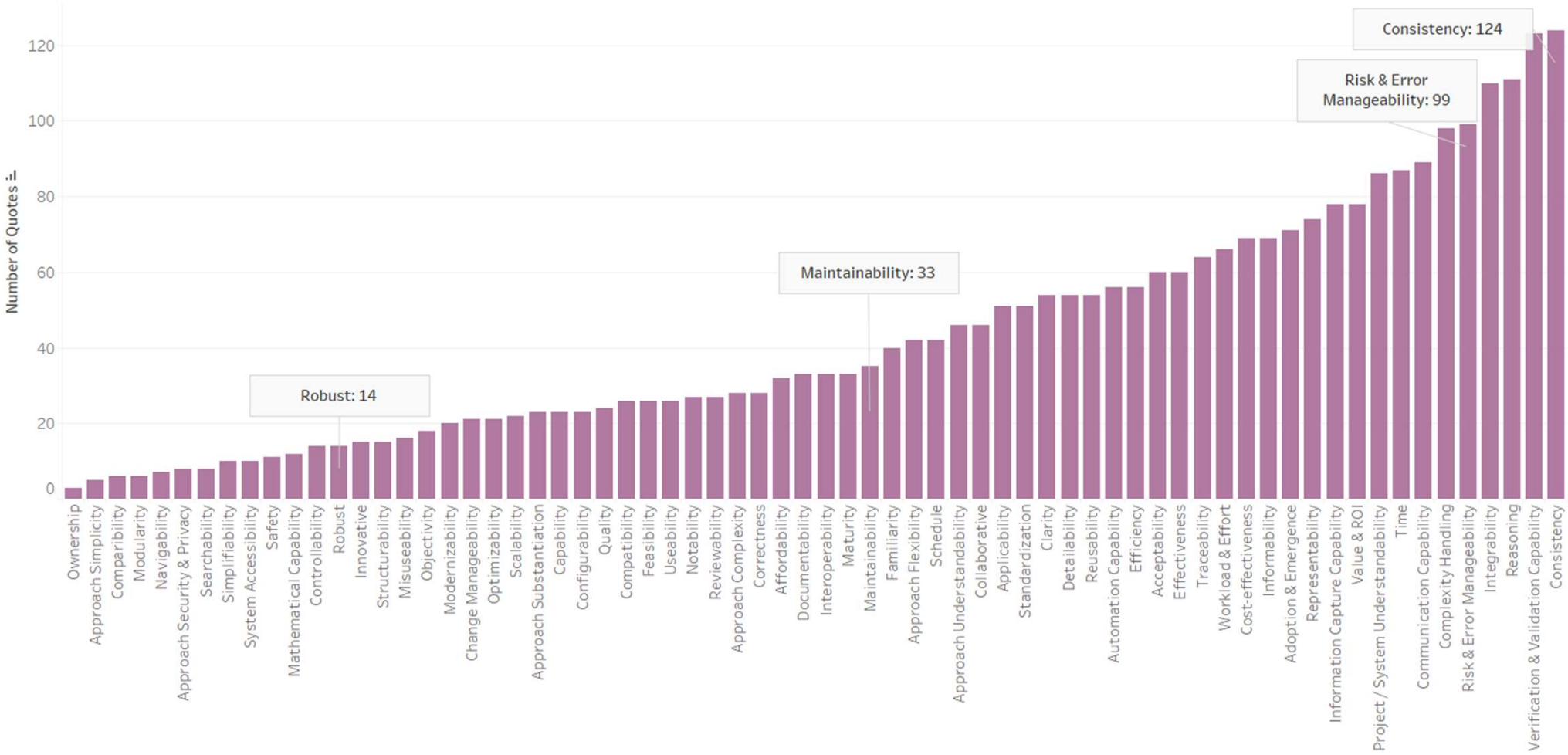
Metrics

- Types of measurable data used to substantiate quotes

- Example 1: “At the same time, [MBSE] aims to **reduce both process and product risks** by ensuring a more precise, complete, and centralized specification of the system design” (Kim et al., 2019).
  - Metric: Risk
- Example 2: “Raytheon found a **68% reduction in specification defects** since MBSE practices were introduced” (Dabkowski et al., 2013).
  - Metric: Defects

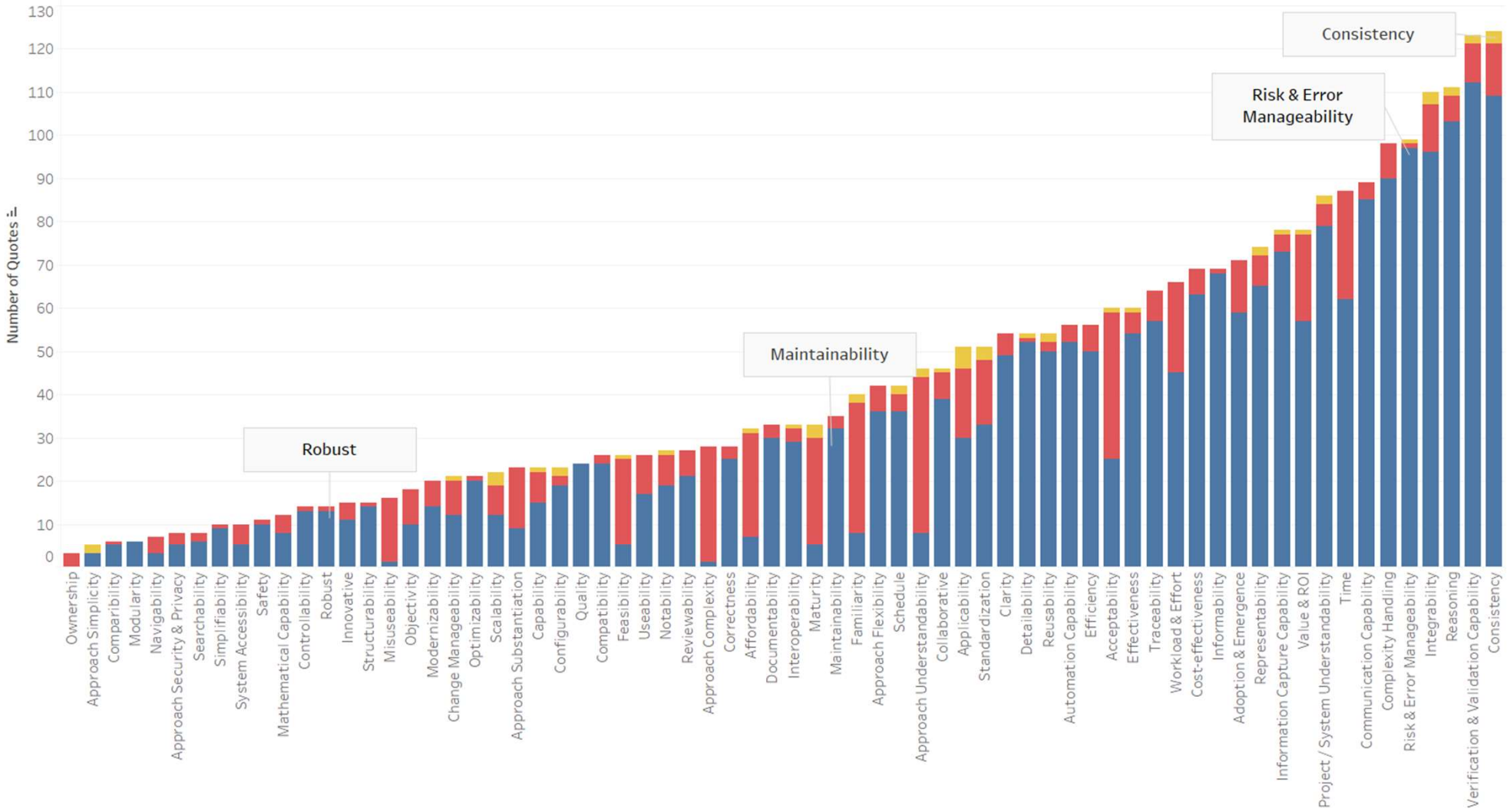
Metrics	
Time	Defects
Cost	Requirements
Risk	Rework
Errors	Miscellaneous
Success and Failures	

Results


Number of Quotes
120
100
80
60
40
20
0
Consistency: 124
Risk & Error Manageability: 99
Maintainability: 33
Robust: 14
Ownership
Approach Simplicity
Comparibility
Modularity
Navigability
Approach Security & Privacy
Searchability
Simplifiability
System Accessibility
Safety
Mathematical Capability
Controllability
Robust
Innovative
Structurability
Misuseability
Objectivity
Modernizability
Change Manageability
Optimizability
Scalability
Approach Substantiation
Capability
Configurability
Quality
Compatibility
Feasibility
Useability
Notability
Reviewability
Approach Complexity
Correctness
Affordability
Documentability
Interoperability
Maturity
Maintainability
Familiarity
Approach Flexibility
Schedule
Approach Understandability
Collaborative
Applicability
Standardization
Clarity
Detailability
Reusability
Automation Capability
Efficiency
Acceptability
Effectiveness
Traceability
Workload & Effort
Cost-effectiveness
Informability
Adoption & Emergence
Representability
Information Capture Capability
Value & ROI
Project / System Understandability
Time
Communication Capability
Complexity Handling
Risk & Error Manageability
Integrability
Reasoning
Verification & Validation Capability
Consistency

Positive, Negative, Neutral

Results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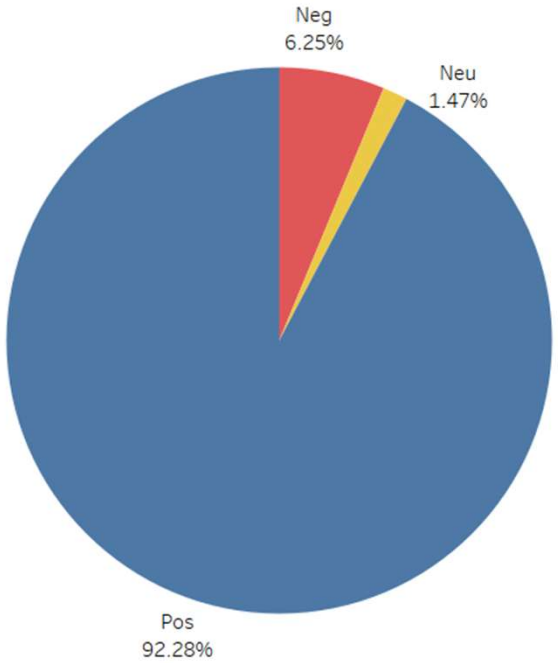
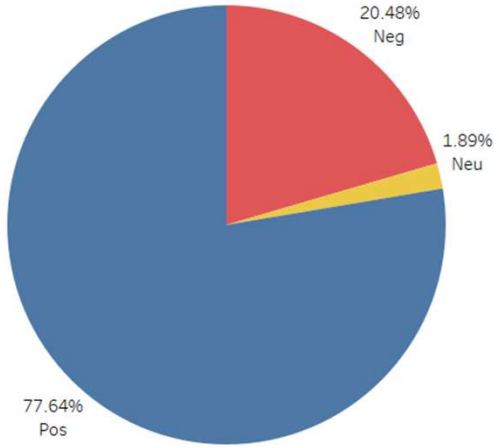
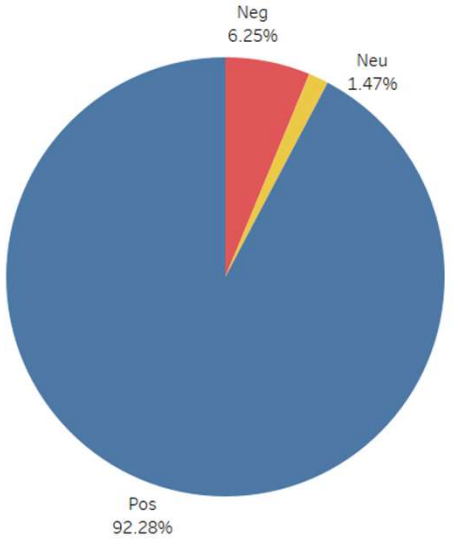
Positive, Negative, or Neutral Percent Distribution



Positive, Negative, or Neutral Percent Distribution RAM Data vs. Other

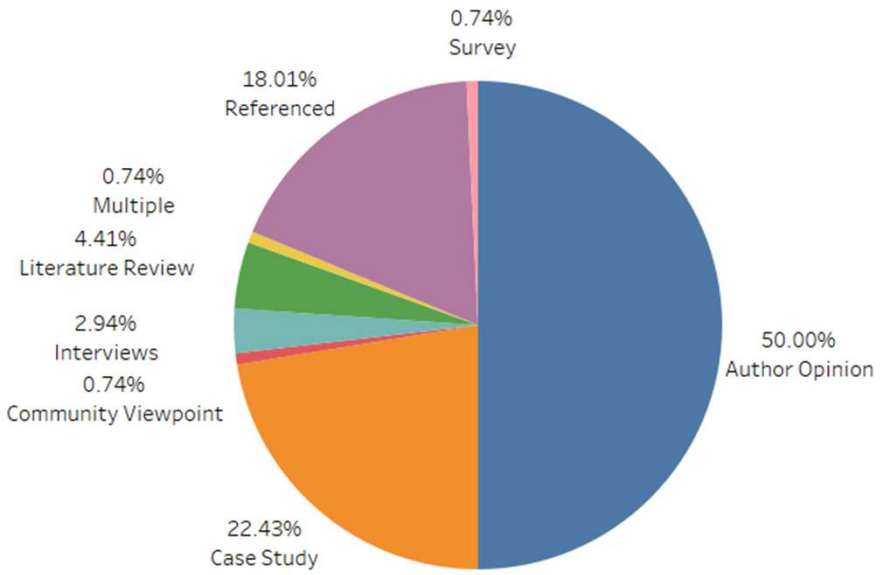




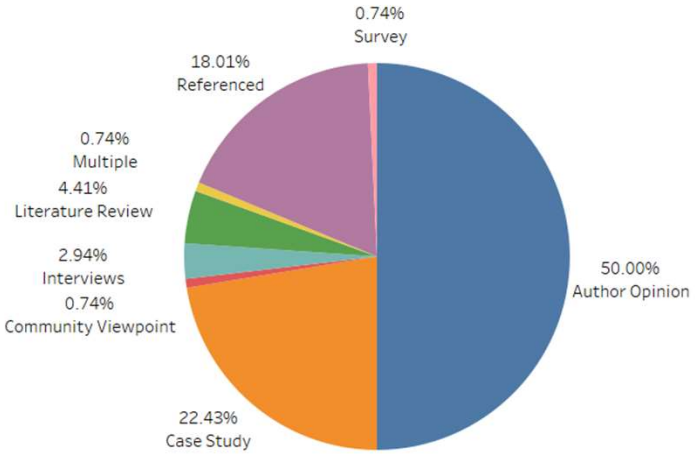
Evidence

Results

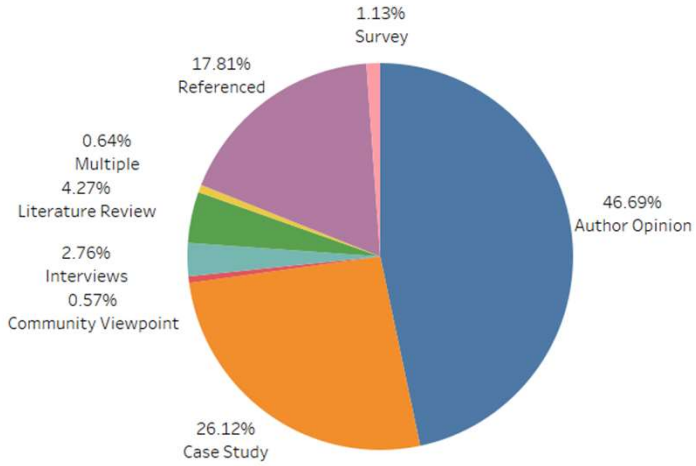
Evidence Percent Distribution



RAM Evidence vs. Other



RAM Data



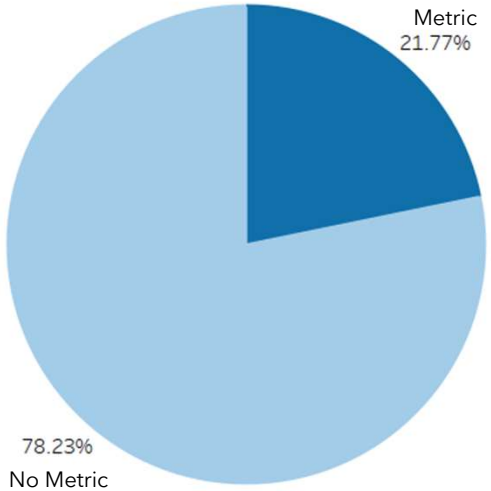
Other

Metrics

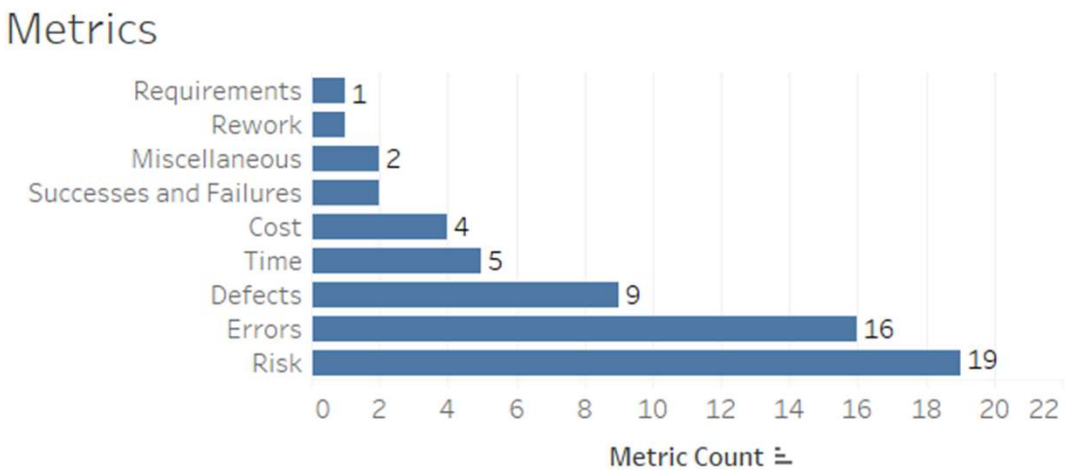
Results

Metrics

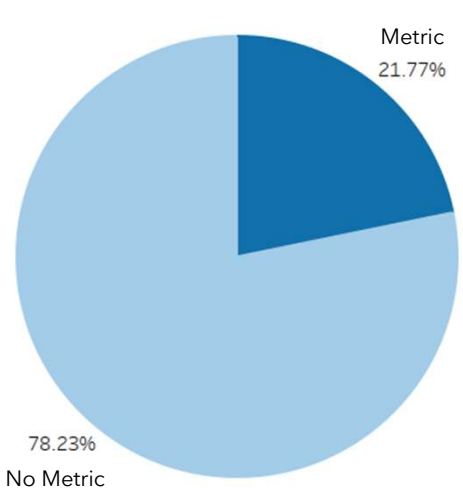
These metrics were measured in association with one of the RAM attributes



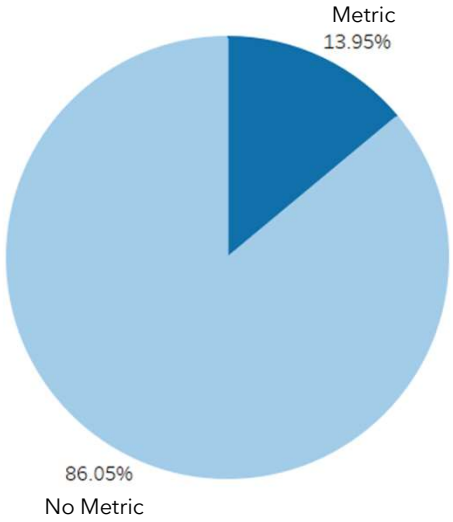
Metric Percent Distribution



RAM Metrics vs. Other



RAM Data

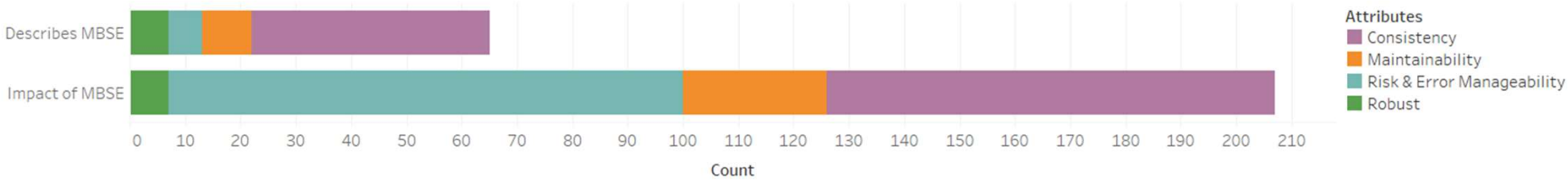


Other

Descriptions vs. Impacts of MBSE

Results

Descriptions vs. Impacts



01

Risk & Error Manageability was the most mentioned impact of MBSE out of the RAM attributes

02

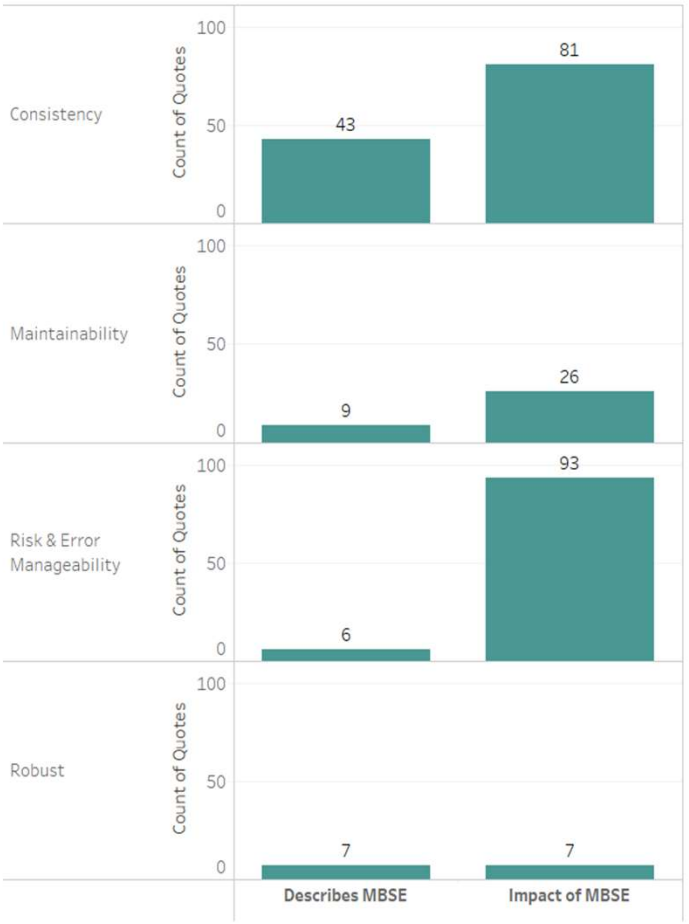
Impacts were mentioned more often than descriptions of MBSE

03

The low count of descriptions may be showing a lack of capability of MBSE – due to MBSE being perceived as an immature approach (75% negative)

Descriptions vs Impacts of MBSE by Attribute

- **Risk & Error Manageability** is perceived to have the highest impact on a system or project
- **Consistency** is the most used attribute to describe MBSE



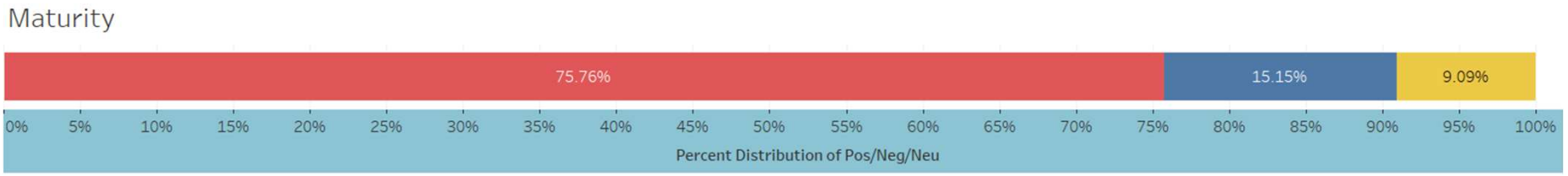
Discussion

RAM Attributes

- Risk & Error Manageability
  - MBSE is perceived to improve Risk & Error Manageability by reducing risk, defects, and errors resulting in a positive impact on the system and project.
- Maintainability
  - MBSE is perceived to help in maintaining a system or project. There were few mentions about MBSE being able to be maintained itself.
- Robust
  - Not much was mentioned about MBSE's ability to be robust or its ability to improve the robustness of a system.
- Consistency
  - MBSE is perceived as consistent and as being able to improve system consistency.

Reliability

- Reliability was not mentioned much in the literature after performing a word search on the data
- This may be because MBSE is a relatively new and may be seen as an immature approach therefore not as reliable



Conclusion & Impacts

- High percentage of positive perceptions of RAM attributes
- These findings can be used to understand what attributes are perceived positively by the SE community
- Risk & Error Manageability and Consistency were perceived to be the most impactful of the RAM attributes
- This data also shows how the SE community is supporting their claims about MBSE and the lack of supporting evidence and metrics

Future Work

Focus on RAM specific sources to evaluate the RAM community's perceptions of MBSE

Analyze sources about MBSE that use more substantial and peer-reviewed data

Questions?

Implementation	Adoption & Emergence	the degree to which <APPROACH> is being implemented by community / company
	Acceptability	likelihood that community / company would want to adopt or implement <APPROACH>
	Notability	distinguishability of the <APPROACH> by the community
	Applicability	appropriateness of <APPROACH> for particular community, purpose, or situation
	Familiarity	the degree to which community is experienced with using / can recognize <APPROACH> or <APPROACH> elements
	Feasibility	the ability of <APPROACH> to be practically implemented by the community/company based on metrics of affordability and other factors
	Approach Substantiation	evidence supporting implementation and/or benefits of <APPROACH>
	Value (ROI)	the worth of an <APPROACH> to a particular community/company in metrics of benefits and return on investment
	Quality	the ability of <APPROACH> to improve the caliber of system elements and/or the final product
Structure & Representability	Correctness	the degree to which <APPROACH> represents elements/values correctly
	Detailability	the degree to which <APPROACH> represents elements/values precisely, rigourously, and in detail
	Consistency	the degree of consistency and dependability present in <APPROACH> methodology and elements
	Standardization	the process of making <APPROACH> implementation conforms to a community standard
	Maturity	the development status of <APPROACH> technology and methods, including the time in implementation and reduction of system problems and bugs, as well as the development of tools
	Representability	the degree to which <APPROACH> can depict, describe, illustrate system elements
	Structurability	the construction or arrangement of <APPROACH> according to a plan, pattern, or defined organization
	Modularity	the degree to which <APPROACH> or <APPROACH> elements can be divided into subcategories
	Scalability	the ability of <APPROACH> and/or <APPROACH> system to be expanded to other projects, situations, etc.
	Approach Complexity	<APPROACH> is difficult to describe, trace, implement, produce products from, etc.
	Complexity Handling	the ability of <APPROACH> to mitigate complexity in model design and other project elements
	Approach Simplicity	<APPROACH> is easy to describe, trace, implement, produce products from, etc.
	Simplifiability	the ability of <APPROACH> to represent the system in a simpler way

Management & Handling	Controllability	the ability of <APPROACH> to allow for an external input (by a user) to move the internal state of a system from **any** initial state to **any** other final state in a finite time interval (i.e, control)
	Configurability	the ability of <APPROACH> to allow for customization of the system to suit project requirements and needs
	Change Manageability	the ability of <APPROACH> to manage configurations, their contents, their lifecycles - in particular, identifying and controlling changes to configurations
		the ability of <APPROACH> to track and provide control over **changes to source code** (i.e., version control)
	Approach flexibility	the ability of <APPROACH> to allow for / adapt to project developments over time
	Robustness	the ability of <APPROACH> to respond to errors, inconsistencies, and mistakes in project and system implementation to continue operation at a constant level or to return to pre-change levels
	Maintainability	ability of <APPROACH> to allow for maintenance of the system, including isolating defects or their cause, correct defects or their cause, meet new requirements, make future maintenance easier, or cope with a changing environment, preventing obsoletion
	Risk & Error Manageability	the ability of <APPROACH> to successfully manage and mitigate risks, and therefore reduce errors
Information & Understandability	Clarity	ability of <APPROACH> to make system/ project elements **visible** to all parties of interest in a way that is coherent and intelligible
	Reasoning	the ability of <APPROACH> to aid in decision making and design based on criteria
	Information Capture Capability	the ability of <APPROACH> to allow for the process of **collecting** paper documents, ideas, elements, changes, etc. and transforming them into accurate, retrievable, digital information, and delivering the information into the system model or database for future use
	Informability	ability of <APPROACH> to present **useful** information about the project/system in a way that is educational, enlightening, etc.
	Documentability	ability of <APPROACH> to allow for project documentation and document generation
	Objectivity	ability of <APPROACH> to develop, present, interpret information without bias
	Approach Understandability	ability of people to understand / learn <APPROACH>; understanding of <APPROACH> and its benefits
	Project / System Understandability	ability of <APPROACH> to facilitate project and system understanding among team members and stakeholders

Modernity	Modernizability	the conversion and rewriting of legacy approaches, software, and established processes to modern <APPROACH> methods, including programming languages, architecture, software libraries, methods, etc.
	Innovative	ability of <APPROACH> to promote new methods, ideas, or products
Performance & Evaluability	Capability	the ability of <APPROACH> to execute a specified course of action
	Optimizability	the ability of <APPROACH> to facilitate performance/productivity at the highest efficiency
	Effectiveness	the degree to which <APPROACH> is successful at producing desired results
	Comparability	the ability of <APPROACH> to analyze the differences between system elements/evolution over time
	Mathematical Capability	the ability of <APPROACH> to allow for mathematical assessment
	Reviewability	whether the internal state variables of the <APPROACH> system can be externally measured, such as approval, system parts, monitoring, etc.
	Verification & Validation Capability	the degree to which <APPROACH> allows for verification, certifiction, testing, and analysis of system, data, etc.
Approach Utilization	Navigability	the ease by which <APPROACH> system models can be traversed
	Misuseability	the ease by which <APPROACH> can be incorrectly used
	Searchability	the ease by which <APPROACH> allows system to be searched
	Useability	the degree to which <APPROACH> allows specific user in a specific context to use a product/design to achieve a defined goal effectively, efficiently and satisfactorily
	Traceability	capability of <APPROACH> to trace course of development from origin to current status; ability to verify the history, location, or application of an item by means of documented record identification
	Reusability	the ability of <APPROACH> to allow for the reutilization of system elements and architecture

Legal & Security	Ownership	the degree to which <APPROACH> relies on model ownership to moderate system access, modification, and integrity of elements
	Approach Security & Privacy	the ability of <APPROACH> to protect against unauthorized system function or software service alterations through abstraction, encryption, etc.
	Safety	the ability of <APPROACH> to protect against danger, risk, or injury
	System Accessibility	the ability of <APPROACH> to allow information sharing about system between various levels of clearance and/or outsiders
Communications	Collaborative	ability of <APPROACH> to promote teamwork
	Communication Capability	ability of <APPROACH> to transmit data and information between team members and/or stakeholders
	Compatibility	the ability of two or more systems or components in <APPROACH> implementation to perform their required functions while sharing the same environment
	Interoperability	the ability of two or more systems (or components) to exchange and subsequently use that information
	Integrability	the ability of <APPROACH> to combine two or more components to form an integrated system, which behaves as the system as a whole is expected to behave
Resources	Efficiency	the degree to which <APPROACH> minimizes costs (labor, monetary, time, etc.) to achieve a desired result
	Affordability	cost of <APPROACH> is the only thing preventing/allowing for implementation by community/company throughout system lifecycle
	Cost-effectiveness	ability of the <APPROACH> create a change in monetary resources
	Schedule	the ability of the <APPROACH> to facilitate rearrangement in the current schedule to make the schedule more time efficient
	Time	amount of time it takes for <APPROACH> to perform various processes
	Automation Capability	ability of <APPROACH> to reduce human input and workload (i.e., perform tasks autonomously)
	Workload & Effort	the amount of effort required to be done by team members using <APPROACH> to achieve expected result