THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

Qualifying the Value of Life-Cycle Process Models to System Development

2021 RAM Training Summit

Thomas Teper, Kelly Campo, Casey Eaton, Bryan Mesmer, PhD

Presentation Overview

Introduction & Background

Methodology

Results & Discussion

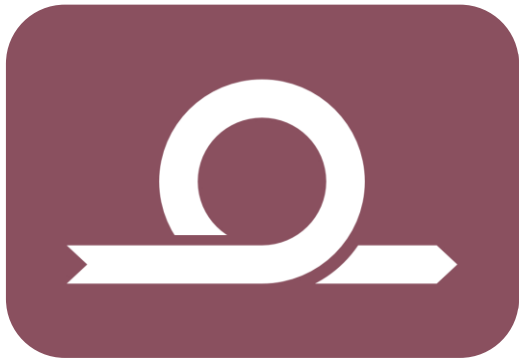
Conclusion

Introduction & Background

Approaches to System Development

- When starting a project, the choice of methodology for managing the life-cycle of system development is vital in directing the project goals and timeline
- The chosen methodology can impact development promoting or limiting flexibility, consistency, innovation capability, maintainability, etc.
- Understanding the benefits and drawbacks of these life-cycle methodologies can help decision-makers determine the applicability to their project goals

Life-Cycle Models



Agile

Spiral

Vee

Waterfall

Agile Model

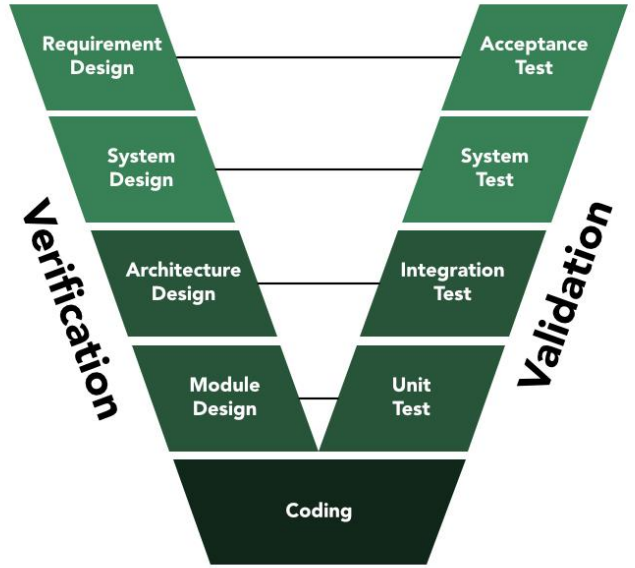
- Agile is an approach to system life-cycle development that prioritizes incremental and timely deliveries of software
- Agile methods typically abide by the principles laid out in the Agile Manifesto, prioritizing face-to-face collaboration, simplicity, team self-organization, flexibility, etc.

Spiral Model

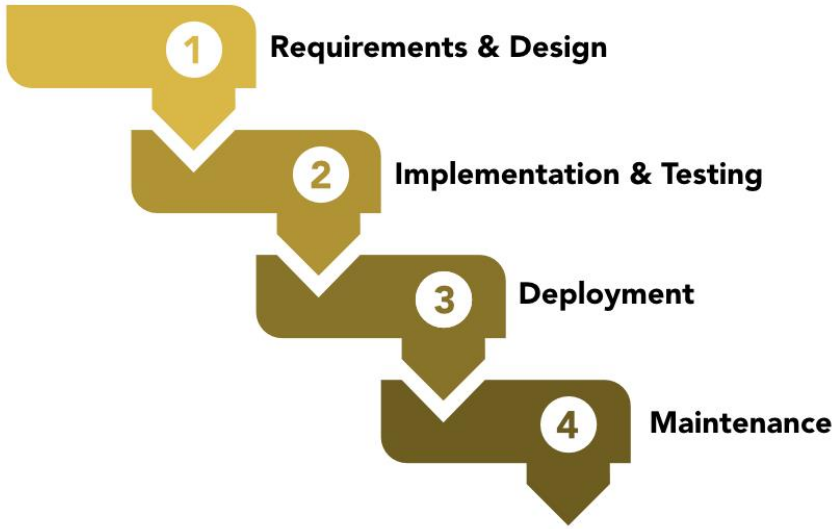
- Spiral is an iterative approach to software system development that prioritizes risk-handling and allows for the ability to evolve by progressing outwards along the spiral
- Progress is measured by the angular dimension through the spiral, while cost is measured by the radial dimension

Vee Model

- Vee is an approach to system development that sequentially progresses through plans, specifications and products, while simultaneously analyzing risk and validating the product
- This is a very structured approach that doesn't typically offer much flexibility and evolution capability



Waterfall Model



- Waterfall was one of the foundational life-cycle models, focusing on system development through a linear sequence; it is utilized on software and hardware projects
- It is a rigid but simple process, which is usually present in some form in other life-cycle process phases, such as Spiral

Project Goal

- Each model offers benefits to specific applications, but each is also limited by various factors, such as flexibility or rigidity, consistency, maintainability, etc.
- Important for decision-makers to holistically understand the benefits and drawbacks of these models in order to better achieve their project goals
- Systematic literature review of 41 academic sources

Methodology

Overview


Step 1
Source Identification
Step 2
Data Extraction
Step 3
Coding Process
Step 4
Analysis

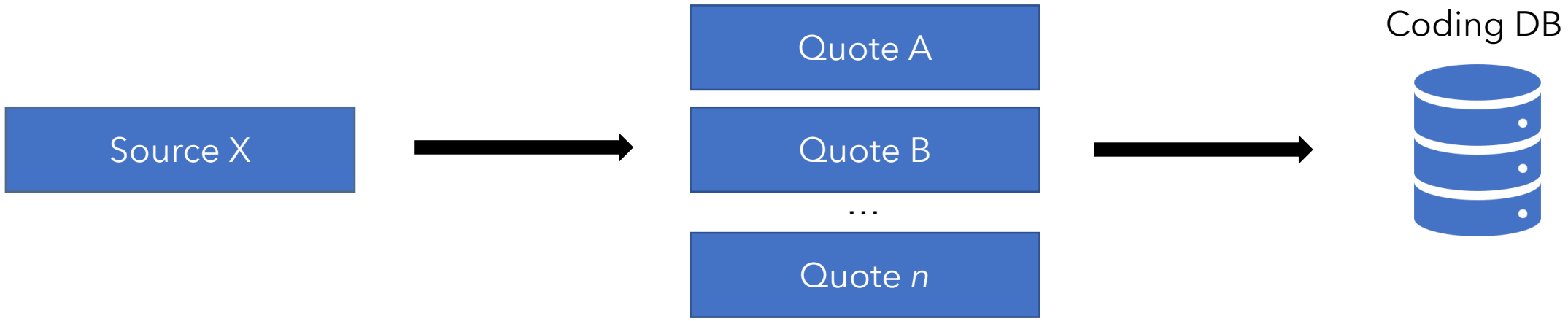
Step 1: Source Identification

- We used Google Scholar to identify literature for this study
- Using neutral search terms, we were able to identify 41 sources that described all four process models
- Each of these sources was categorized by the lifecycle approach they primarily discussed
- The distribution of sources per approach is as follows:

Life-Cycle Model	Number of Sources
Waterfall	10
Vee	10
Spiral	10
Agile	11

Step 2: Data Extraction

- For each source, we read through the material and when we came across a description about the lifecycle model, we extracted it into a database
- We aggregated quotes about the methodologies and labeled relevant attributes, such as approach type, source number, etc.
- These quotes were all formatted for the coding process



Step 3: Coding Process

- 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 the process model (e.g., Consistency, Maintainability, Robustness, etc.)	"[Agile] possesses the ability to successfully deliver result [sic] **quickly** and **inexpensively** on **complex projects** with ill-defined requirements." [5.08]
Positive and Negative (P/N)	A tag that categorizes whether a quote is positive or negative towards process model	
Evidence (EVID)	A tag that categories the level of substantiation an author uses to back up a claim made about the model	

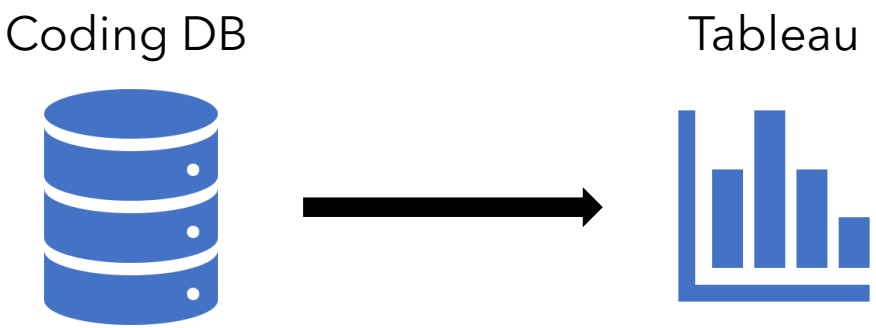
ATTR:	Time
P/N:	Positive
EVID:	Author Opinion

ATTR:	Cost-Effectiveness
P/N:	Positive
EVID:	Author Opinion

ATTR:	Complexity Handling
P/N:	Positive
EVID:	Author Opinion

Step 4: Analysis

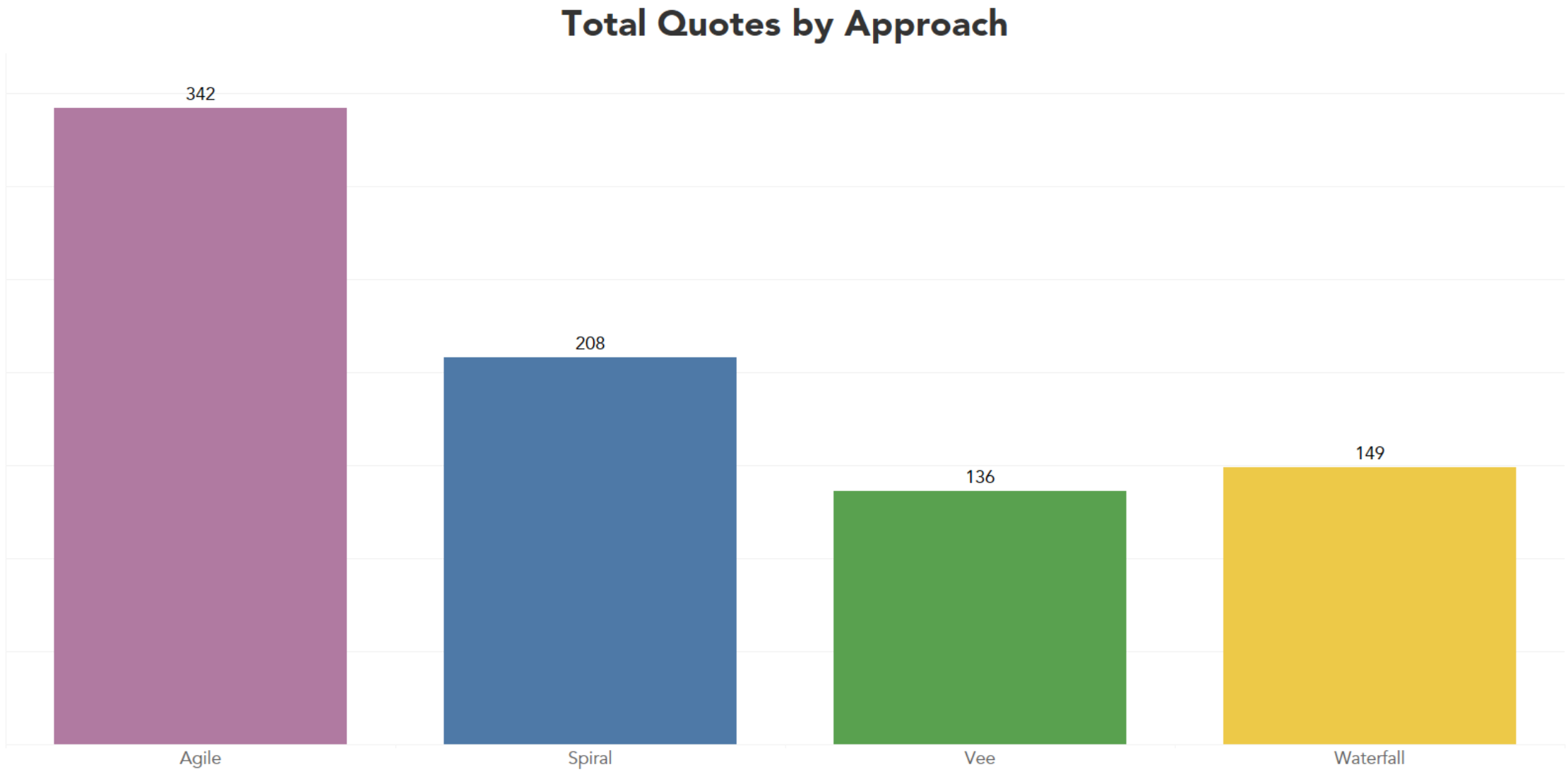
- Once all the quotes had been coded, we exported this data to Tableau for further analysis
- From there, we were able to develop visual depictions of this qualitative data

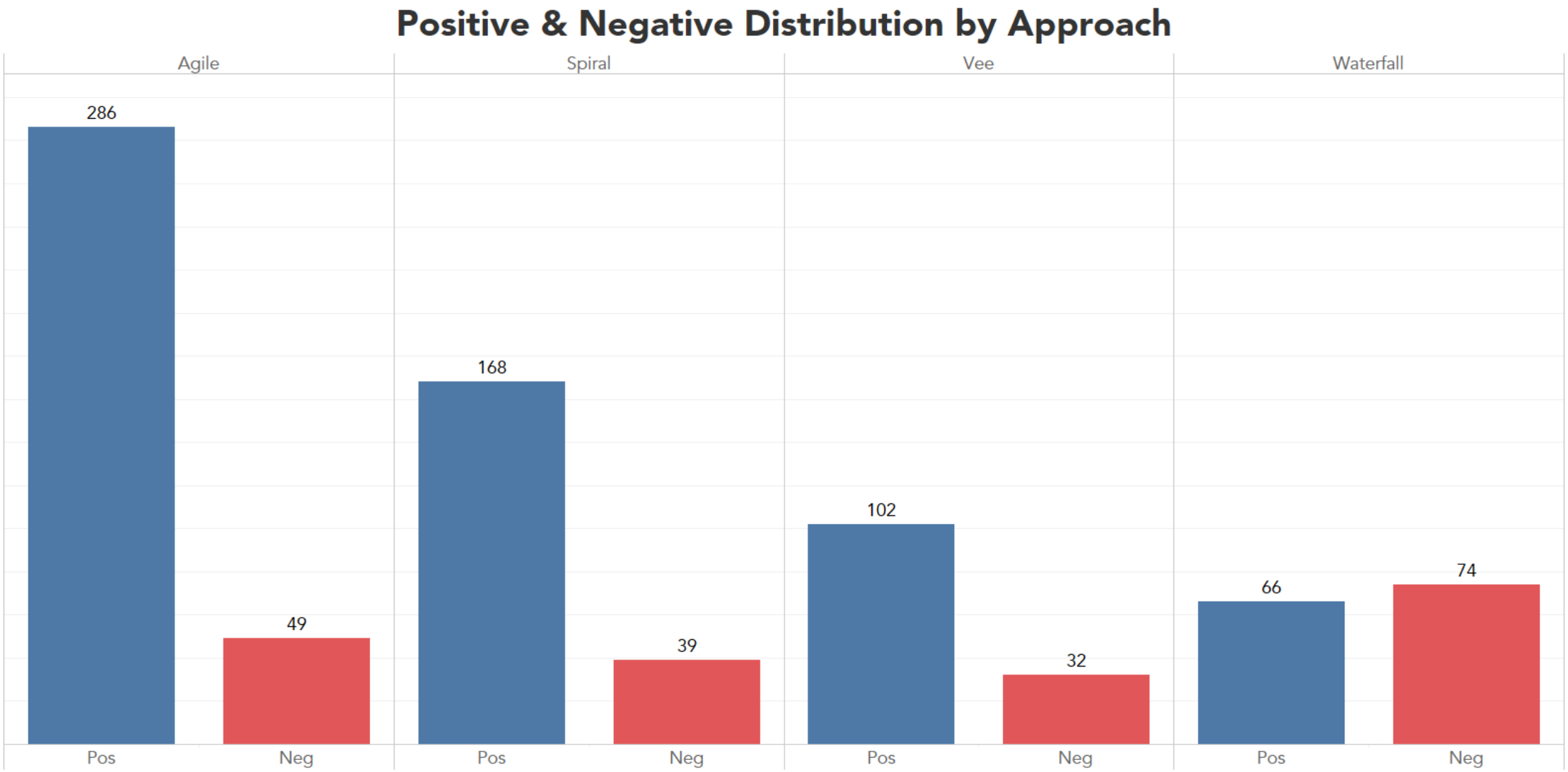


Results & Discussion

Overview

Results & Discussion


Total Quotes by Approach
342
208
136
149
Agile
Spiral
Vee
Waterfall


Positive & Negative Distribution by Approach
Agile
Spiral
Vee
Waterfall
286
49
168
39
102
32
66
74
Pos
Neg
Pos
Neg
Pos
Neg
Pos
Neg

Attribute Categories

Results & Discussion

What is an Attribute Category?

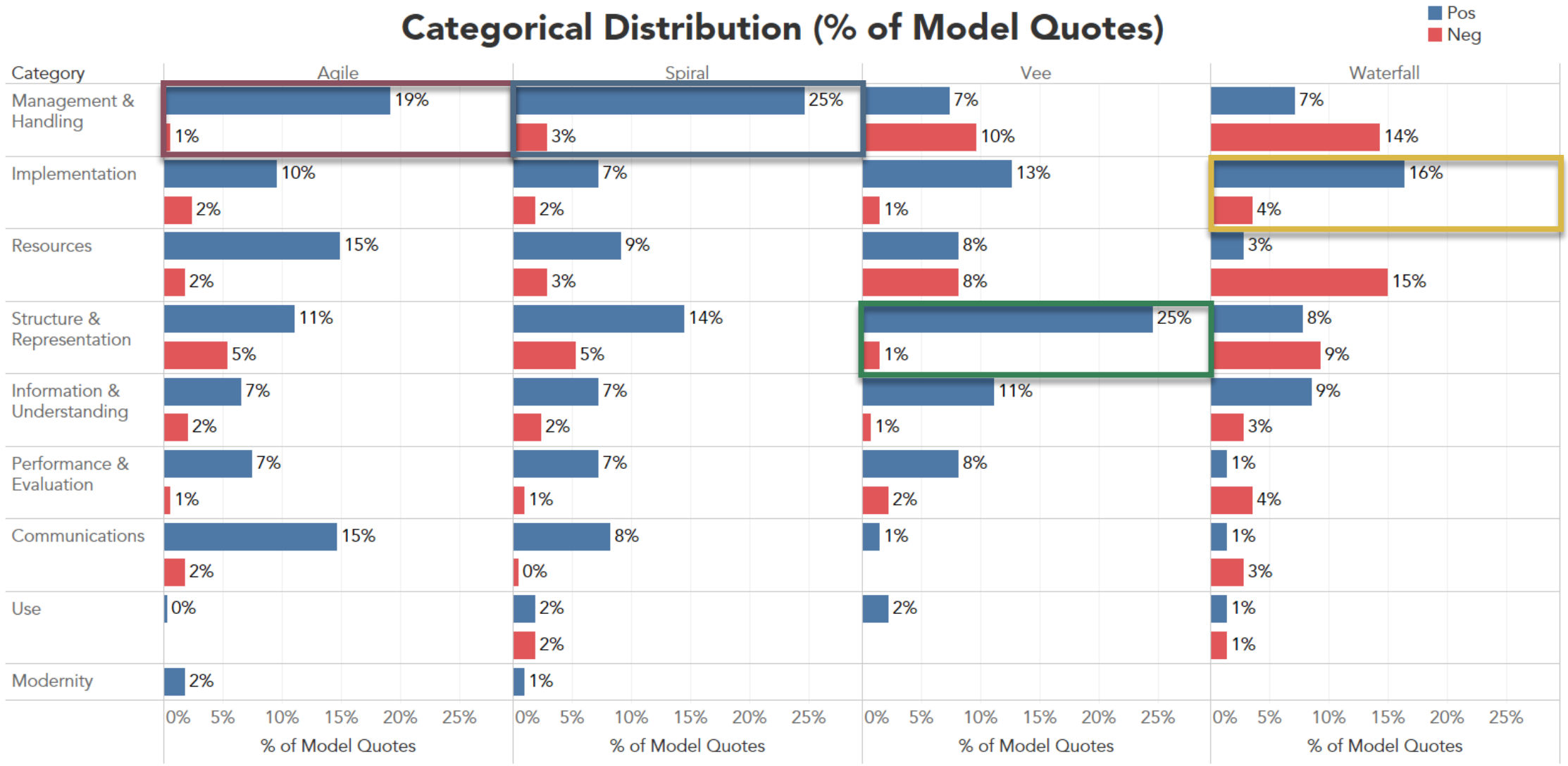
- An **attribute** is a tag that captures a specific description or impact of a process model (e.g., "Spiral allows for *innovative* product development" [ATTR: Innovative])
- An **attribute category** is a collection of attributes, which are grouped by similarity; for example:

Category	Attributes
Management & Handling	Approach Flexibility
	Risk & Error Manageability
	Maintainability
	Controllability
	Change Manageability
	Configurability
	Robustness

Why use categories?

- High-level view of what aspects of each life-cycle model are perceived positively and negatively
- This study has 10 categories:
  - Management & Handling
  - Implementation
  - Resources
  - Structure & Representation
  - Information & Understanding
  - Performance & Evaluation
  - Communications
  - Use
  - Modernity

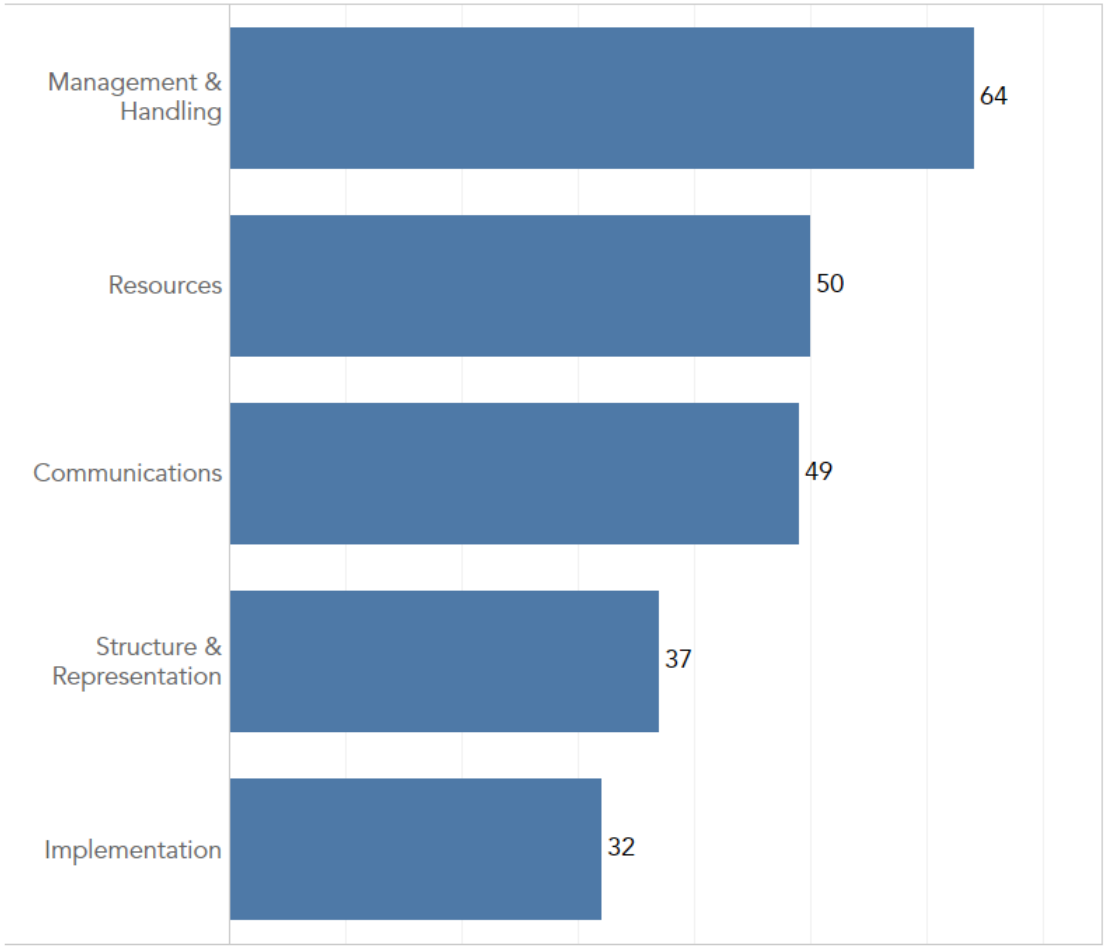
Categorical Distribution



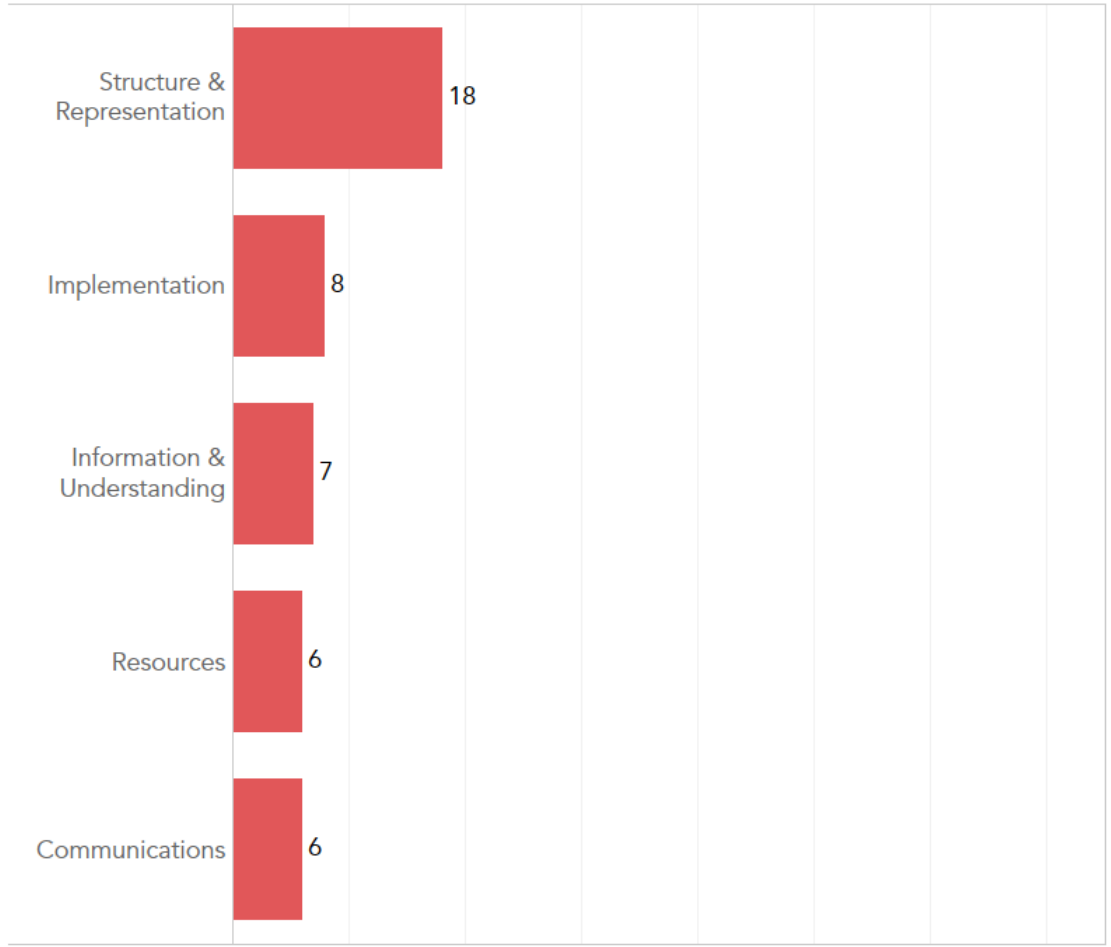
Agile Analysis

Agile Distribution

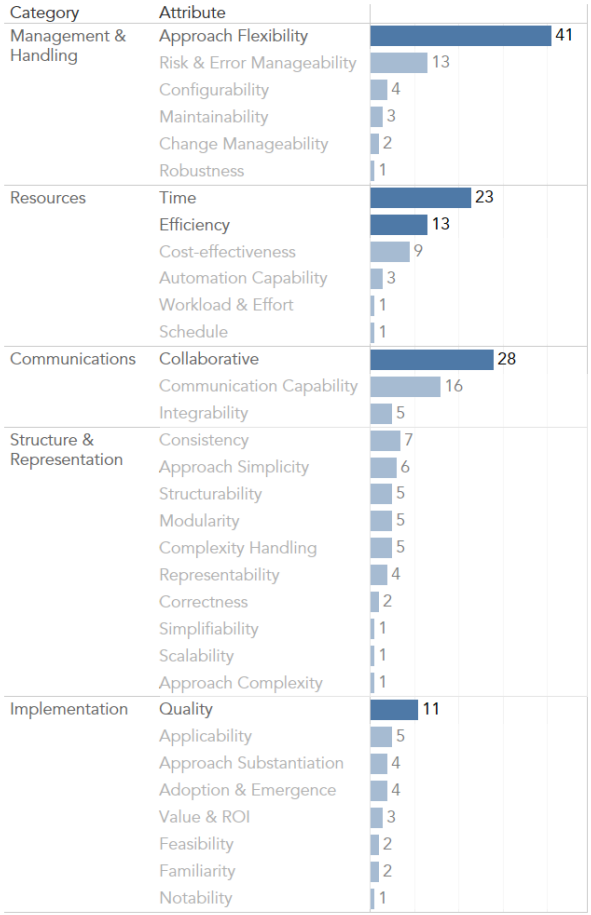
Top 5 Positive



Top 5 Negative



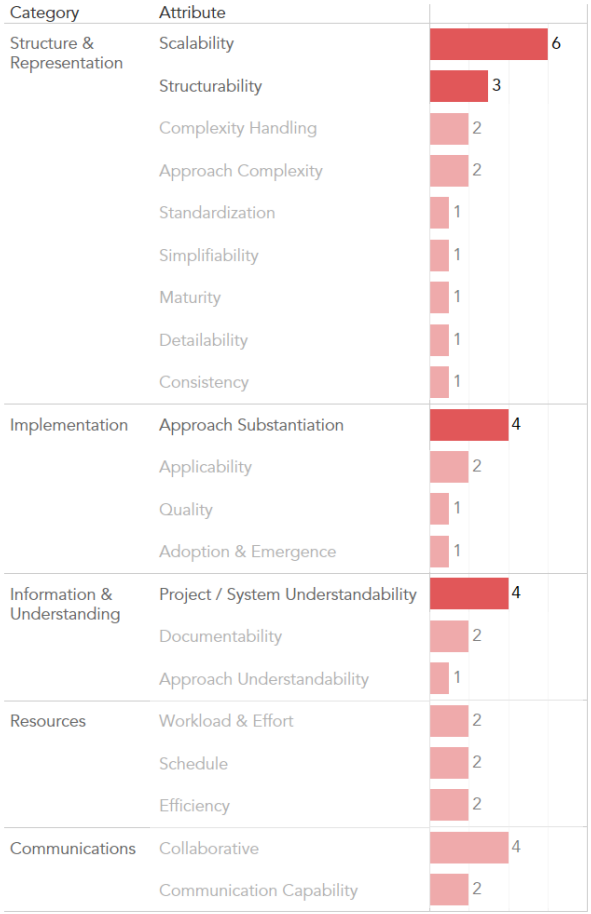
Positives of Agile



Agile is positively perceived for its…

- **Core flexibility and promotion of collaboration**
  - Because of the focus on short development cycles, Agile emphasizes quality at each step and the incorporation of new changes and ideas
  - Teams self-organize and work closely together, leading to the improvement of team member skills
- **Good time management and efficiency**
  - Short iterative development cycles allow rapid production
  - Core features can be added quickly, and new features can be developed in later sprints

Negatives of Agile



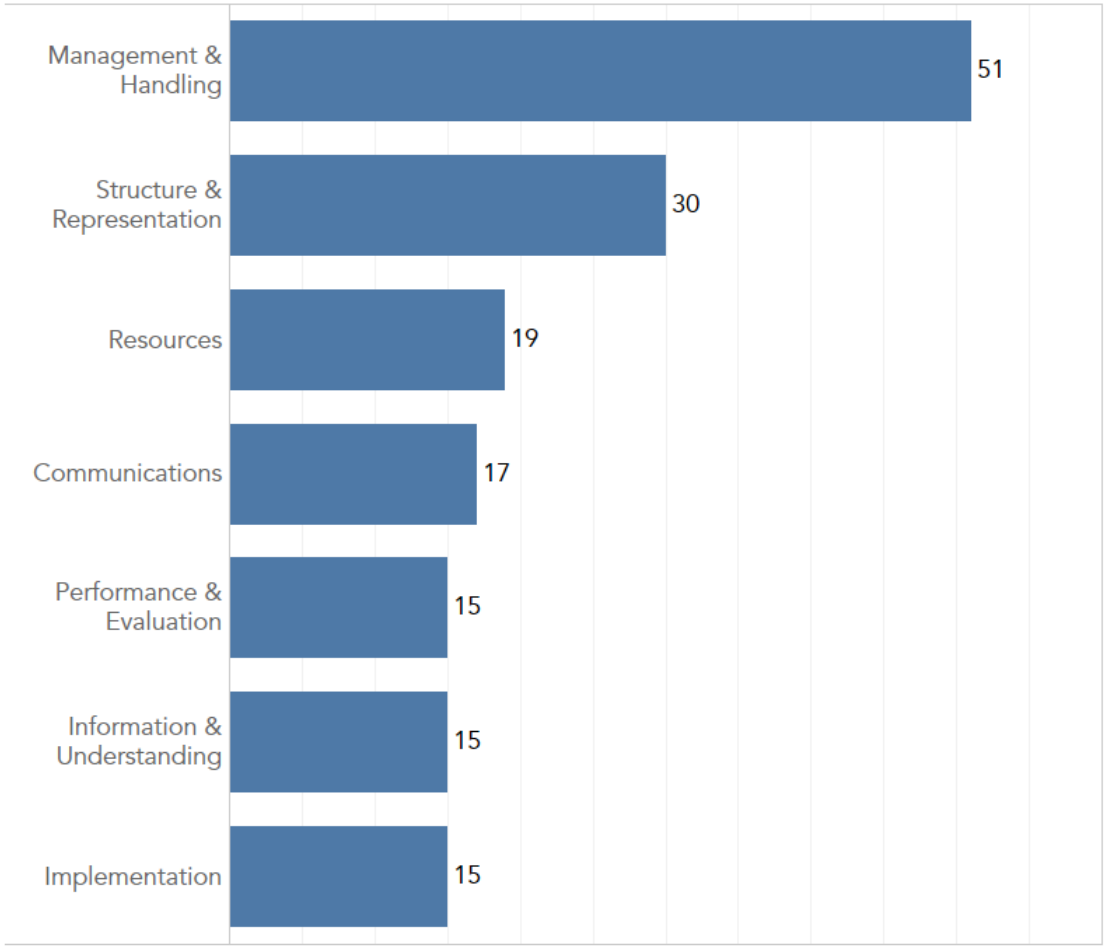
Agile is negatively perceived for its…

- **Project scalability limitations**
  - Typically seen as ideal for small projects and unsuitable for large, complex projects
- **Lack of structure**
  - Key strength of flexibility is also its downfall
  - Teams typically self-organize and lack a hierarchical team leader; thus, they lose perspective of the larger project goal
  - This can lead to a loss of focus and the development of gimmick features that can result in bloated software, known as *feature creep*

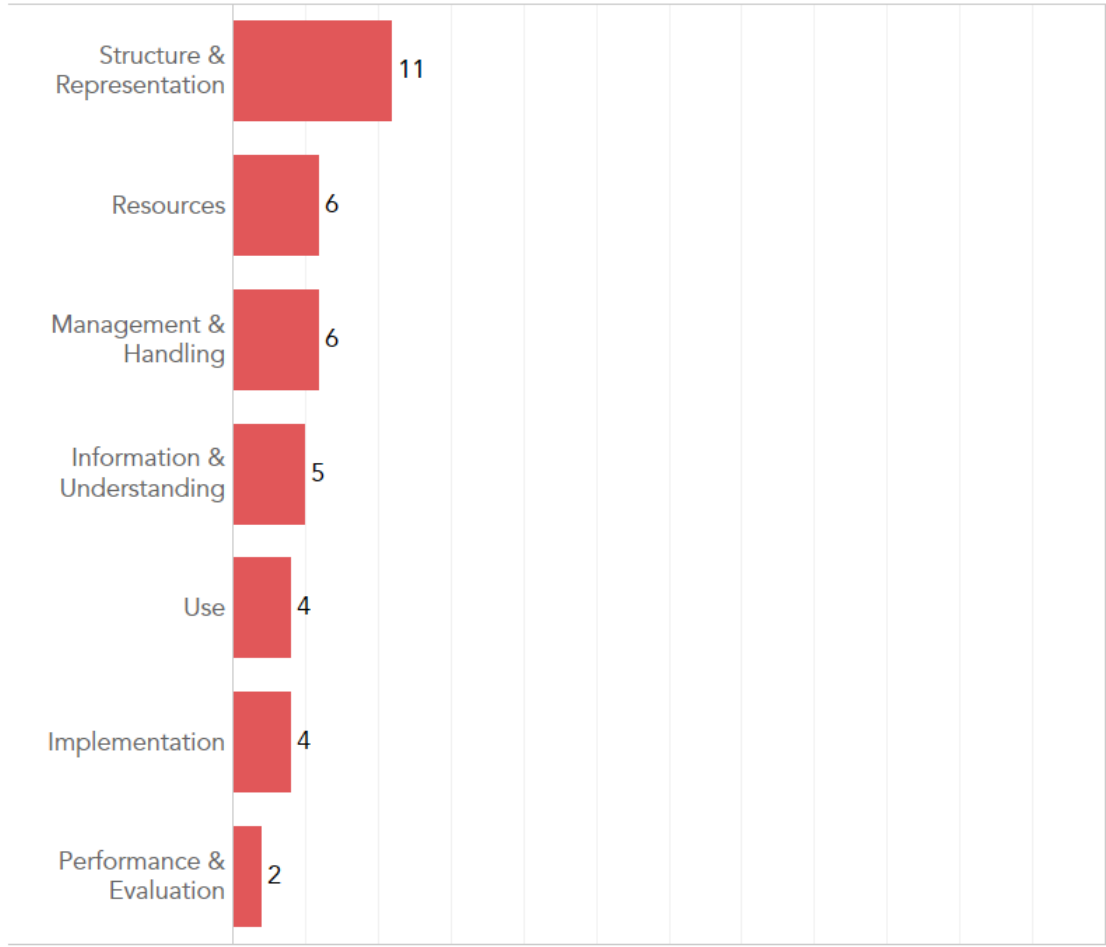
Spiral Analysis

Spiral Distribution

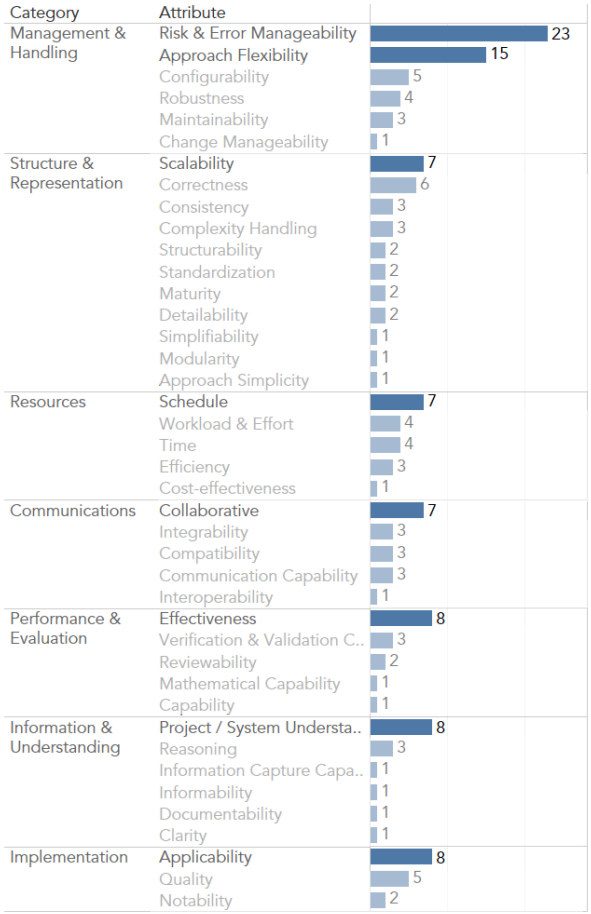
Top 7 Positive



Top 7 Negative



Positives of Spiral

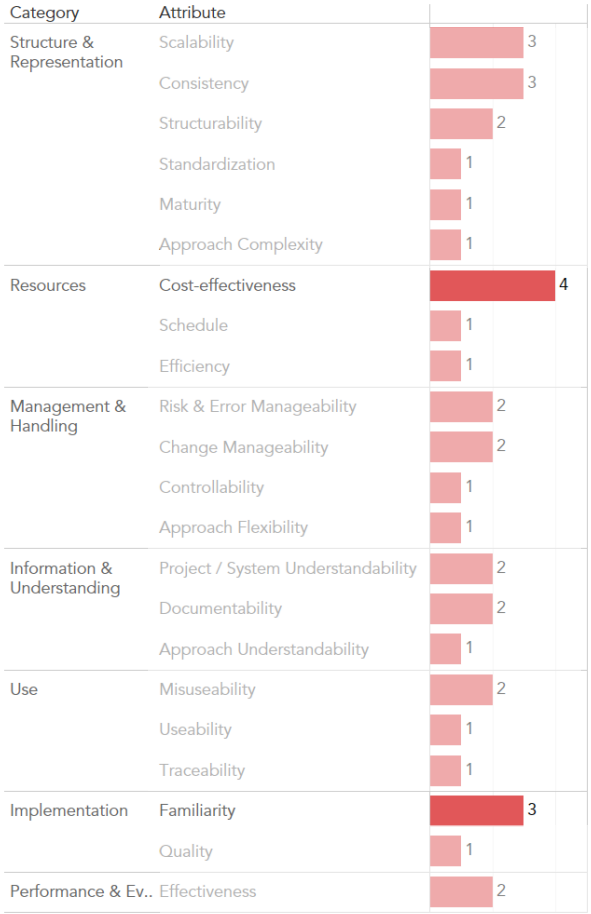


Category	Attribute	
Management & Handling	Risk & Error Manageability	23
	Approach Flexibility	15
	Configurability	5
	Robustness	4
	Maintainability	3
	Change Manageability	1
Structure & Representation	Scalability	7
	Correctness	6
	Consistency	3
	Complexity Handling	3
	Structurability	2
	Standardization	2
	Maturity	2
	Detailability	2
	Simplifiability	1
	Modularity	1
	Approach Simplicity	1
Resources	Schedule	7
	Workload & Effort	4
	Time	4
	Efficiency	3
	Cost-effectiveness	1
Communications	Collaborative	7
	Integrability	3
	Compatibility	3
	Communication Capability	3
	Interoperability	1
Performance & Evaluation	Effectiveness	8
	Verification & Validation C..	3
	Reviewability	2
	Mathematical Capability	1
	Capability	1
Information & Understanding	Project / System Understa..	8
	Reasoning	3
	Information Capture Capa..	1
	Informability	1
	Documentability	1
	Clarity	1
Implementation	Applicability	8
	Quality	5
	Notability	2

Spiral is positively perceived for its…

- **Ability to effectively manage risk**
  - As teams progress through the spiral, there is a constant assessment and reassessment of project risk
  - The flexibility of the process also allows for continuous evolution of the product as requirements and team composition change
- **Applicability to small and large projects**
  - Spiral's structure allows for its expansion from small, simple projects to very large projects with high complexity
  - Its flexibility and iterative development can lead to broad applications in industry

Negatives of Spiral

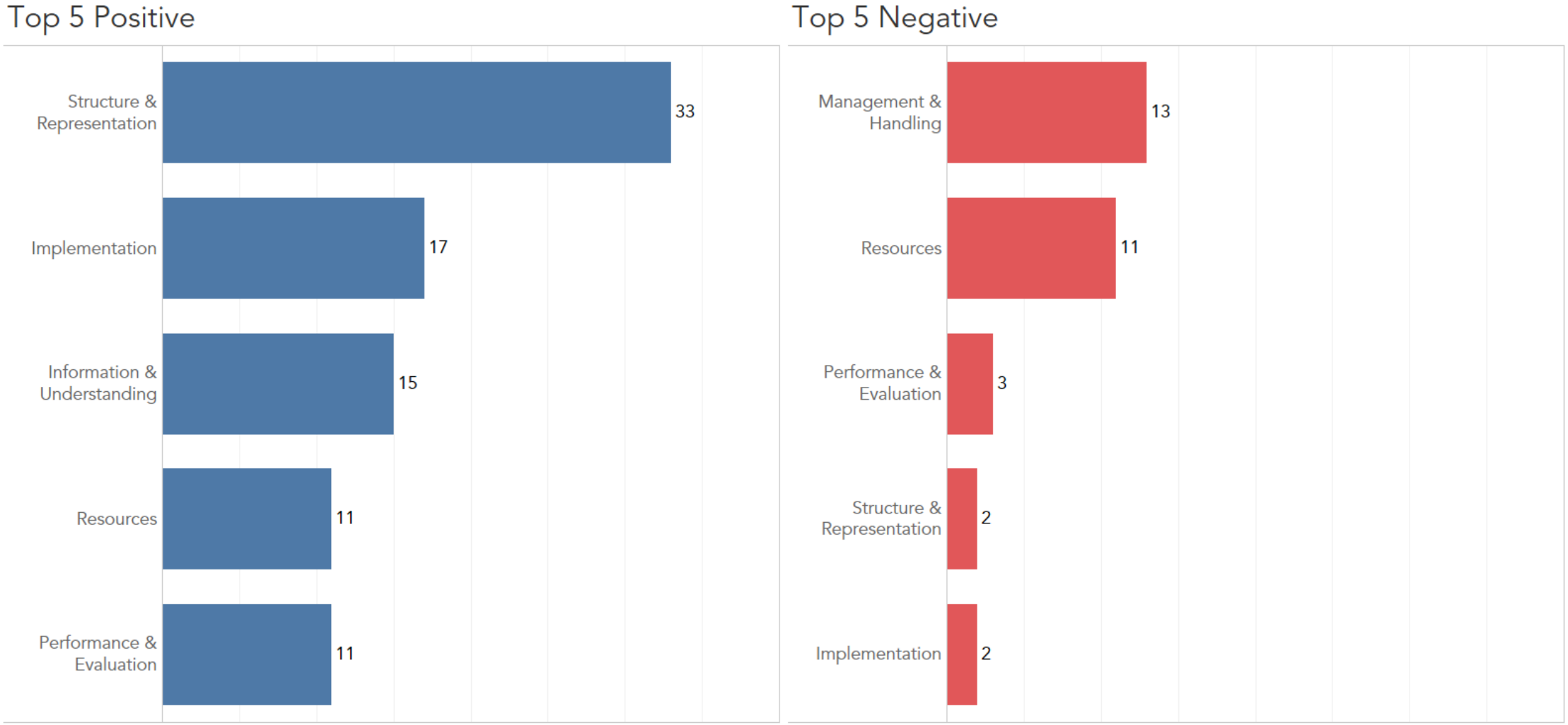


Spiral is negatively perceived for its…

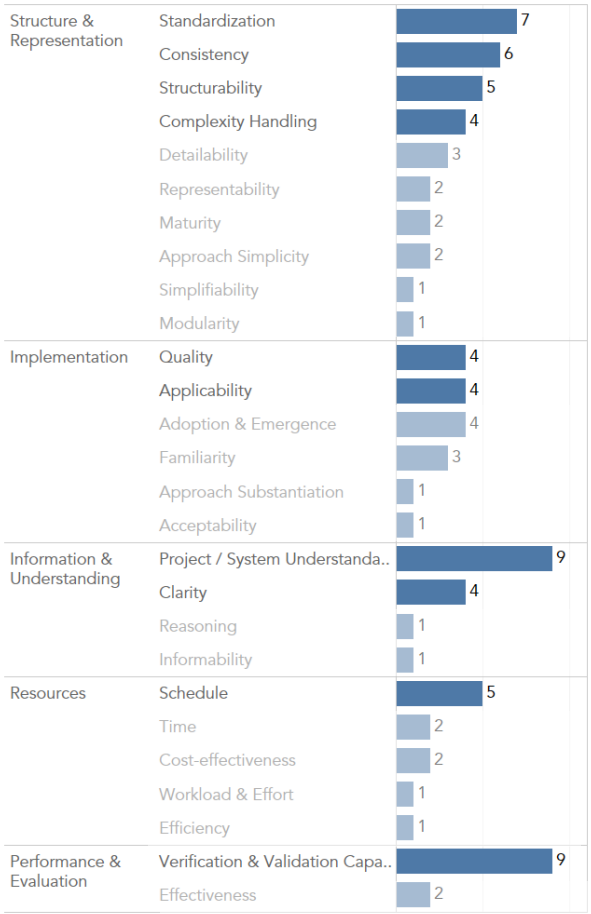
- **Cost of development**
  - This is often due to the required risk-analysis and unpredictable cost assessments
- **Required level of expertise**
  - Again, this is typically due to risk-analysis, which requires experience and understanding of the project scope and original requirements

Vee Analysis

Vee Distribution



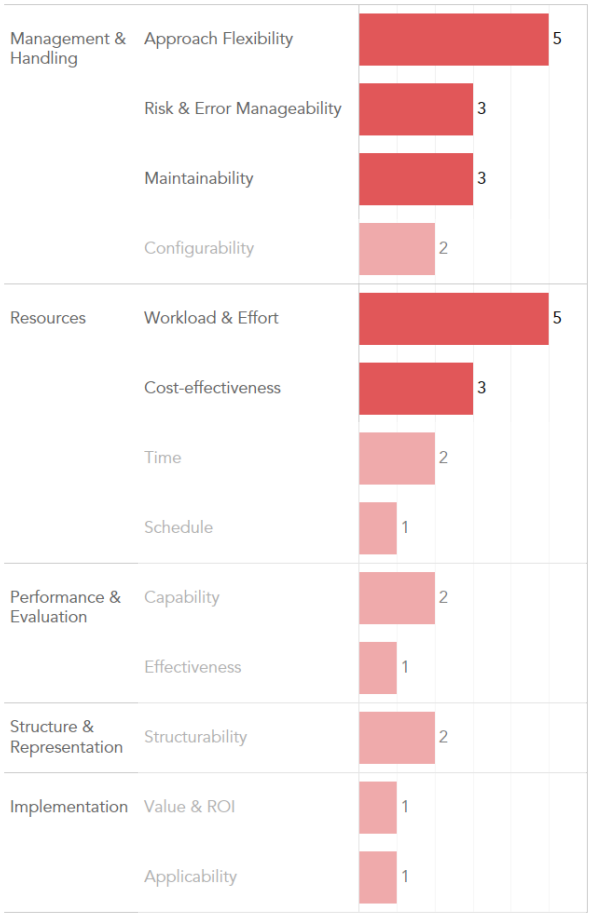
Positives of Vee



Vee is positively perceived for its…

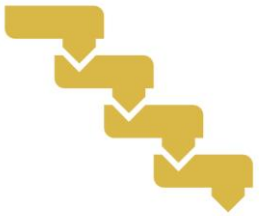
- **Standardized methodology**
  - Vee is a very consistent, uniform, pre-defined process that is easy to follow and understand by team members
  - It is also a very well-planned out approach, meaning much of the project phases are defined and linked in predictable ways
    - for projects complying with regulatory requirements (like vehicle development), this could be useful
- **Strong focus on V&V**
  - Verification and Validation is incorporated into the entire development process, which can lead to better QA

Negatives of Vee



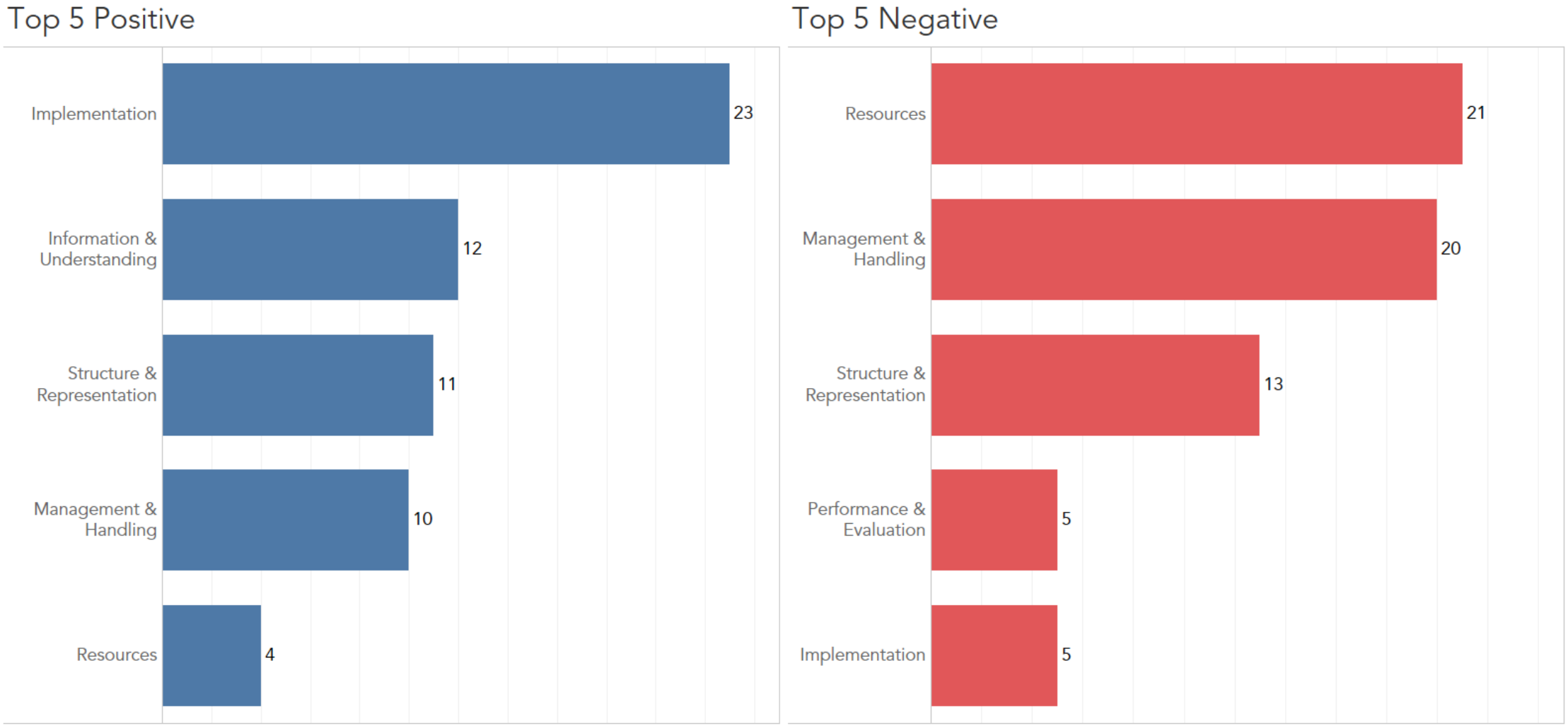
Vee is negatively perceived for its…

- **Rigidity & Risk Management**
  - Unlike Agile and Spiral, Vee is well-defined and inflexible after requirements specification
  - Introducing new requirements or features not anticipated at the initiation is very difficult
  - Difficult to maintain and evolve the system once the project is concluded
- **Effort and Cost**
  - Vee requires a lot of effort for V&V at every stage of the process
  - Any unanticipated changes can lead to cost overruns

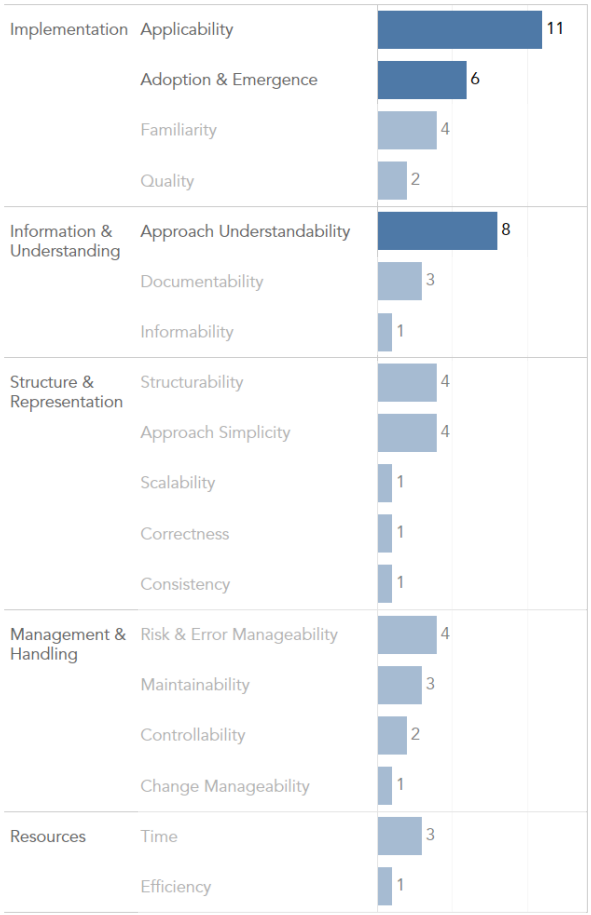


Waterfall Analysis

Waterfall Distribution



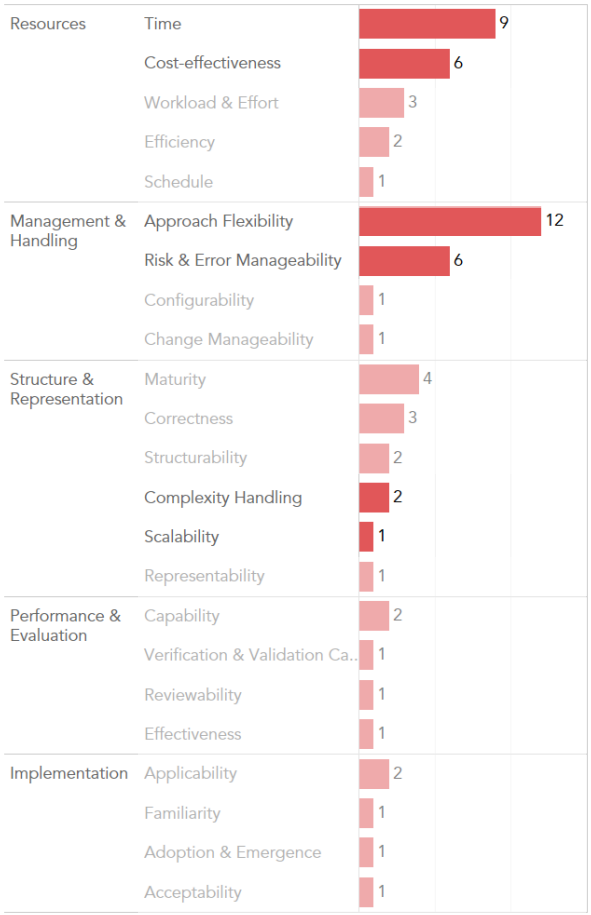
Positives of Waterfall



Waterfall is positively perceived for its…

- **Applicability to fixed-contract, straightforward projects**
  - Waterfall is very rigid, but for projects with pre-defined, unchanging requirements, it can be effective
  - It is very popular on small-scale, simple projects

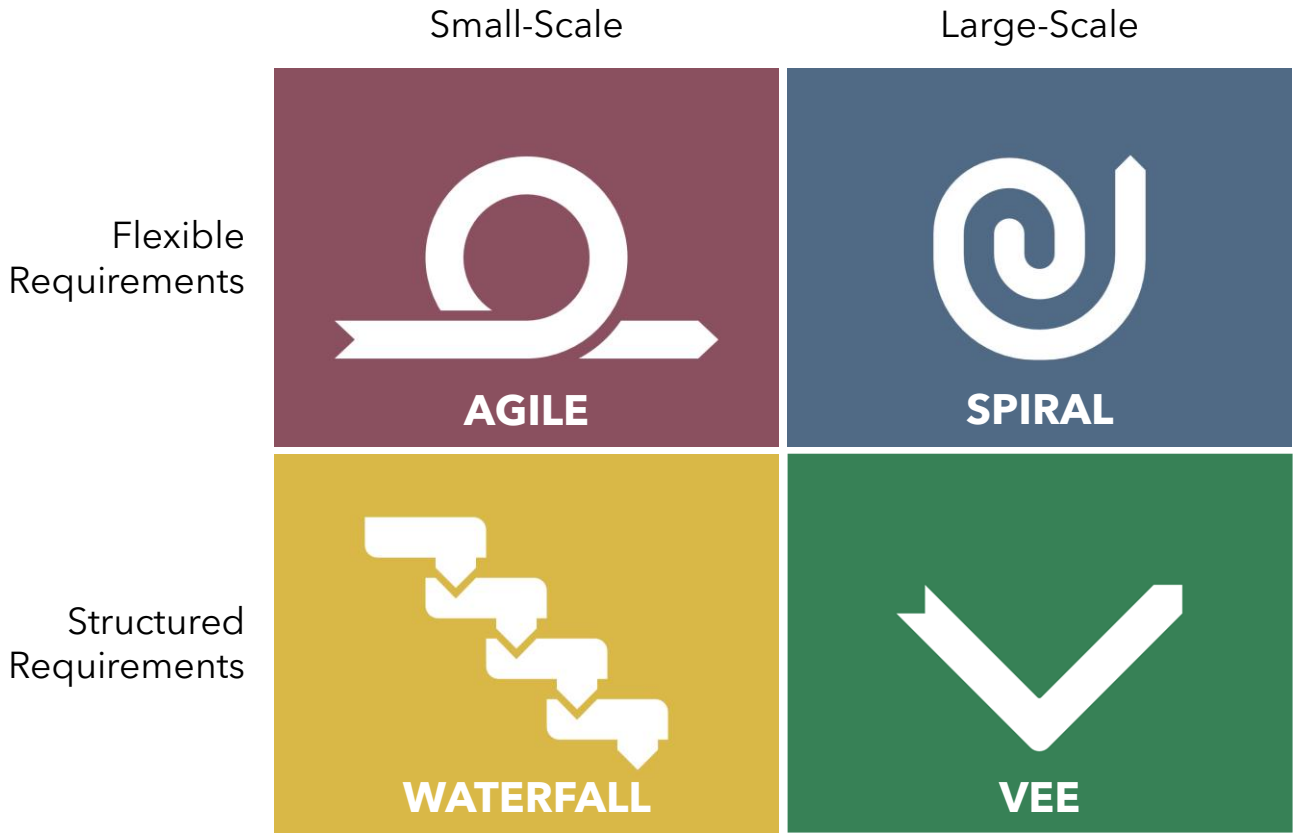
Negatives of Waterfall



Waterfall is negatively perceived for its…

- **Rigidity and Time Limitations**
  - For any project with changing requirements and ambiguous risk assessments, Waterfall could prove fatal as accounting for any changes is very difficult
  - Inability to complete an upcoming project phase until the previous one is finished can lead to huge schedule overruns
- **Inability to accommodate large-scale, complex projects**
  - Large projects would have to be predefined and all risks accounted for prior to any prototyping due to structure
- **Cost**
  - Any restarts due to project changes can be accommodated by going to a previous phase, but this will be expensive

Recommended Project Applications



Conclusion

Impacts

- In this project, we examined the perceptions of each lifecycle model in academic literature to qualify a value to each process
- From this, we determined that each model is applicable to a particular project depending on the requirement
- However, Waterfall is generally disliked in the examined literature, which could point to the evolution of industries' complexities and needs
- This research can help improve decision-makers' understanding of lifecycle processes and their applicability to their project objectives

Future Work

Future work involves…

- Expanding the source database for the lifecycle models to other approaches to system development
- Integrating findings into analysis of Model-based Systems Engineering (MBSE) to develop a high-level value model of approaches to systems development

Acknowledgements

We would like to thank Dr. Michael Watson for his support and guidance on this research.

Funding provide by the NASA Systems Engineering Technical Discipline Team (TDT) Research and Development (R&D)


THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE