Strategy-V: Adaptive Model and Experimental Validation of Strategy and Implementation for Teamwork

by

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Submitted to the System Design and Management Program
in Partial Fulfillment of the Requirements for the Degree of

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Abstract

Project management has three dimensional constraints: scope, schedule, and cost. The Agile project management framework is increasingly a challenge for cross-organizational teamwork, since the framework often results in strategy implementation deviation from the original strategic intent due to the three project constraints associated with teamwork. To bridge the gap between strategy and implementation, the Strategy-V Model is proposed as an adaptive framework to semantically inject Agile activities and interactions into Waterfall functional structures of strategy and implementation in software development extended organizations. To quantify such framework performance, new measures are proposed as sociotechnical sensors namely Project Emergent Value (PEV) and Project Utilization Value (PUV) using a fourth dimension of teamwork reward for project quality. The Strategy-V Project Utilization Theorem is mathematically set forth as flexible options for the use of the new adaptive framework based on the sociotechnical sensors. The theorem is generalized to the Theory of Project Framework Utilization as a guideline to choose effective framework. Further work explores the Strategy-V Model variants in organizational strategy management and Flexible Strategy design under uncertainties. A case study shows the use of the Strategy-V Model in analyzing Open Source projects to advance the adaptive strategy formation.

Open source as a corporate strategy has been redefining corporate innovations, saving development cost, and gaining faster time to market and larger market shares. A corporate open source project faces many uncertainties during strategy implementation such as effective contributions from external development community, projects dependencies, competitions, and economic impacts. This research also proposes a Flexible Option design as a case study for corporate decision making that leverages corporate internal resources and investments to optimize strategy implementation across organizations.

Thesis Supervisor: Professor Bryan R. Moser
Title: Academic Director and Senior Lecturer, System Design and Management Program

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Dedication

"Simplicity is the ultimate form of sophistication."

\- Chinese Proverb

To my mother Defen, who encouraged me to continue MIT education during her final hours fighting cancer. Her courage and spirit keep me going and overcome complex matters at difficult times.

To my beloved father Pingzhi, who taught me how to learn from simple things to understand complex things. He inspired me going back to school following his steps doing research as a physicist at the MIT Science Library.

To my wife Tongbo and daughter Andrea for their understanding and support.

Many thanks to Prof. Bryan R. Moser who kindly accepted to be my advisor and led me through this research on project complexity problem and solution space exploration! He helped me shaping the thesis theme from his teaching and insights on strategy and implementation based on project scope, time, and cost constraints and teamwork fundamentals.

Many thanks to Prof. Richard de Neufville who taught me flexible strategies dealing with project uncertainties, and Prof. Edward F. Crawley on System Architecture complexity and principles. The lectures made me thinking of my Top 10 Architectural Principles from Chinese proverbs e.g. Simplicity is the ultimate form of complex system architecture.

Many thanks to Prof. Steven Eppinger for system modular design process, Prof. Eric Rebentisch for the System V approach, and Prof. Bruce Cameron for transforming product platform to industry platform.

Many thanks to Joan Robin. William Foley and staff at the MIT SDM program who brought me back to System Thinking – my favorite undergraduate subject from the Department of Computer and System Sciences at Nankai University in China.

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1. Introduction

Principle of Goal Persistency 知其不可而为之

- ***Confucius:*** When the goal appears to be unreachable, don't adjust the goal, adjust the action steps.
- ***My System Thinking:*** Instead of changing the goal, seek out emergent functions by varying processes and architectural decisions.

This chapter introduces the research goal in form of problem statement for this thesis. Then the associated research questions are specified for which the thesis approach and chapters are outlined.

1.1. Motivation and Background

There are many definitions of Strategy, for example,

- a contingent plan of action designed to achieve a particular goal [1].
- a set of committed choices made by management [2] for a common goal.
- the creation of a unique and valuable desired future position, involving a set of activities [3] to reach the goal.

The definitions all point to the intent of a goal and related course of actions for implementation. However strategy implementation often deviates from the strategic intent due to uncertainties such as evolving technologies, shifting regulations, customers choices, macroeconomic variability and competition [4]. For example, according to recent research from the Project Management Institute (PMI), 91 percent of organizations are feeling the impact of disruptive technologies, and 59 percent of senior executives admitted their organizations struggle to bridge the strategy implementation gap, which wastes $1m globally every 20 seconds [5]. Closing this gap is imperative by aligning strategy goal of the organization leveraging cross-organizational partnership with teamwork implementation as a sociotechnical system [6].

My thesis inspiration came from 2018 MIT SDM Symposium: Characterizing the Gap between Strategy & Implementation [7]. During the symposium, many interesting topics were discussed that prompted my thinking in the three dimensions of scope, time, and cost to control strategy implementation processes. My initial Strategy-V thought came in shape for organizational strategy management as the "Strategy Design and Implementation V" work [8] posted at the symposium. This thesis aims to further explore the theoretical foundation and empirical evidences for bridging strategy implementation gap.

1.2. Problem Statement and Research Questions

The problem statement follows the System Thinking form:

To bridge strategy and implementation gap
By architecting Strategy-V framework
Using new sociotechnical sensors and flexible strategies

Figure 1. Problem Statement

To solve the problem space, the following Top 10 research questions will be addressed through theoretical and experimental work.

RQ1: What are the causes of the gap between strategy and implementation in project management, especially in software projects?
RQ2: What are the key factors in Project Management and how to quantify them in regards to project performance?
RQ3: How to measure project complexity and its relation to project scope, time, and cost dimensions?
RQ4: How can teamwork be reflected in project dimensions as sociotechnical sensors in theory?

RQ5: How to measure project performances in context of Waterfall, V-Model, Agile frameworks?

RQ6: Why Agile framework might go wrong in strategy alignment? Why would project complexity require more strategy planning and system decomposition?

RQ7: Any better frameworks? Any theoretical proof? Any guideline on how to use the frameworks?

RQ8: How would theoretical sociotechnical sensors compare to empirical evidence such as project popularity? Would the evidence show S-curve pattern over time? Any evidence on why project complexity would require more strategy planning and system decomposition?

RQ9: How to transform System Thinking from Project Management to Organization Management?

RQ10: Any other Flexible Strategy design for the frameworks, especially in cross-organizational teamwork?

Figure 2. Top 10 Research Questions

1.3. Thesis Approach and Outline

The thesis is addressing the research questions by theoretical methodologies and experimental case studies in the following chapters.

1) **Literature Review**

   Investigate research questions RQ1-RQ3 for existing work on key factors in Project Management that might cause the gap between strategy and implementation, especially on project complexity factors. These factors become the basis to build up new theory and methods, which in turn guide experimental design.

2) **Research Approach and Hypothesis**

Based on the Literature Review, align research methodologies and form research hypotheses from research questions RQ4-RQ7. The hypotheses lead to the experimental design for testing the theoretical results.

3) **Theory and Methods**

Following the thought flow of the research questions, explore the Project Management space for the problem statement. Introduce new sociotechnical sensors as Project Emergent Value (PEV) and Project Utilization Value (PUV). Propose new Strategy-V Model project management framework using the sociotechnical sensors. Provide mathematical proof of the Strategy-V Project Utilization Theorem as a flexible strategy guideline for research questions RQ4-RQ7.

4) **Experimental Design**

To test the research hypotheses applying the theoretical results, design three case studies to apply Strategy-V Framework and Flexible Strategy to project management and organization management scenarios.

5) **Case Study I – Strategy-V in Project Management**

Instrument the new sociotechnical sensors in GitHub open source projects and apply Strategy-V Framework to address research question RQ8.

6) **Case Study II – Strategy-V in Organization Management**

Explore Strategy-V architecture in Organization Management to address research question RQ9.

7) **Case Study III – Flexible Strategy Corporate Open Source Project**

For an open source project, corporates face many uncertainties during strategy implementation. For example, the uncertainties could be effective contributions from external development community, projects dependencies, competition, and economic impacts. This chapter proposes flexible option designs for corporate decision making on corporate projects at GitHub. The designs leverage corporate internal resources and investments to optimize strategy implementation across organizations to address research question RQ10.

8) **Conclusions**

From theoretical and experimental exploration, summarize key findings and recommendations.

1.4. Chapter Summary

Strategy implementation often deviates from the strategic intent due to uncertainties. The goal of this research is to address the problem on how to bridge the gap between strategy and implementation by architecting Strategy-V framework from various development frameworks using new sociotechnical sensors and flexible strategies in project management. Also explore the theorem generalization to organizational strategy management and other flexible strategies. The problem is then decomposed into ten research questions following the personal thought flow from the learnings at MIT System Design and Management (SDM) program. To find the answers to the questions, theoretical and experimental research will carry out in the outlined chapters.

2. Literature Review

Principle of Out-of-Box System. 天外有天

- ***Chinese Proverb:*** There are always skies beyond the sky.
- ***My System Thinking:*** There is always an outer system containing this system.

From the SDM Project Management Core class, we have learned the followings that empower us to strategically plan, budget and manage product and service development projects and programs in organizational and business context.

2.1. Project and Project Dimensions

Project is a set of Tasks that relate to each other, with a start and a finish in time having possible funding and time limits, and consumes resources driven by an objective of scope targets to complete [9], [10]. Project quality is constrained by scope, time schedule, and cost three dimensions or "Iron Triangle" (Figure 3, MIT EM.411_PM0_Introduction-2017 Slide 15, ©Bryan Moser) [11].

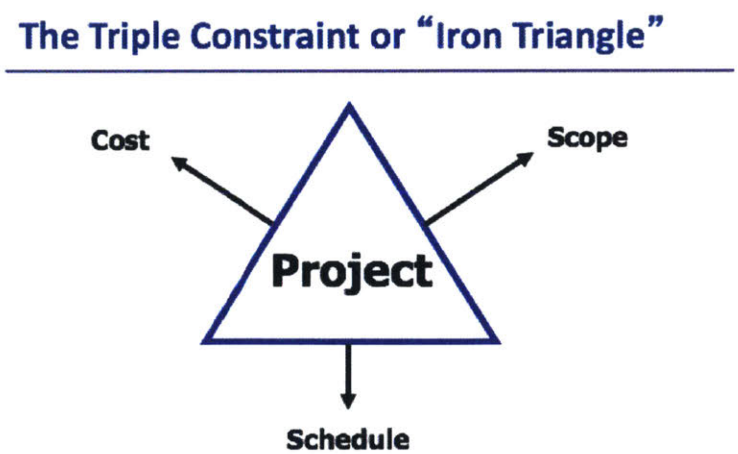


Figure 3. Project Triple Constraint Dimensions

2.2. Project Management and Organizational Strategy Management

From class, Project Management comprises a body of methods and tools that facilitate the achievement of project objectives within time, within cost, within scope at the desired performance and specification level while effectively and efficiently utilizing resources and carefully managing risks and opportunities.

Organizational Strategy Management or Organization Management is at higher level of management paradigm that have organizational strategies as requirements in strategy formulation and implementation [12].

2.3. Why do projects fail or overrun or overbudget due to strategy implementation gaps?

Due to project complexity under project uncertainty, any bad move would result in project quality loss at any stage of strategy formulation, planning, and implementation due to bad scoping in strategy, bad planning, or bad implementation performance (Figure 4, MIT EM.411_PM0_Introduction-2017 Slide 14, ©Bryan Moser). On the other hand, a good move can lead toward good implementation. Each step is a decision option with a chance to deviate from the strategy which might not be good to begin with.

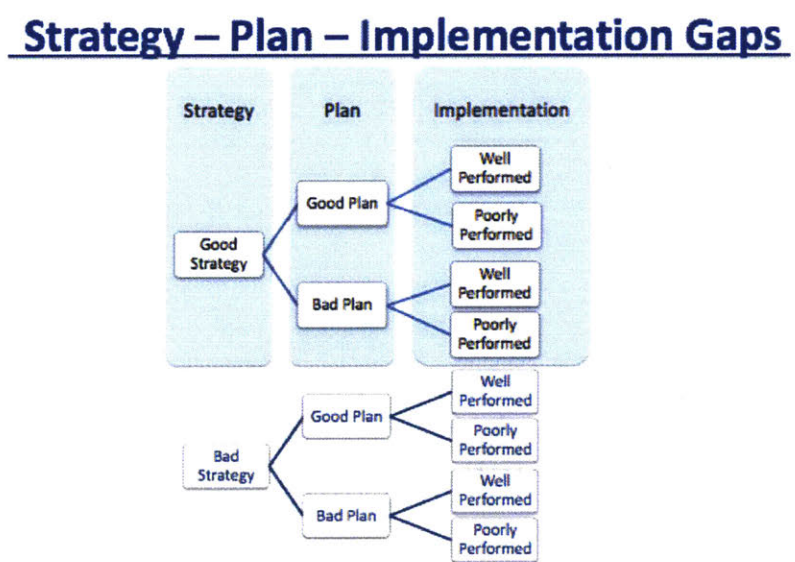


Figure 4. Causes of Strategy Implementation Gaps

2.4. *Project Complexity and Measures*

Project Complexity involves the dynamics between Structural Complexity and Behavioral Complexity. Behavioral complexity emphasizes the linkage between cognition and actions in social behavior. Many structural complexity measures have been proposed [13][14] from system component dependency or interaction network through graph theory such as clustering coefficient [15], power-law degree distribution [16], correlation of node degrees [17], modularity structures [18], global edge complexity [19], and structural complexity metric in systems engineering [20].

2.5. *Earned Value and EVM*

Earned Value (EV) is the percent of the total budget actually completed at a point in time. This is also known as the budgeted cost of work performed (BCWP). EV is calculated by multiplying the budget for an activity or work package by the percentage progress. In 1967, using earlier work by the U.S Air Force, the Department of Defense (DOD) issued the Cost/Schedule Control System Criteria (C/SCSC), which imposed 35 criteria on a contractor's management control system for cost or incentive contracts. The C/SCSC is often referred to as earned value, but EV is only one of the many techniques embodied in the criteria [24].

Earned Value Management (EVM) is a project management methodology for objectively measuring project performance using an integrated schedule and budget based on the project Work Breakdown Structure (WBS) [24]. EVM only covers cost and schedules and, therefore, no quality control is factored into EVM. Without the right vision and guidance, a project can be on time and on budget–and still be the worst product ever made [25].

2.6. *Project as Sociotechnical Systems*

Project presents the so called “Socio” attribute that has Project Teams in Organizations with values, behavior, skills, structure, priorities, capacities, skills, and costs. Project also has the "Technical" attribute in that Projects Outcomes are product systems, with architecture, interfaces, materials, information, services, etc. Behaviors of teams and the demand for outcomes combine, constrained by limits and dependencies of the systems and teamwork that form the sociotechnical systems [21].

2.7. Sociotechnical Sensors

Sociotechnical sensors [22] are project performance measures in regards to social and technical attributes, which characterize the holistic system combined with the human factor. Such system represents sociotechnical systems that the technology complexity is amplified by the organizational and procedural complexity of the application domain. The systems inherently need to be conceived, designed and developed considering both the technological and the human/organizational aspects from the earliest stages [23].

2.8. Flexible Option and Flexible Strategy

Flexibile Option or Real Option [26] concept came from financial option analysis formulation by the Black-Scholes Model [27]. Flexibility is the property of a system that allows the system to respond to changes in the initial objectives and requirements. The Flexible Strategy for a project involves the analysis of the cost and value of embedding flexibility in selecting the optimum flexible options.

2.9. Waterfall, V-Model, Agile Project Management Frameworks

In software development, the uncertainties arise from requirement changes, software errors and rework [10], [28]. Traditional Waterfall framework comprises a sequence of plan, design, development, test, and review activities for the whole project [29] which is rigid to adapt for the uncertainties[30]. Traditional V-Model framework is a variation of the Waterfall framework by adding extensive validation test steps, but is still considered not flexible.

The more recent Agile framework on the other hand aims to be adaptive by iterative sprint through shortened time cycle of plan, design, development, test, and review activities from narrow to full scope of a project [28]. However, the Agile shortened time cycle approach might not be suitable for many kinds of projects because of scope deviation from the original strategy intent, especially for cross-organizational teams due to cultural and behavioral differences. At the cross-organization teams level, the main productivity factors are teams effective coordination by proper interfaces and other dependencies to avoid delays in providing software [31].

Hybrid framework approaches leverage advantages from each framework for the scale of project scope, the culture of organization, the probability of uncertain changes [28]. These methodologies have been applied to other industries as well [32].

The present paper proposes new project valuation measurements in a whole sociotechnical system [21] considering teamwork factors, and apply them as sociotechnical sensors to a new hybrid framework that injects Agile framework into an extended V-Model by Flexible Option conditions as a Strategy-V Model.

2.10. Chapter Summary

In this chapter, key concepts and methodologies are reviewed such as Project, Project Management, Project Complexity, Sociotechnical Systems and Sensors, Flexible Options and Strategies, and Waterfall, V-Model, Agile management frameworks. Research question RQ1 to RQ3 are also addressed as the followings.

- **RQ1:** What are the causes of the gap between strategy and implementation in project management, especially in software projects?

  Answer: Due to project complexity with human factor under uncertainty, each project step might lead to deviation from strategy intent in activities that result in "bad move".

- **RQ2:** What are the key factors in Project Management and how to quantify them in regards to project performance?

Answer: Currently Project Management comprises a body of methods and tools that facilitate the achievement of project objectives within time, cost, and scope three dimensions measurable at desired performance.

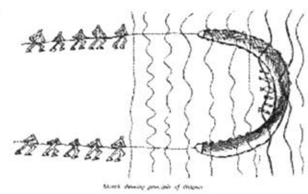
- **RQ3:** How to measure project complexity and its relation to project scope, time, and cost dimensions?

Answer: Project scope is represented by project complexity. Project Complexity involves the dynamics between Structural Complexity and Behavioral Complexity, which could be measured by sociotechnical sensors.

3. Research Approach and Hypothesis

Principle of Encapsulation 纲举目张

- ***Chinese Proverb:*** Once the head rope of a fishing net is pulled out, all the meshes open.
- ***My System Thinking:*** Encapsulate a system by the key information that would lead to the system details as a whole.



From the literature review, the research goal can be further explored with focus on new findings through theoretical and experimental approaches on hypothesis raised.

3.1. Research Focus

Based on the Project Complexity formula, theoretically propose new sociotechnical sensors on project emergent values to examine project management frameworks, for which new framework could be proposed to bridge the gap between strategy and implementation.

Provide a guideline on how to apply the new framework in theory and in practice by case studies.

3.2. Research Hypotheses

After theoretical results are established for new sociotechnical sensors in theorem, are there any empirical evidence or experimental support? The following hypothesis are proposed based on new framework instrumentation.

One assumption is that such sensors would reveal the underlying management framework such as would the framework more agile or more waterfall or in between. Since more waterfall means more planning and design activities would be detected through the sensors, the first hypothesis is about the relationship between the new sensors representing project complexity and the characteristics of project planning and design activities for system decomposition and integration.

- **H1**: High project complexity would require more planning activities on project dependencies in conforming the Strategy-V Model.

The progress of a successful project accelerates the growth for a period of time before reaching a plateau. The trend is so called S-curve [33] trend over time. A hypothesis is on whether the new sensors would detect such project development pattern.

- **H2**: Project sociotechnical sensors for the Strategy-V Model should show S-curve for project development.

Project popularity is an empirical measure of project success. Would the new sensors be effective to represent the project status quo? This leads to another hypothesis.

- **H3**: Project sociotechnical sensors the Strategy-V Model should reflect empirical project popularity or success in project comparison.

Organizational Strategy Management is in higher form of Project Management paradigm. A hypothesis is to test if the proposed framework could be generalized.

- **H4**: Strategy-V Model as a management framework could be generalized from project management to organization management in broader scope by more sociotechnical sensors.

Would the same Strategy-V thinking also be applied to other measures of Flexible Options? This leads to the last hypothesis.

- **H5**: Strategy-V Model as a Flexible Strategy could be generalized to other Flexible Option sensors to optimize organization or corporate strategies.

3.3. Chapter Summary

The research focus is the theoretical proposal of new sociotechnical sensors based on project emergent value for which new framework is introduced to bridge the gap between strategy and implementation. Five hypotheses from the new framework theories are raised for which case studies can be carried out to test them.

4. Theory and Methods

Principle of Causality 知其然知其所以然

- ***Chinese Proverb:*** Not only know how but also know why.
- ***My System Thinking:*** Understand not only how the system works but also why the system works. Go beyond system forms and functions to reason from functions to forms for conception and system decomposition.

This chapter proposes the theoretical framework and sociotechnical sensors instrumentation methods with mathematical proof of the underlying theory as a form of flexible strategy. The framework provides the guidelines for experimental design to address the hypotheses from the research questions.

4.1. *Strategy-V Framework*

Strategy management of a project consists of strategy planning and strategy implementation. Strategy-V framework (Figure 5) is introduced to inject Agile processes into the traditional System V-Model to form sociotechnical model framework and provide a semantically consistent representation of the activity and interactions amongst functions of strategy and implementation. Teamwork drives project through strategy formulation and implementation stages at the micro-scale (individuals and small teams within an organization), the meso-scale (across functional or organization teams), and the macro-scale (whole system level) [34]. The teamwork across critical system interfaces is observed including those that are intentionally open and those made available for extensions and external development. The sociotechnical sensors [22] at the system interfaces are further proposed to monitor implementation results at different stages.

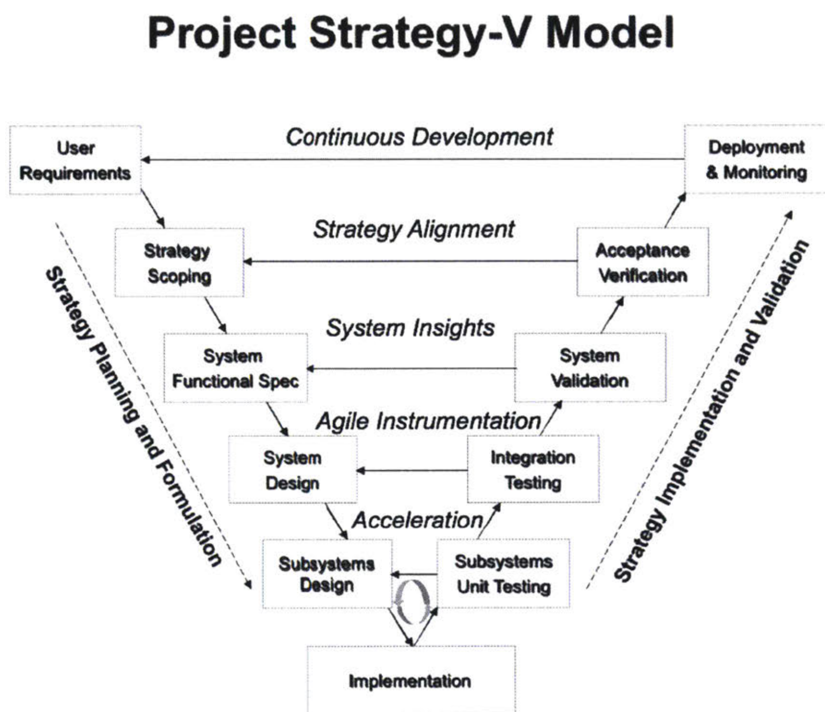


Figure 5: Strategy-V framework to inject Agile processes into System V-Model

4.2. Project Complexity and Emergent Value

A project for producing a system has three dimensional constraints, namely scope, time schedule, and cost [35], [36]. When teams work on a project, a sociotechnical dimension could be added for the consideration of human resources. Such dimension would bring out the emergent value of the project with the whole domain (denoted by Ω) composed of four-dimensional elements.

Project Emergent Value (V_E or PEV) is the project scope value achieved through teamwork. This PEV measure is based on a combination of technical and social systems characteristics: the product of system architectural or structural complexity (S) [37] and human team creativity reward to produce the system (H). PEV can be further decomposed to many aspects where exists interactions between S_i and H_i for the aspect i.

$$V_E = S \cdot H = \sum_i S_i \cdot H_i \quad (1)$$

From the many structural complexity measures have been proposed [13][14], we will illustrate global edge complexity and structural complexity metric in systems engineering [20] as theoretical examples below and the global edge complexity measure [19] in the case study.

Recall that the structural complexity metric S is defined as $S1 + S2 \cdot S3$ where $S1$ = System Component Complexity, $S2$ = System Interface Complexity, and $S3$ = System Topological Complexity. Teamwork dynamics could be measured by individual team achievement ($H1$) and teams dependency based on collaborations in teamwork achievement ($H2$).

$$V_E = S1 \cdot H1 + S2 \cdot S3 \cdot H2 \quad (2)$$

4.3. Project Utilization Value and Ratio

Project Cost Value (V_C) is defined as the product of Time (T) and Cost (C). **Project Utilization Value** (V_u or PUV) is defined as the difference between Project Emergent Value and the Project Cost Value.

$$V_U = V_E - V_C = S \cdot H - T \cdot C \quad (3)$$

Note that these factors are not independent. Interesting system structure might attract more people interested working on the system with more creativity. More creativity might produce better structure for more scoped value. On the other hand, prolonged time could incur more cost. More teams might incur more cost.

Comparing to Earned Value (EV), PUV includes not only cost and schedule factors but also project quality associated teamwork reward and project complexity. Treating all these factors together would potentially improve project performance measurement.

Project Utilization Ratio (R_u) is the ratio between Project Utilization Value and the total in and out value generation at macro-scale ranged from -1 to 1.

$$R_U = \frac{V_E - V_C}{V_E + V_C} \tag{4}$$

Assume the project works on a system with domain Ω that can be decomposed in n subsystem modules M_1, M_2, ..., M_n, m time periods (or stages) T_1, T_2,, ..., T_m, p teams of human teamwork task rewards H_1, H_2, ..., H_p at micro-scale level with module dependencies and teamwork dependencies (Figure 6). Then V_U could be further decomposed as

$$V_U = \sum_{\substack{1 \le i \le n \\ 1 \le t \le m \\ 1 \le k \le p}} [S(i,t)H(i,k,t) - T(i,k,t)C(i,k,t)] \tag{5}$$

Note that n, m, p and all the functionals could change by time due to newly discovered or changed subsystems, additional iterations of time needed for new work or rework, and team changes by team dynamics. All formulations provide a snapshot of the system state at given time for analysis.

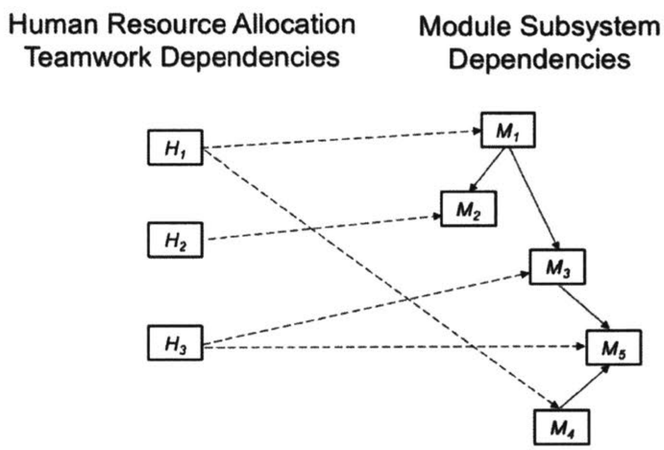


Figure 6. Example of Module Dependencies and Teamwork Dependencies

4.4. Waterfall Utilizations

The characteristics of Waterfall framework is that all subsystem modules are decomposed and treated, which takes longer time at each stage by teams (see Figure 7 as extension to [29]). Rework could be costly if required, especially at later stage. The Waterfall utilization V_U^W as an example can be calculated by

$$V_U^W = \sum_{k=1}^{p} \sum_{t=1}^{m} \sum_{i=1}^{n} [S_t(i) H_t(i,k) - T_t(i,j) C_t(i,k)] \quad (6)$$

Further expansion of formula (2) for Project Emergent Value yields,

$$V_E^W = \sum_{k=1}^{p} \sum_{t=1}^{m} \sum_{i=1}^{n} [\alpha_t(i) h_{tk}(i) + \sum_{j=1}^{n} \beta_t(i,j,k) A_t(i,j) E(A_t) E(W_t)] \quad (7)$$

Module dependencies are denoted by DSM [38] adjacency matrix $A_{n \times n}$. Team-to-module task dependencies are denoted by DSM adjacency matrix $W_{n \times p}$. $E(A_t)$ and $E(W_t)$ are the corresponding graph energy values as the sum of the absolute eigenvalues or singular values of the adjacency matrix [20].

For example, consider a simple example that has initially two stages, say T_1, T_2 as strategy planning and implementation stages, working on a system with two modules M_1 depending on M_2. Two teams H_1, H_2 are assigned to M_1, M_2 correspondingly.

$From\ A_t = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix}$, $W_t = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$ at the first stage (t = 1) the graph energies $E(A_t) = 1$, $E(W_t) = 2$. Assume individual module complexity $\alpha_t(i)$ all have 1-unit value. Teamwork rewards are ratings from \$1 to \$10 with individual team at \$5 on one module and team dependency collaboration at \$8 levels. Then $h_{tk}(i) = \$5$ when $i = j$ and \$0 otherwise; $\beta_{tk}(i,j) = \$8$ for matching time t and task team k when $i \neq j$, and \$0 otherwise. So V_E^W for the first stage is \$5 + \$5 + 2·\$8 = \$26. Also assume the second implementation stage performed equally well with the total V_E^W= \$58. If each stage cost the same at \$10 (\$5 for each module), then V_C^W = \$20. The total utilization V_U^W = \$38 and R_U^W = 0.49.

If rework of M_1 is needed in a new stage after the implementation stage, the cost would be doubled but the rewards for the second stage might be diminished on total recall maintaining V_E^W= \$58 but V_C^W = \$40 which leads to V_U^W = \$18 and R_U^W = 0.18.

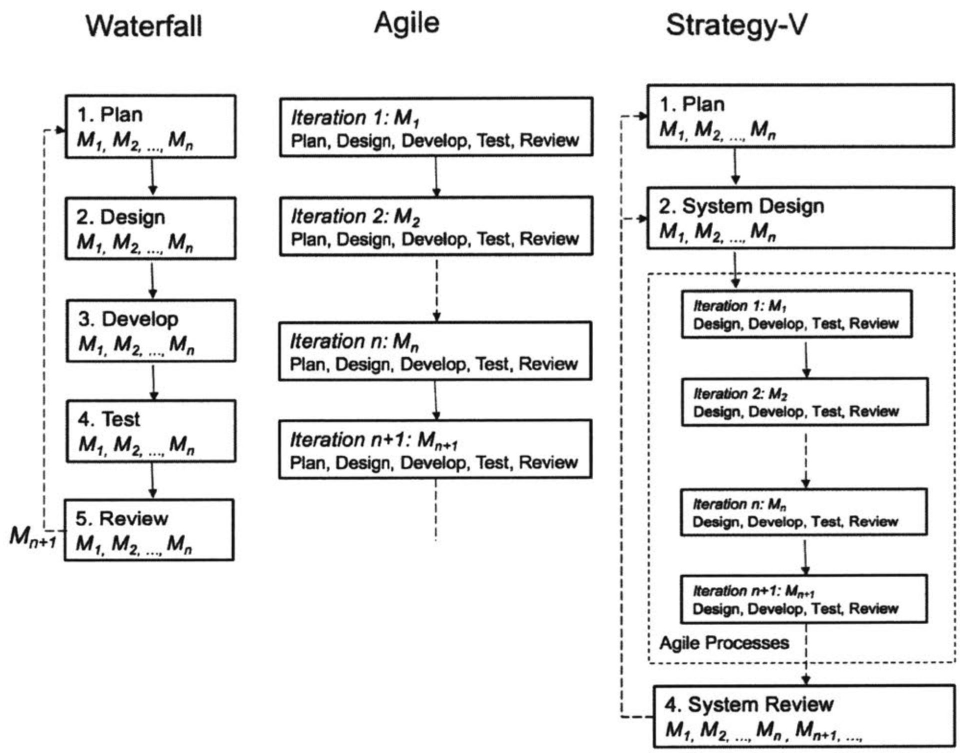


Figure 7. Sample workflow comparison for Waterfall, Agile, Strategy-V Frameworks

4.5. Agile Utilization

Agile framework on the other hand iterates all the stages for each module adapting to changed scope by teams (Figure 7). However, the implementation might deviate from the original strategy defined scope. The Agile utilization V_U^A and Emergent Value V_E^A are defined by

$$V_U^A = \sum_{k=1}^{p} \sum_{i=1}^{n} \sum_{t=1}^{m} [S_i(t) H_i(k,t) - T_i(k,t) C_i(k,t)] \quad (8)$$

$$V_E^A = \sum_{k=1}^{p} \sum_{i=1}^{n} \sum_{t=1}^{m} [\alpha_i(t) h_{ik}(t) + \sum_{j=1}^{n} \beta_k(i,j,t) A_t(i,j) E(A_t) E(W_t)] \quad (9)$$

The key difference is the order of the sum with respect to different dimensions. The corresponding value functions might differ considerably such as cost functions $C_t(i,j)$for Waterfall and $C_i(j,t)$ for Agile are totally different functions.

In the above example, Agile would iteratively work on one implementation stage (m =1) until all modules are finished by the corresponding teams. The best case with the same assumptions is that the module dependency is discovered early on by starting first stage with M_2, then finished with implementing M_1. The rewards per stage are doubled since the same effect is achieved producing the module in one stage instead of two stages in Waterfall. That is, $\alpha_i(t) = 1$ but $h_{ik}(t) = \$10$ and $\beta_k(i,j,t) = \$16$ for each module. So, total V_E^A remains at \$58 since each module development would be rewarded \$26. But the cost is half since there is no planning stage and V_C^A = \$10. Shortened time per period could also bring cost down. The total utilization V_U^A = \$48 and R_U^A = 0.71.

However, if starting with M_1 and discovered the dependency on M_2 at almost the end of the first stage and need two more stages to get both modules implemented correctly, then the final utilization value and ratio would remain the same as Waterfall, i.e. V_U^A = \$18 and R_U^A = 0.18.

If the result deviates from the original scope to a lesser quality, the rewards should be penalized to less amount, say less than half instead of doubled with $h_{ik}(t) = \$2$ and $\beta_k(i,j,t) = \$4$. Then $V_E^A = \$12, V_C^A = \$15$ (cost for 3 modules). The project utilization $V_U^A = -\$3$, $R_U^A = -0.11$ which is far worse than Waterfall.

4.6. Strategy-V Utilization

Strategy-V Model injects Agile model to the lower level of the V-Model (Figure 3). The Strategy-V utilization V_U^V can be calculated by the following where X and X^c are complement subsets of the domain Ω.

$$V_U^V = V_U^W(X^c) + V_U^A(X),\ if\ \exists X \subset \Omega \qquad (10)$$

One expansion could be in the following which after the initial planning to design in stage t_x, iteratively accelerates the cycle of detailed design, implementation, and testing to individual module level then at stage t_y go back to higher level of system testing.

$$V_U^V = \sum_{t=1}^{t_x} \sum_{i=1}^{n} \sum_{j=1}^{p} [S_t(i)H_t(i,k) - T_t(i,k)C_t(i,k)] + \sum_{i=1}^{n} \sum_{t=t_x+1}^{t_y} \sum_{j=1}^{p} [S_i(t)H_i(k,t) - T_i(k,t)C_i(k,t)] + \sum_{t=t_y+1}^{m} \sum_{i=1}^{n} \sum_{j=1}^{p} [S_t(i)H_t(i,k) - T_t(i,j)C_t(i,k)] \quad (11)$$

V_E^V can be expanded similarly to formula (7) and (9). With strategy focus of original scope intent, Strategy-V would reach some mid-ground between Waterfall and Agile methods at the best case of each method, and wins over both methods in the worst case of rework.

For the Waterfall worst case in the above example, rework of M_1 is needed after implementation. The cost would be less than doubled comparing to Waterfall at $V_C^V = \$30$ since only one module needs rework in the Agile section of Strategy-V. with V_E^V remains at \$58 which leads to V_U^V = \$28 and R_U^V = 0.32, which are better than the rework case for Waterfall at V_U^W = \$18, R_U^W = 0.18 and the rework case for Agile at V_U^A = \$18, R_U^A = 0.18 or even worse at $V_U^A = -\$3$, $R_U^A = -0.11$.

4.7. Project Framework Identification by PEV

Projects are more of hybrid framework type in nature comparing to framework they claim to adopt nowadays. Such nature could be revealed by Project Emergent Value.

From Formula (2), the Project Emergent Value V_E measures the project complexity in both system architecture and teamwork. V_E changes by time in form of $V_E(t)$ as more system complexity is discovered. For Waterfall and Strategy-V, project initial scoping and resource estimation efforts are more thorough in system modules decomposition with dependency analysis and teamwork allocation. So $V_E(t)$ is high for both frameworks in the early stage if the scoping is correctly aligned with the project strategy goal. $V_E(t)$ for Agile in contrast would start small but increase over time as more complexity are discovered. The pattern would also be reflected in $V_E(t)$ for Strategy-V as the acceleration in the increased value.

4.8. Theoretical Result: Strategy-V Project Utilization Theorem by PUV

From Formula (10), if $V_U^A(X) \geq V_U^W(X)$ for some $X \subset \Omega$, then $V_U^V = V_U^W(X^c) + V_U^A(X) \geq V_U^W(X^c) + V_U^W(X) = V_U^W$, or if $V_U^W(X^c) \geq V_U^A(X^c)$ for some $X \subset \Omega$, then $V_U^V = V_U^W(X^c) + V_U^A(X) \geq V_U^A(X^c) + V_U^A(X) = V_U^A$. This leads to the **Strategy-V Project Utilization Theorem** as flexible options for the domain space is Ω:

$$V_U^V \geq V_U^W, \qquad if\ \exists X \subset \Omega, V_U^A(X) \geq V_U^W(X)$$

$$V_U^V \geq V_U^A, \qquad if\ \exists X \subset \Omega, V_U^W(X^c) \geq V_U^A(X^c) \quad (12)$$

For Formula (11), if the Agile component scoped rewards are higher i.e. $S_i(t)H_i(k,t) \geq S_t(i)H_t(i,k)$ or the cost is lower i.e. $T_i(k,t)C_i(k,t) \leq T_t(i,k)C_t(i,k)$ such that $[S_i(t)H_i(k,t) - T_i(k,t)C_i(k,t)] \geq [S_t(i)H_t(i,k) - T_t(i,k)C_t(i,k)]$ for $t_x < t \leq t_y$, then

$$V_U^A(t_x + 1, t_y) = \sum_{i=1}^{n} \sum_{t=t_x+1}^{t_y} \sum_{j=1}^{p} [S_i(t)H_i(k,t) - T_i(k,t)C_i(k,t)] \geq$$
$$\sum_{i=1}^{n} \sum_{t=t_x+1}^{t_y} \sum_{j=1}^{p} [S_t(i)H_t(i,k) - T_t(i,k)C_t(i,k)] =$$
$$\sum_{t=t_x+1}^{t_y} \sum_{i=1}^{n} \sum_{j=1}^{p} [S_t(i)H_t(i,k) - T_t(i,j)C_t(i,k)] = V_U^W(t_x + 1, t_y)$$

So, from Formula (11), $V_U^V = V_U^W(1, t_x) + V_U^A(t_x + 1, t_y) + V_U^W(t_y + 1, p) \geq V_U^W$.

Similarly on the other hand, if the Agile component scoped rewards are lower or the cost is higher due to more iterations such that $[S_t(i)H_t(i,k) - T_t(i,k)C_t(i,k)] \geq [S_i(t)H_i(k,t) - T_i(k,t)C_i(k,t)]$ for $t \leq t_x$ and $t > t_y$, Formula (11) implies $V_U^V \geq V_U^A$.

The theory could be further generalized to the **Theory of Project Framework Utilization** as a Flexible Strategy in framework decision choice: At any framework decision making time of a project, choose the framework methodology that has the best Project Utilization where the scope complexity rewards are higher or cost is lower for any subset of project domain constrained by scope, time schedule, cost and human resource.

4.9. Chapter Summary

In addition to project three dimensions in scope, time, and cost, this work brings the fourth dimension of teamwork human factor to project management using the proposed Project Emergent Value, Project Utilization Value, and Project Utilization Ratio. They are effective sociotechnical sensors to measure the holistic combination of project system complexity in scope, teamwork dependency, cost, and time constraint domain. Project Emergent and Utilization Values help to identify project management framework patterns and compare them based on the Strategy-V Project Utilization Theorem. By analyzing the framework, Strategy-V Model framework is proposed that has the advantage of adaptability and strategy alignment over Waterfall and Agile methodologies.

The research results provide some theoretical answers to the research questions RQ4-RQ7.

- **RQ4:** How can teamwork be reflected in project dimensions as sociotechnical sensors in theory?

  Answer: Project Emergent Value is the project scope value achieved through teamwork. This PEV measure is based on a combination of technical and social systems characteristics: the product of system architectural or structural complexity and human team creativity reward to produce the system.

- **RQ5:** How to measure project performances in context of Waterfall, V-Model, Agile frameworks?

  Answer: Project Utilization Value is the difference between Project Emergent Value and the product of project time and cost. The value can be computed for Waterfall, Strategy-V Model, Agile frameworks.

- **RQ6:** Why Agile framework might go wrong in strategy alignment? Why would project complexity require more strategy planning and system decomposition?

Answer: Project Emergent Value measures the project complexity in both system architecture and teamwork. The value changes by time as more system complexity is discovered. The Agile project emergent value would start small but increase over time as more complexity are discovered. The Agile rewards are lower or the cost is higher due to more iterations are needed when the implementation deviates from the original intent. For Waterfall and Strategy-V frameworks on the other hand, project initial scoping and resource estimation efforts are more thorough in system modules decomposition with dependency analysis and teamwork allocation. The project emergent value is high for both frameworks in the early stage if the scoping is correctly aligned with the project strategy goal.

- **RQ7:** Any better frameworks? Any theoretical proof? Any guideline on how to use the frameworks?

  Answer: The Strategy-V framework has advantage under the conditions formulated in the Strategy-V Project Utilization Theorem as a Flexible Strategy leveraging Waterfall and Agile frameworks. The Theorem is proved mathematically given the flexible option conditions.

  Use a Flexible Strategy guideline as the Theory of Project Framework Utilization in framework decision choice: At any framework decision making time of a project, choose the framework methodology that has the best Project Utilization where the scope complexity rewards are higher or cost is lower for any subset of project domain constrained by scope, time schedule, cost and human resource.

5. Experimental Design

Principle of Inference 举一反三

- ***Confucius:*** Three things could be inferred from one thing.
- ***My System Thinking:*** The whole system could be inferred or learned from the parts by observing specific system perspectives for clues.

By using Strategy-V Framework and Flexible Strategy, three case studies are designed to leverage GitHub open source projects on project management and organization management.

5.1. GitHub Project Data Sampling and Analysis

Open source as a project development model [39] promotes universal access and redistribution via free license to a product's design or code base, including subsequent improvements to the product by anyone. In software development for example, Google currently has over 2000 open source projects hosted at GitHub among the top contributors from many organizations (Figure 8) [40].

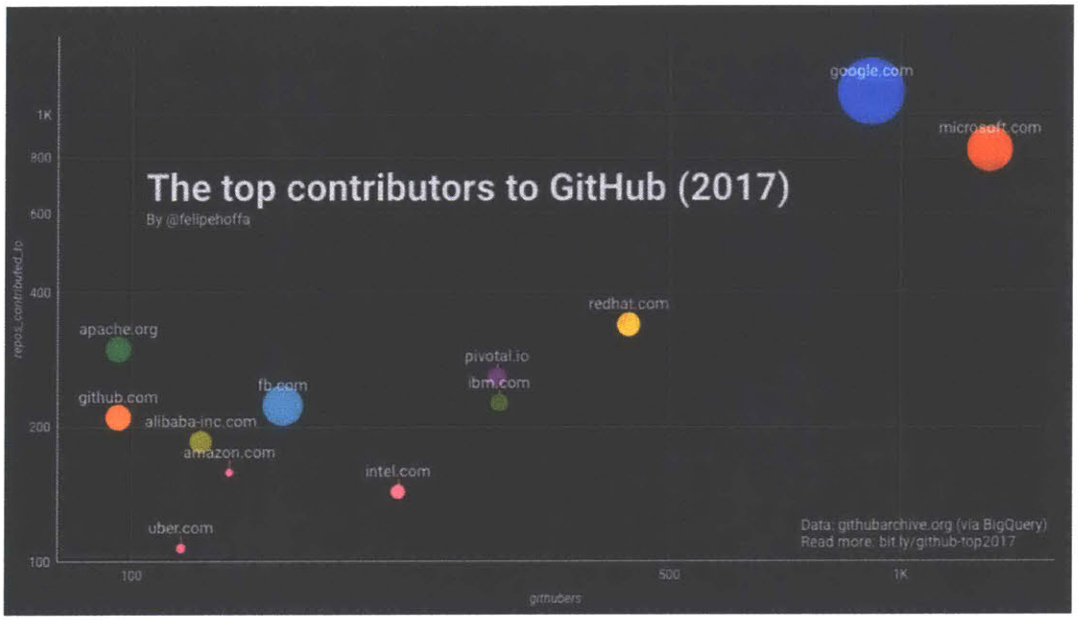


Figure 8. Number of Projects vs. Number of Contributors by Organizations

GitHub is the largest open source online social coding host with for 31 million developers around the world for 2.1 million organizations with 96 million project repositories containing 1.1 billion of code contributions as of 2018 [41].

Based on the GitHub Open Source project collection, Sensitivity Analysis can be performed between project planning and implementation activities from GitHub BigQuery data samples to test hypothesis H1 as to the evidence of Strategy-V architecture characteristics.

Project complexity could be analyzed by instrumenting sociotechnical sensors, based on which GitHub Strategy-V project management architecture could be further explored.

Then Trend Analysis of the Strategy-V sensors can be conducted on historical GitHub Archive dataset to test hypothesis H2 and H3.

5.2. Architecture Variation and Analysis

Organizational Strategy Management is in higher form of Project Management paradigm. To test hypothesis H4, generalize Strategy-V Model as a management framework to Organizational Strategy Management by more sociotechnical sensors at each level of Strategy-V. Then apply the Strategy-V Framework to Corporate Open Source Strategy as a case study to analyze the causes of Strategy Implementation gaps and their solutions using multi-layer feedback loops.

5.3. Simulation Based Experiments on Flexible Options

To test hypothesis H5, the Strategy-V framework thinking can also be applied to other Flexible Options that helps corporate open source projects to define and quantify Open Source system by characterizing the form and interactions between corporate internal and external developers.

From the baseline scenario to more complex scenarios, make assumptions from the system interfaces to simply the simulation model first, then add more building block to make the model more complete with uncertainty observed. The uncertain sensitivity analysis further identifies the major factors affecting the bottom line of a project through the Tornado diagram.

Learning the uncertainties of project factors helps to broaden the view of a system. Another type of Strategy-V framework value of carrying out the project could be brought out by the traditional Net Present Value (NPV) [30] analysis which enables comparison between different project options. However, the NPV value alone is not representative enough. The distributions with ENPV, STDDEV, P5, P95 statistics should be considered as sociotechnical sensors in the comparison of different flexible strategies. Corporate open source projects are attractive due to low CAPEX and high ENPV/CAPEX or ROI ratio.

By using Monte Carlo simulations, many scenarios of flexible options could be experimented, which provides efficient guidelines to the details of the options such as uncertain external contribution demand versus controllable factor in hiring and productivity.

Through the in-depth analysis, sensible flexible strategies could be found such as leverage the power of flexible hiring and productivity, more value of the project could be achieved by cutting the risks when external interests are low and gaining the upside when the hiring and productivity capacity could be expanded. Also, these flexible options could be implemented against the obstacles by recommended actions.

The Flexible Strategy approach is mostly useful to for projects with uncertainties to manage. The underlining assumptions could be verified. The ranges of project value and uncertainties could be quantified. There should be controllable factors in the project to leverage as the flexible options to make decisions based on uncertainty conditions. With the Flexible options built into design, higher value could be obtained over time balancing economy of scale and discounted cash flow benefits.

5.4. Chapter Summary

Three case studies are outlined to leverage GitHub open source projects.

- Instrument the new sociotechnical sensors in to apply the Strategy-V Framework to address RQ8.
- Explore Strategy-V architecture in Organization Management to address RQ9.
- Further explore more Flexible Strategies in Corporate GitHub projects for RQ10.

6. Case Study I – Strategy-V in Project Management

Principle of Balance or Dualism 一分为二

- ***Chinese Proverb:*** There are always two sides to everything.
- ***My System Thinking:*** At each project development stage, different inputs and outcomes might occur. Be adaptive to adopt flexible options to achieve better result. Theory and experiment come in tandem to study the system.

To apply Strategy-V Framework to real projects, GitHub Open Source projects are selected to instrument the new sociotechnical sensors using sensitivity analysis and trend analysis.

6.1. GitHub Open Source Project Collection

GitHub is based on Git as a distributed version control system that manages and stores revisions of projects [42], project managers and developers coordinate, plan, and update their work by creating issues to track ideas, enhancements, tasks, or bugs in one place using repositories. External developers can "star" a repository to mark their interest with the favorite host project, resulting in the project star status as the main project popularity measure [43]. The developers can voluntarily contribute to the project by proposing ideas as "issues" and creating an own "fork" copy of the repository without disrupting the core team's work on the root repository. Then they can work and improve the code independently in a repository under their name. When the proposed changes are ready, they can submit "pull request" as special kind of issue to integrate their changes into the root repository. The core team can review the changes in iteration with comments around the issues and additional code change commits by the developers in the forked repository. Then the core team can either reject or pull and merge the changes into the root repository [44]. The resolved issues would change from "open" to "close" stage.

6.2. Global Edge Complexity and Sociotechnical Sensor Instrumentation

For real life relationship network like GitHub, global edge complexity (GEC) [19] can be used to measure structural complexity due computing intensity of high dimensional eigenvalues. The GEC metric is defined as the sum of adjacency matrix A_i i.e. counting the relationship edges $S_i = \sum a_i$ for each project relationship aspect i in formula (1).

Each project could be observed with subsystem decomposition around merged Pull Requests (S_1) as the building blocks or modules for a product to publish feature set. They depend on hosted fork and pull review comments through individual Committer's contribution (H_1). And they are affected by related issues with help from Issue Commenters modules (H_2) for the efficiency ratio of Closed Issues over Total Issues (S_2). Yet the percentage of Opened and Reopened Issues would be the cost factor for new work and rework ($T \cdot C$).

Based on formula (2) and Global Edge Complexity, the estimates of project values could be expressed by

$$V_E = PullRequests \times Committers + IssueCommentters \times ClosedIssues/TotalIssues$$

$$V_c = (OpenedIssues + ReopenedIssues) \times IssueCommentters/TotalIssues$$

6.3. Sensitivity Analysis on GitHub BigQuery Data Samples

Project structural complexity brings out Project Emergent Value. Project planning through GitHub Wiki provides developers guidelines on feature module decomposition that form the pull-based development model. Pull Requests and related data has been collected from GitHub Archive BigQuery (githubarchive.day.2018* dataset; see Appendix for BigQuery SQL) to calculate Project Emergent Value (V_e)as the impact by complexity and Wiki action count as evidence of project planning based on Google newer GitHub projects shown in Figure 9 scatterplot.

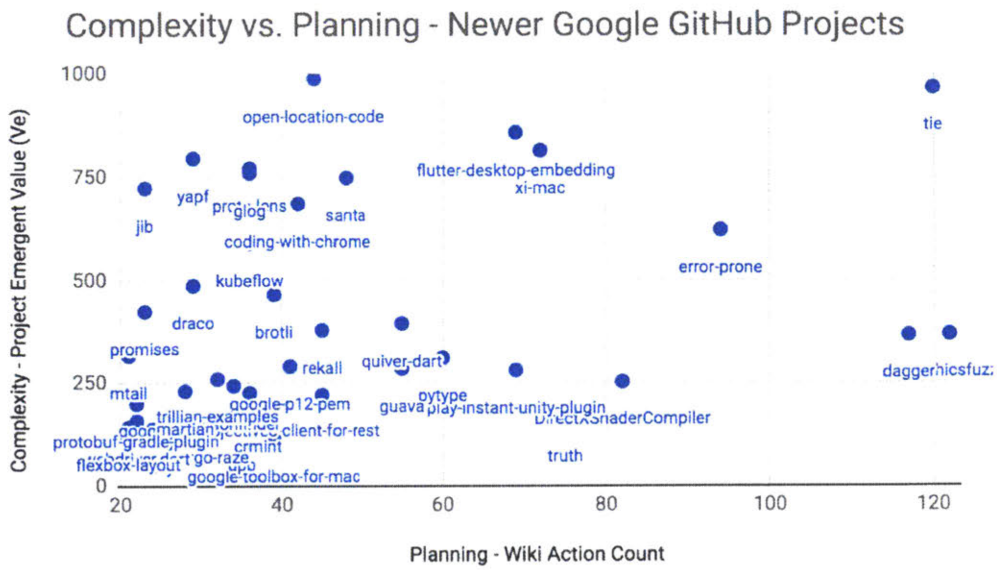


Figure 9. Sensitivity of Project Complexity vs. Planning for GitHub

The sensitivity does not show strong correlation between the two factors (correction coefficient at 0.26) due to some projects host planning and communication elsewhere. The graph does indicate higher planning activities bring out more emergent value as the trait for the V-model for H1.

6.4. GitHub Projects Strategy-V Architecture

GitHub could be further decomposed by a simplified Strategy-V model due to short cycle of merged pull requests as project modules that formed the final software product system (Figure 10). Pull requests are connected through fork repository and comment review. Developers are assigned or volunteer to work on the pull request modules.

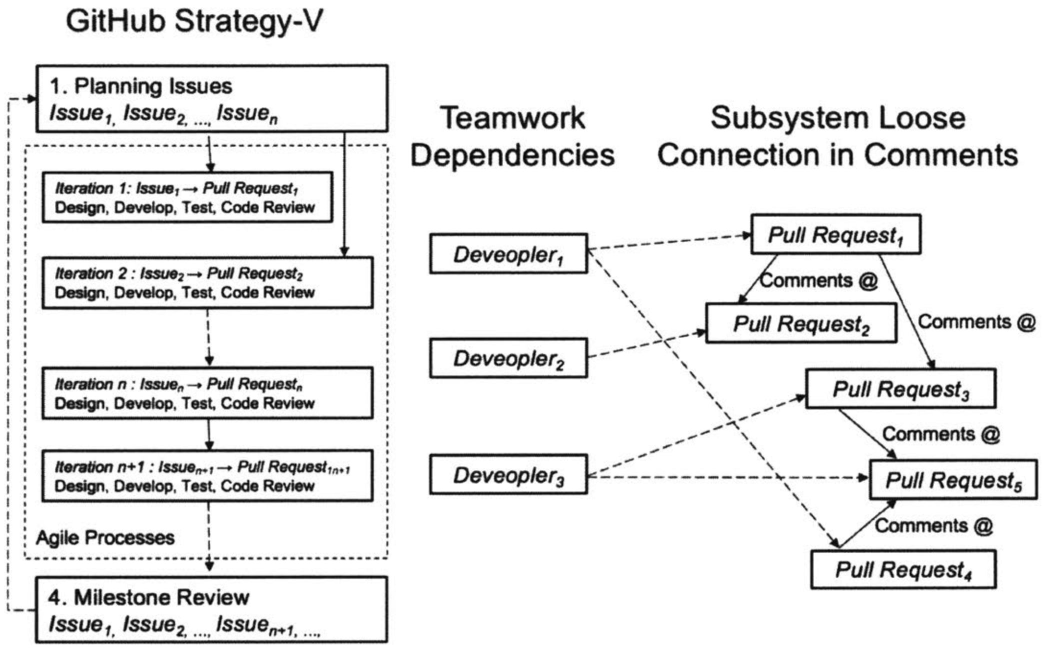


Figure 10. Sample Strategy-V workflows for GitHub

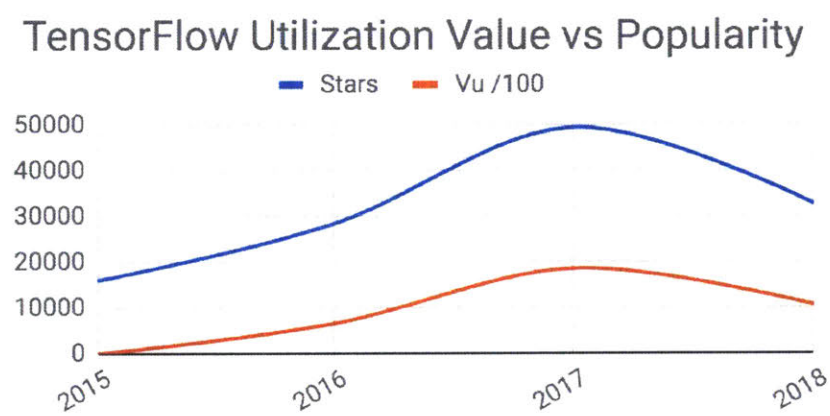
6.5. Trend Analysis of Strategy-V Sociotechnical Sensors

Some projects contain substantial evidences in GitHub such as project "dotnet/roslyn" with both Waterfall of roadmap planning and milestones reviews as wiki pages and customized issue labels on feature specifications, and Agile of extensively Project Board Kanban [45]. Some however choose to host all planning elsewhere such as project "tensorflow/ tensorflow" has tensorflow.org web site separately from GitHub. Table 1 shows the results for the above two projects with trend graph in Figure 11.

Table 1 Trend of Project Utilization Value

Project Name	Year	Stars	Committer	Pull Request	Issue Comment	Open Issue	Re-opened	Closed	Vu /100
tensorflow	2015	15999	17	21	651	590	27	413	2.28
	2016	28284	437	1499	3801	3548	204	3218	6,547.72
	2017	49275	736	2515	6973	5450	298	5165	18,506.68
	2018	32563	560	1885	7261	4503	222	4424	10,553.61
.net/roslyn	2015	4390	116	2877	1149	4276	234	2745	3,334.52
	2016	2986	115	3064	1366	4613	194	3158	3,520.77
	2017	2222	124	2972	1350	4024	168	3593	3,684.24
	2018	1957	133	3164	1129	3021	111	1982	4,205.58

The data shows that Project Utilization Value might provide insight to explain the trend of project popularity by Project Stars in some stages of project technology S-curve for H2 and H3, especially for TensorFlow Project. For the Roslyn Project, even though popularity is fading, the value is increasing slowly.



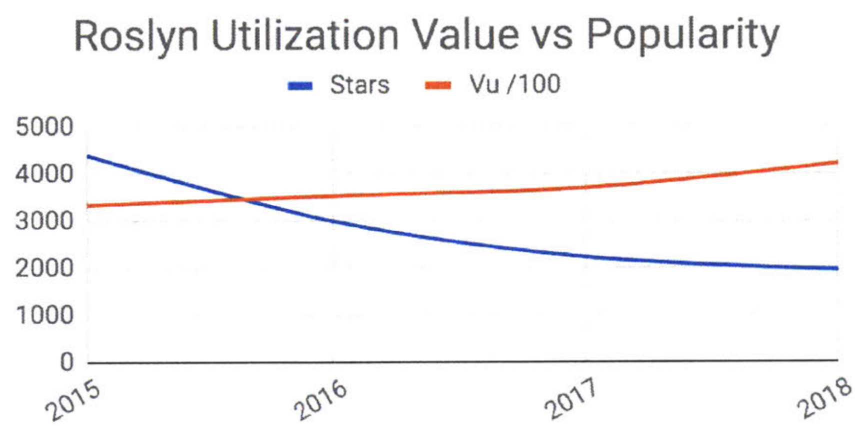


Figure 11. Trends in Project Utilization Value and Project Popularity Comparison

6.6. *Chapter Summary*

Project Emergent Value and Project Utilization Value are effective sociotechnical sensors to measure the holistic combination of project complexity in scope, teamwork dependency, cost, and time. They can be instrumented in the Strategy-V framework for GitHub projects to take the advantage of adaptability and strategy alignment over Waterfall and Agile methodologies. Based on the metrics, the first three hypotheses have been tested with the following findings to address research question RQ8.

RQ8: How would theoretical sociotechnical sensors compare to empirical evidence such as project popularity? Would the evidence show S-curve pattern over time? Any evidence on why project complexity would require more strategy planning and system decomposition?

Answer: From the experiments in the Case Study I, there are some empirical evidences that could be outlined by the following hypotheses testing results.

- From the sensitivity analysis, there is evidence from GitHub open source projects that high complexity represented by PEV would require more planning activities on project wiki actions for project dependencies which conforms the Strategy-V Model. However, the correlation is not strong due to some projects host planning and communication elsewhere. (H1).

- Based on the trend analysis, PUV as sociotechnical sensors for the Strategy-V Model could show project development S-curve trend over time in certain level from historical data for two GitHub projects (H2).
- The project sociotechnical sensor PUV for the Strategy-V Model also could reflect empirical project popularity or success in project comparison to some degree by the trend comparison (H3).

7. Case Study II – Strategy-V in Organization Management

Principle of Generalization 触类旁通

- ***Chinese Proverb:*** Know the category from the sample.
- ***My System Thinking:*** Solution specific concept could be generalized to solution neutral concept.

Can Strategy-V framework be generalized to apply to other settings or context? What are the layers in Strategy-V to enable interactions and feedback loops for efficiency? Let's explore more in the organizational strategy management.

7.1. Organizational Strategy Management Framework

Organizational strategy management consists of strategy planning (formulation) and strategy implementation. The strategy and implementation processes are linear stages which consists of four major steps: making sense of a situation, making choices on what to do (and what not to do), making those things happen and making revisions based on new information [4] as shown in Figure 12 from [46].

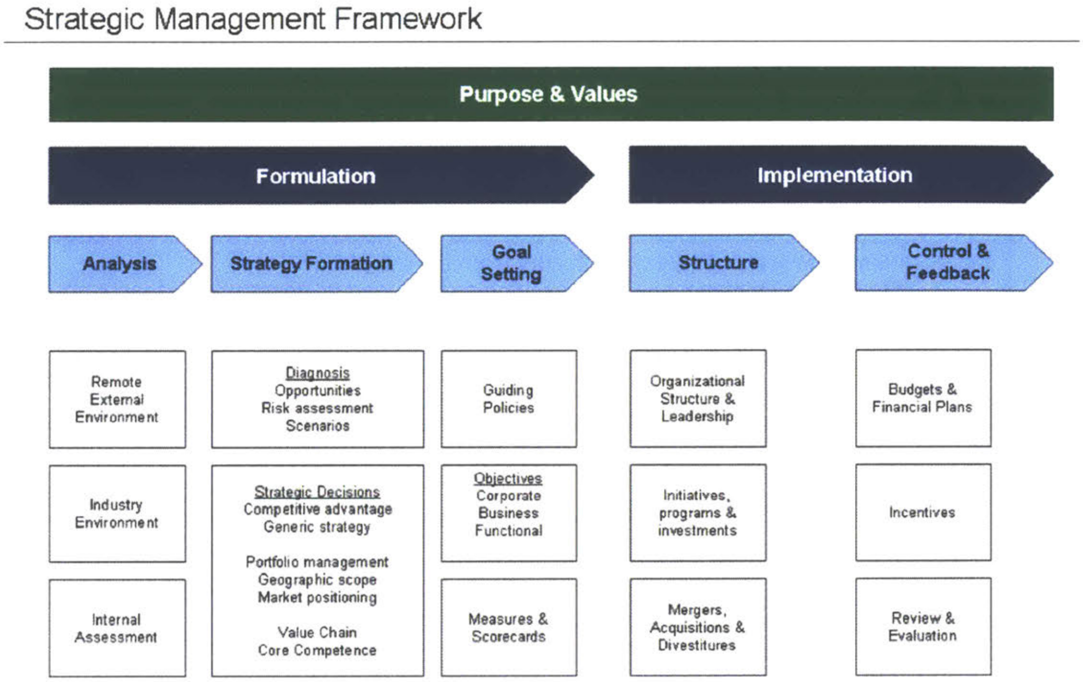


Figure 12. Linear Organizational Strategy Implementation Model

Strategy management can be drill down two levels in more details. Strategy Formulation as a part of strategy management includes strategy analysis, strategy conception, strategy synthesis, strategy formation, and strategy design for business and project development, whilst Strategy Implementation carries out strategy articulation, strategy validation, strategy communication, strategy engagement, and strategy monitoring activities to ensure values are achieved or strategy adjustment should be made for the organization vision [47]–[50].

7.2. *Strategic Thinking vs. System Thinking: A Strategy-V Model Variant*

A variant of Strategy-V model is proposed as a holistic organization strategy management framework by creative strategy formulation and strategy implementation on the two sides of the V with multiple layers of feedback loops in processes (Figure 13).

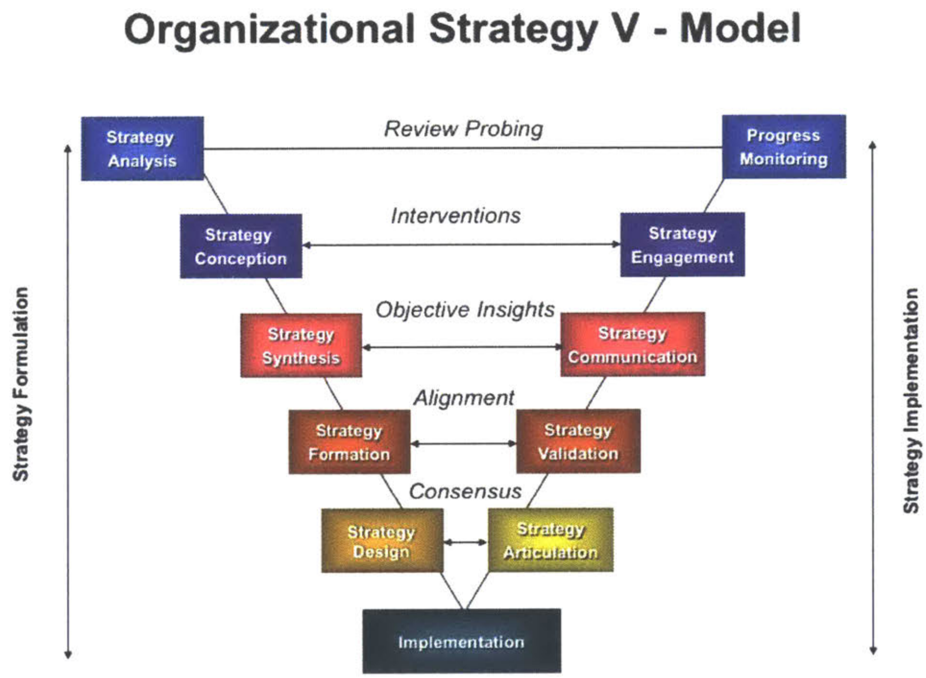


Figure 13. Strategy-V Model Framework and Multi-Layer Feedback Loop Processes

The Strategy-V Model can be classified by five layers from top down.

Strategy-V Left: Strategy Formulation Layers

- Layer 1 Strategy Analysis: Identify the needs of business.
- Layer 2 Strategy Conception: Determine the overall vision to succeed.
- Layer 3 Strategy Synthesis: Generate creative business insights and opportunities to create competitive advantage.
- Layer 4 Strategy Formation: Create activities connecting the dots of business to align direction.
- Layer 5 Strategy Design: Detailing implementation plan.

Strategy-V Right: Strategy Implementation Layers

- Layer 1 Strategy Monitoring: Monitor the progress of the organization in delivering the strategic objectives.
- Layer 2 Strategy Engagement: Managerial interventions designed to ensure organization achieves strategic outcomes.
- Layer 3 Strategy Communication: Convert strategic objectives into operating objectives to be assigned to groups for delivery.
- Layer 4 Strategy Validation: Engage with stakeholders and others to confirm strategic outcomes pursued are acceptable.
- Layer 5 Strategy Articulation: Build consensus within the team for strategy delivery about the outcomes to be achieved.

7.3. *Causes of Implementation Gaps and Multi-Layer Feedback Loop Solutions*

At each layer, possible causes of implementation gaps are analyzed. Different sociotechnical sensors can be instrumented for the processes at interfaces bottom up from Layer 5 to Layer 1 upon implementation. Process success in strategy implementation would "bubble up" at each layer while failure would loop back to the left to strategy formulation.

Layer 1: Fail to adapt strategy. Fail to sustain strategy.

Solution: Review Probing Sensor for Strategy Monitoring to Strategy Analysis Interface - Monitoring provides continuous implementation data points for further strategy review and probing and for more in-depth analysis.

Layer 2: Implementation runs short due to cost, schedule, and strategy scope constraints.

Solution: Interventions Sensor for Strategy Engagement to Strategy Conception Interface - Strategy vision conception is checked by close team engagement and intervention feedback. When interventions present issues, the overall business direction should be revisited for the soundness of the concept choice.

Layer 3: Wrong interpretation in Implementation.

Solution: Objective Insights Sensor for Strategy Communication to Strategy Synthesis Interface - If the short-term operating objectives cannot be reached for delivery, communicate to reconsider strategic objectives by creative insights for synthesis.

Layer 4: Constant internal and external changes.

Solution: Alignment Sensor for Strategy Validation to Strategy Formation Interface - If good articulation failed to convince stakeholders, the alignment should be adjusted to validate their needs to the vision formation.

Layer 5: Vision falls short against reality. Fail to translate strategy.

Solution: Consensus Sensor for Strategy Articulation to Strategy Design Interface - Detailed design is refined by articulation activities. If consensus cannot be reached, the design should be revisited and updated to further articulate strategy better for consensus.

7.4. Apply Strategy-V Framework to Corporate Open Source Strategy

Consider the example of Google corporate open source strategy. Google currently has over 2000 open source projects. Each such software project spans over multiple organizations for collaboration. Typically, the project contributors are corporate internal developers and external volunteer developers. The corporate internal developers often initiate and setup the project, publish open software API as system interfaces to protect proprietary software for integration, make substantial contributions to the code base, and attract external developers to make contributions.

The strategy formulation of corporate open source project is to save development cost by code contributions from external volunteer developers, gain faster time to market, and obtain larger market shares by extra free help from the use and distribution of software and services from external helpers. The strategy implementation is to leverage sociotechnical sensors at system interfaces in Strategy-V Model to attract external developers for code contribution.

7.4.1. Corporate Open Source Project Strategy Formulation

- Layer 1 Strategy Analysis: Identify the needs from corporate stakeholders and external developer communities.
- Layer 2 Strategy Conception: Determine the project vision including mission (goals) and scope of software.
- Layer 3 Strategy Synthesis: Drill down the software functional specification.
- Layer 4 Strategy Formation: Put the requirements into clear definition and documentation including the internal software making open source and proprietary IP scope.
- Layer 5 Strategy Design: Detailing design according to functional specification.

7.4.2. Corporate Open Source Project Strategy Implementation

- Layer 1 Strategy Monitoring: Monitor the progress of the project and external interests in number of helpers and quality code contributions.
- Layer 2 Strategy Engagement: Manage internal/external interactions to achieve strategic outcomes.
- Layer 3 Strategy Communication: Convert strategic objectives into marketing and operating objectives for delivery.
- Layer 4 Strategy Validation: Engage with internal and external developers to confirm strategic planning are acceptable.
- Layer 5 Strategy Articulation: Build consensus within corporate internal teams for open source marketing and development.

7.4.3. Corporate Open Source Project Multi-Layer Feedback Loops

Sociotechnical sensors can be instrumented at each layer.

- Layer 1 Review Probing Sensor: External development participation and download usage rate would directly indicate if the project strategy is successful.
- Layer 2 Interventions Sensor: The Corporate Internal vs. External Developer Ratio and Contribution Ratio are good indicator of how much internal leadership is effective.
- Layer 3 Objective Insights Sensor: The development forum on each topic would reveal the objective insights in discussion level.
- Layer 4 Alignment Sensor: Software bug produce rate and fix rate would be key indicators to validate the implementation.
- Layer 5 Consensus Sensor: Detailed design specification revisions is used as the sensor to articulate the path to implement the software functional requirements with internal/external developers.

7.5. Chapter Summary

This chapter addresses research question **RQ9:** How to transform System Thinking from Project Management to Organization Management?

From the Strategy-V framework, organization teamwork would benefit from the followings comparing to traditional frameworks.

- Easy to adapt to new strategy.
    - Feedback loops make adaptive changes possible at multiple implementation layers.
    - Escalate implementation to formulation feedback up a level if could not be resolved at current level.
- Translate strategy better.
    - At higher level, vision is checked by close engagement feedback.
    - At lower level, detailed design is refined by articulation activities.
- Sustain strategy longer.

- Consensus is built through the iterative design and interpretive implementation.
- Multi-layer feedbacks reinforce Strategy Implementation to conform with Strategy Formulation perpetually.

8. Case Study III – Flexible Strategy for Corporate Open Source Project

Principle of Categorization 物以类聚

- ***Chinese Proverb:*** Birds of a feather flock together.
- ***My System Thinking:*** Related components of a system should be grouped together.

Open source as a corporate strategy has been redefining corporate innovations, saving development cost, and gaining faster time to market and larger market shares. For an open source project, corporates face many uncertainties during strategy implementation such as effective contributions from external development community, projects dependencies, competition and economic impacts. This case study proposes an organizational extranet modeling framework to evaluate cross-organizational open source projects as systems within corporate overall product development system. Based on the framework, a Flexible design is further proposed using Flexible Options for corporate decision making that leverages corporate internal resources and investments to optimize strategy implementation across organizations. For the case study, Google open source software development projects are examined to demonstrate the mythologies.

8.1. Corporate Open Source Development Model

Corporate would leverage the open source model to save development cost from code contribution by external volunteer developers, gain faster time to market, and obtain larger market shares by extra free help from usage and distribution from external developers [51]–[53]. For example, Google currently has over 2000 open source projects hosted at GitHub among the top contributors from many organizations (Figure 8) [40].

8.2. Form of Corporate Open Source Project

Managing the projects effectively is very challenging [54], [55]. Each project could attract contributors from within and outside an organization over the years [56]. Contributors commit software source code to the code repositories at an open source host such as GitHub. For a successful project like Google Chrome browser (Figure 14) [57], the number of contributors grows to 1000+ developers over more than 10 years. The contributions are measured by the commits of quality reviewed source code.

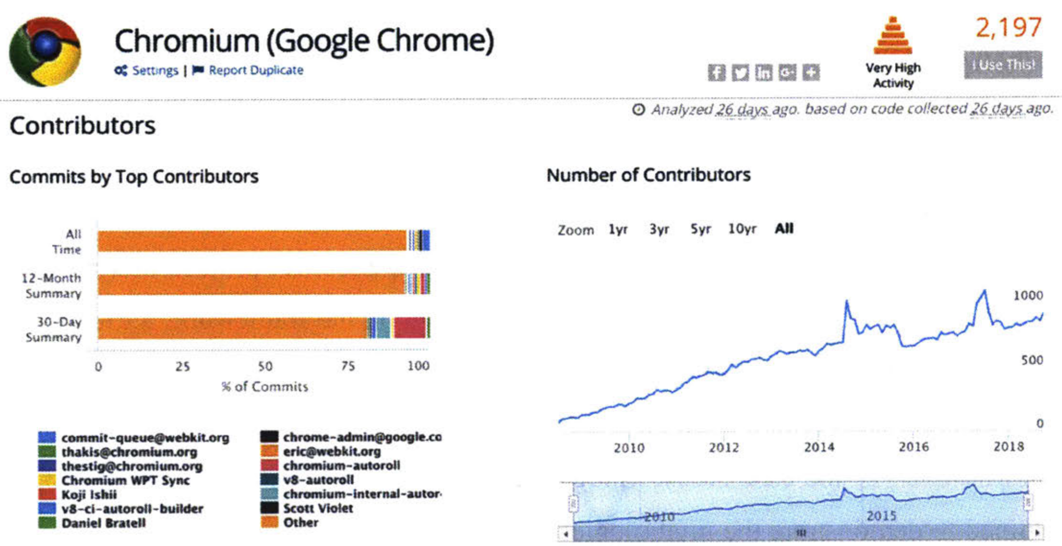


Figure 14. Open Source Project Contributors and Contributions

8.3. Interactions in a Corporate Open Source Project

For a corporate open source software project, the contributors are corporate internal developers hired to start and maintain the project and external volunteer developers who are interested in the project contribution for reuse, for fun, or for the greater good. The corporate internal developers often initiate and setup the project, make substantial contributions to the code base, and attract external developers to make contributions. Such interactions form the extranet [58] of external developers around internal organization as a system of systems [37]. For instance, a study shows that one internal contributor would potentially attract 0~30 external contributors, and the corporate internal contribution ratio could be 10% out of the total contributed commits based on 5 Google projects (Figure 15) [59].

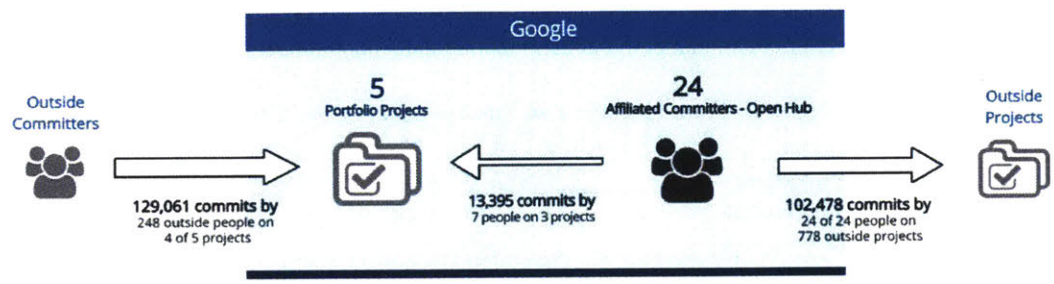


Figure 15. Corporate Internal vs. External Contributors (Committers)

From the study, external contributions could lead up to 120 source code commits per developer per year for a project, while internal (affiliated) contributions could be much higher up to 600 commits.

8.4. Baseline Model

The project development **demands** are the number of codes commits by the developers over time that build the software. The **revenue** could be reflected by value generated by the software and the money saved if the external volunteer developers were to be hired internally. The **cost** would be the hiring cost of internal developers and other project maintenance cost. Often a corporate project is open sourced due to internal development **capacity limit**. A base model is explored to characterize the performance and benefit of an open source project. Based on demand variations, further Flexible Strategies as Flexible Options [26], [30], [60] are analyzed to enhance the performance of the system.

For a project base case, the demand is projected as a static, non-probabilistic function for which the NPV analysis is applied.

8.4.1. Time Horizon and Discount Rate

Assume 10 years as the time period for a typical open source project lifecycle. The discount rate is assumed 15% as the risk is relatively low for the open source software industry (Table 2).

Table 2. Time Horizon and Discount Rate Assumptions

Projections	Value	Unit
Time horizon	10	years
Discount rate	15%	

8.4.2. Demand Projection

As open source project is source code commits driven, the model demand assumptions are listed in Table 1. The **Corporate Internal Contribution Ratio** (CICR) is the ratio of the number of internal commits contributions over the total commits. When a project grows, more external contributions would be attracted such that this ratio is close to the number of internal hires over the number of external contributors or **Corporate Internal to External Developer Ratio** (CIDR). Assume the internal team capacity is 5 developers for the project, and the number of external developers varies throughout the years (Table 3).

Table 3. Model Demand Projections Per Year

Demand Projections	Value	Unit
External demand in year 1	20	external developers
Additional demand by year 5	200	external developers
Additional demand after year 5	100	external developers
External developer productivity	120	commits per developer
Internal capacity limit	5	internal developers
Internal developer productivity	500	commits per developer

Effective project contribution would require growing number of external developers during the first five years of lifecycle from 20 developers with additional 200 by year 5 and back to 100 additions after year 5. The demand for the base case model is characterized as the function of external developers shown in Figure 16.

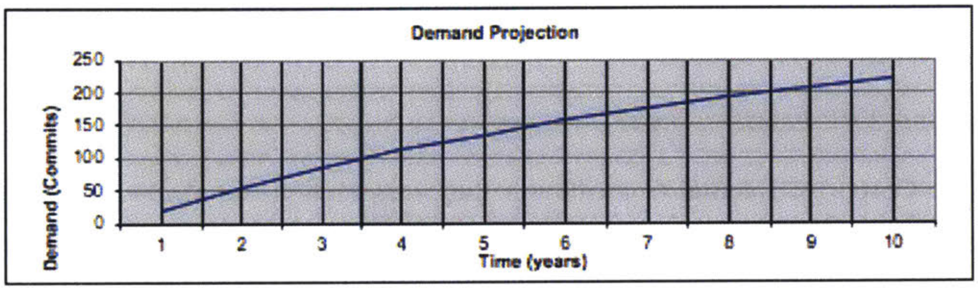


Figure 16. Baseline of External Developer Demand Projections over Time

The demand projection values are listed as the first row in Table 5 of Net Present Value (NPV) evaluation.

8.4.3. Price and Cost Projections

Assume that the initial capital expense is the commuting setup cost at $10K. The yearly maintenance cost is assumed to be $20K. The CIDR internal contribution ratio is assumed to be 10. An internal hired developer is assumed at $100K per year level with higher productivity of 500 commits per year comparing to external developer. The long-term benefit from code commits embody the software value with average annual revenue estimate at $200 per commit price, i.e. $100K/500 (Table 4).

Table 4. Price and Cost Projections

Price and Cost Projections	Value	Unit
Setup cost	$10,000	per project per year
Maintenance cost	$20,000	per project
Internal contribution CIDR	10%	
Internal hiring cost	$100K	per internal developer
Average annual revenue	$200	per commit

8.4.4. Baseline NPV Result

By the Corporate Internal Contribution Ratio assumption, the demand for corporate internal commits could be calculated. The Net Present Value (NPV) is around $5.3 million based upon the above assumptions for the base case as baseline (Table 5).

Table 5. Baseline NPV Model for Open Source Project Performance

Year	0	1	2	3	4	5	6	7	8	9	10
External developers demand		20	54	85	112	136	157	176	192	207	220
External capacity		50	50	50	50	50	50	50	50	50	50
External commits		2,400	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
Total commits		4,900	8,500	8,500	8,500	8,500	8,500	8,500	8,500	8,500	8,500
Revenue for total commits		$980K	$1,700K	$1,700K	$1,700K	$1,700K	$1,700K	$1,700K	$1,700K	$1,700K	$1,700K
Operating costs		$500K	$500K	$500K	$500K	$500K	$500K	$500K	$500K	$500K	$500K
CAPEX	$10K										
Maintenance costs		$20K	$20K	$20K	$20K	$20K	$20K	$20K	$20K	$20K	$20K
Cashflow		$460K	$1,180K	$1,180K	$1,180K	$1,180K	$1,180K	$1,180K	$1,180K	$1,180K	$1,180K
DCF		$400K	$892K	$776K	$675K	$587K	$510K	$444K	$386K	$335K	$292K
Present value of cashflow	$5,296K										
Net present value	$5,286K										

8.5. Uncertainty and Sensitivity

8.5.1. Major Uncertainties

The following 5 major uncertainties are characterized for a corporate sponsored open source project.

1) **The number of external developers that the project might attract**

   The number of external developers for a project depends on the project nature and project leadership. For unrealistic projects, external interests might be a quick way to measure the worthiness to cut cost. Corporate could not control this factor but might indirectly influence this factor by internal leadership and external marketing.

2) **The effectiveness of the external developers (independent of their number)**
Other important external performance factors are the number of high-quality commits which vary by external developers.

3) **The project dependencies on other projects**
If the project has external dependencies which are uncertain to be successful, then the outcome of this project is also uncertain assuming the outcomes of other internal or external projects are controlled by corporate sponsor.

4) **The competition offerings**
Normally the project is in a competitive landscape that similar or other disruptive projects might come up.

5) **The overall state of the economy**
The economy might be in favor of the project direction to encourage "open" development, or on the other hand might take down turn that exhausts the resources and interests in the project.

8.5.2. Range Estimates

Estimate the range of potential change in uncertain factors as the following.

- The Number of External Developers (Helpers): 0~60
- The Number of commits per year per Helper by: 0~500
- Other Project Dependency Impact: all loss ~ no impact
  Assume the maximum loss would be the cost of at most 8 internal hires and marketing/maintenance.

- Competition Impact: all loss ~ positive marketing impact
- Economy Impact: all lost (unfavorable) ~ positive marketing impact (favorable)

8.5.3. Sensitivity Performance

1) **\$ of up to 60 Helper: (\$8,000K) ~ \$6,000K**

   Helpers are salary free. The gain is around \$6M comparable to hiring them internally (\$100K per developer). However, if no helper could be attracted, the project is a failed one to leverage external resource even though the project could be continued as open source but only from internal contributions. The potential loss is the whole revenue of \$8M.

2) **\$ of up to 500 of commits/year per Helper: (\$600K) ~ \$4,200K**

   Assume 50% commits are \$200 value per high quality commit (50%*\$200*60*500=\$3,000K), 40% are \$100 per medium quality commit (40%*\$100*60*500=\$1,200K), and 10% are costly (\$200) per bad code commits producing wrong results (-10%*\$200*60*500 = -\$600K) that need more refactor work later on.

3) **\$ of Other Project Dependency Impact: (\$32K) ~ \$0**

   Assume the maximum loss would be the cost of at most 3 internal hires (\$300K) and marketing maintenance (\$20K). Only 10% chance of this project failure is due to dependent projects fail.

4) **\$ of Competition Impact: (\$64K) ~ \$60K**

   Assume the marketing benefit from Competition would be up to \$60K/year (3x marketing maintenance cost). 20% chance of this project failure is due to dependent projects fail.

5) $ of Economy Impact: ($128K) ~ $120K

Assume Economy has 2x more impact than Competition.

8.5.4. Tornado Diagram

The value ranges are summarized in Table 6, based on which the Tornado Diagram (Figure 17) could be shown for sensitivity analysis.

Table 6. Value Range Sensitivity

Factor	Low	High
Project Dependencies	($32)	$0
Competition Impact	($64)	$60
Economy Impact	($128)	$120
Effectiveness of Helpers	($600)	$4,200
Number of Helpers	($8,000)	$6,000

To extend the base case, the above five major uncertainties are characterized with range estimates. The first two factors are the most sensitive ones from the sensitivity analysis. The number and the effectiveness of External Developers (Helpers) would make the most significant impact to the project.

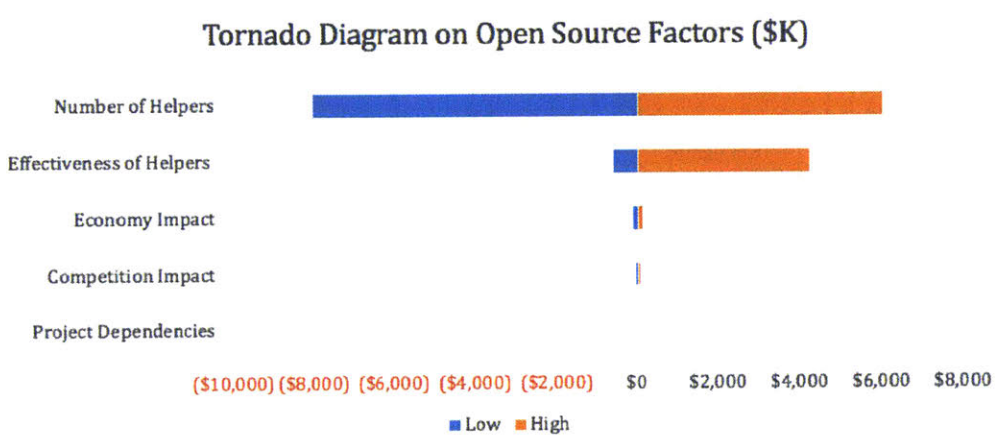


Figure 17. Tornado Diagram for Sensitive Analysis

8.6. Base Case with Uncertain Demand

In contrast to static demand, uncertain or probabilistic demand on external code commits contributions could be simulated by the Monte Carlo method with the histogram and cumulative distribution function graphs shown in Figure 18. By the Corporate Internal Contribution Ratio assumption, the demand for corporate internal contribution could be calculated.

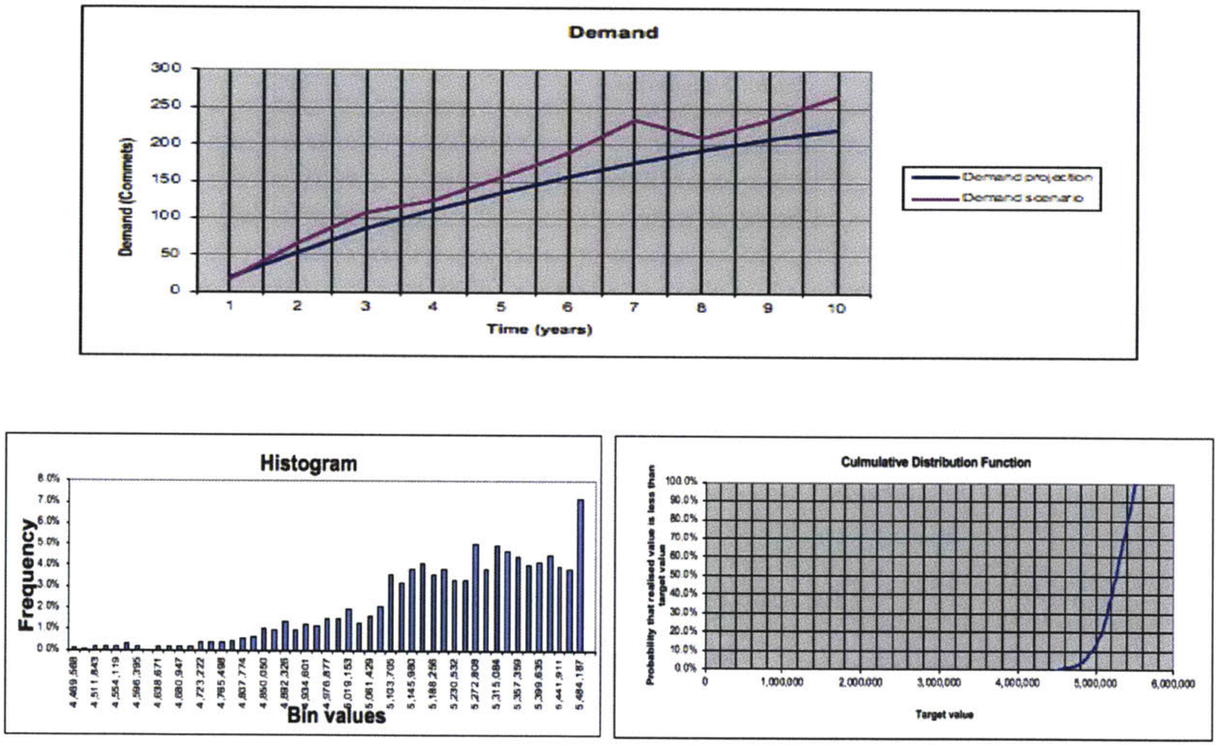


Figure 18. Base Case with Uncertainty Simulation Model for Open Source Project Performance

The histogram values are shifted to the right-hand side of the histogram, attributed to the fact that the maximum capacity of the internal hiring preventing taking advantage of external demand annually.

From the Model result in Table 7, the NPV is at $5.2 million similar to the base case without uncertainty.

Table 7. Base Case with Uncertainty NPV Model

Year	0	1	2	3	4	5	6	7	8	9	10
External developers demand		17	64	104	137	165	188	208	224	238	249
Demand growth projection			278%	62%	32%	20%	14%	10%	8%	6%	5%
Realised demand growth			292%	66%	20%	14%	15%	24%	1%	4%	11%
Realised external demand		17	67	106	125	157	189	233	209	233	264
External capacity		50	50	50	50	50	50	50	50	50	50
External commits		2,040	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
Total commits		4,540	8,500	8,500	8,500	8,500	8,500	8,500	8,500	8,500	8,500
Revenue for total commits		$908K	$1,700K	$1,700K	$1,700K	$1,700K	$1,700K	$1,700K	$1,700K	$1,700K	$1,700K
Operating costs		$500K	$500K	$500K	$500K	$500K	$500K	$500K	$500K	$500K	$500K
CAPEX	$10K										
Maintenance costs		$20K	$20K	$20K	$20K	$20K	$20K	$20K	$20K	$20K	$20K
Cashflow		$388K	$1,180K	$1,180K	$1,180K	$1,180K	$1,180K	$1,180K	$1,180K	$1,180K	$1,180K
DCF		$337K	$892K	$776K	$675K	$587K	$510K	$444K	$386K	$335K	$292K
Present value of cashflow	$5,233K										
Net present value	$5,223K										

8.7. Flexible Strategy Designs

From the results of sensitivity analysis, the external development factors are the most import uncertainties involving the number of external developers would join the project and the productivities of the external developers. By leveraging the leadership of corporate internal developers, Flexible Options [61] can be introduced into the baseline case model to mitigate possible losses and to increase the probability of a higher overall productivity. Three options are considered to compare the impact on the expected net present value (ENPV) and other distribution statistics to optimize the value of the open source project.

8.7.1. Flexible Hiring Option Model

Under the base case with uncertainty, take actions to adjust the number of corporate internal developer hiring depending on the demand of the total contribution goals from external demand.

Expand the corporate team when appropriate by defining decision rule such as adding an internal developer to the team if the demand of current year's total contribution exceeds current team's capacity. Table 8 shows the result of the NPV model with a row of flexible internal hiring strategy from the IF statement based on the variation of external demand projection.

Table 8. Flexible Hiring Option Model

Year	0	1	2	3	4	5	6	7	8	9	10
External developers demand		17	64	104	137	165	188	208	224	238	249
Realised external demand		17	67	106	125	157	189	233	209	233	264
Internal hiring strategy		3	9	12	12	15	15	20	20	20	20
External capacity		25	90	120	120	150	150	200	200	200	200
Internal commits		1,250	4,500	6,000	6,000	7,500	7,500	10,000	10,000	10,000	10,000
External commits		2,040	7,714	12,466	14,400	18,000	18,000	24,000	24,000	24,000	24,000
Total commits		3,290	12,214	18,466	20,400	25,500	25,500	34,000	34,000	34,000	34,000
Revenue		$658K	$2,443K	$3,693K	$4,080K	$5,100K	$5,100K	$6,800K	$6,800K	$6,800K	$6,800K
Operating costs		$250K	$900K	$1,200K	$1,200K	$1,500K	$1,500K	$2,000K	$2,000K	$2,000K	$2,000K
CAPEX	$10K										
Maintenance costs		$20K	$20K	$20K	$20K	$20K	$20K	$20K	$20K	$20K	$20K
Cashflow		$388K	$1,523K	$2,473K	$2,860K	$3,580K	$3,580K	$4,780K	$4,780K	$4,780K	$4,780K
DCF		$337K	$1,151K	$1,626K	$1,635K	$1,780K	$1,548K	$1,797K	$1,563K	$1,359K	$1,182K
Present value of cashflow	$13,978K										
Net present value	$13,968K										

The NPV is increased to $14 million to capture the increasing demand that was capped due to internal capacity limit of team size 5 in the base model by adding a new team member. The project can also cut loss in the first year when demand was low by starting team small at 3 comparing the fixed team size of 5 in the base model.

8.7.2. *Flexible Productivity Option Model*

Under the same fixed number of internal team size in the base case with uncertainty, take actions to adjust the productivity (number of quality reviewed source code commits) from corporate internal developers depending on the total contribution goals by external demand.

Define decision rule such as increasing productivity if the demand is high. Table 9 presents the result of the NPV model with a row of flexible productivity measure of Internal commits per developer strategy evaluated by the IF statement based on external demand variation.

Table 9. Flexible Productivity Option Model

Year	0	1	2	3	4	5	6	7	8	9	10
External developers demand		17	64	104	137	165	188	208	224	238	249
Realised external demand		17	67	106	125	157	189	233	209	233	264
External capacity		50	50	50	50	50	50	50	50	50	50
External commits		2,040	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
Internal commits/dev strategy		500	500	500	500	700	700	700	700	700	700
Total commits		4,540	8,500	8,500	8,500	9,500	9,500	9,500	9,500	9,500	9,500
Revenue		$908K	$1,700K	$1,700K	$1,700K	$1,900K	$1,900K	$1,900K	$1,900K	$1,900K	$1,900K
Operating costs		$500K	$500K	$500K	$500K	$500K	$500K	$500K	$500K	$500K	$500K
CAPEX	$10K										
Maintenance costs		$20K	$20K	$20K	$20K	$20K	$20K	$20K	$20K	$20K	$20K
Cashflow		$388K	$1,180K	$1,180K	$1,180K	$1,380K	$1,380K	$1,380K	$1,380K	$1,380K	$1,380K
DCF		$337K	$892K	$776K	$675K	$686K	$597K	$519K	$451K	$392K	$341K
Present value of cashflow	$5,666K										
Net present value	$5,656K										

The NPV is increased slightly to $5.7 million to capture the increasing demand but was still capped due to team capacity limit.

8.7.3. Flexible Hiring + Productivity Option Model

This scenario is to explore the multi-dimensional combination of both the Flexible Hiring Option and the Flexible Productivity Option due to the following reasons.

- Grow productivity when possible as each team might have team size limit by resource constrains.
- Grow team when possible since each internal developer can just do so much by productivity limit.

Under the base case with uncertainty, take actions to adjust the team size and team productivity for corporate internal developers depending on the total contribution goals by external demand.

Define decision rule by combining the decision rules from both previous options. The result of the NPV model is displayed in Table 9 with two rows of flexible productivity and flexible hiring strategies.

Table 10. Flexible Hiring + Productivity Option Model

Year	0	1	2	3	4	5	6	7	8	9	10
External developers demand		17	64	104	137	165	188	208	224	238	249
Realised external demand		17	67	106	125	157	189	233	209	233	264
Internal hiring strategy		3	9	12	12	15	15	20	20	20	20
Internal commits/dev strategy		500	500	500	500	700	700	700	700	700	700
External capacity		25	90	120	120	150	150	200	200	200	200
Internal commits		1,250	4,500	6,000	6,000	10,500	10,500	14,000	14,000	14,000	14,000
External commits		2,040	7,714	12,466	14,400	18,000	18,000	24,000	24,000	24,000	24,000
Total commits		3,290	12,214	18,466	20,400	28,500	28,500	38,000	38,000	38,000	38,000
Revenue		$658K	$2,443K	$3,693K	$4,080K	$5,700K	$5,700K	$7,600K	$7,600K	$7,600K	$7,600K
Operating costs		$250K	$900K	$1,200K	$1,200K	$1,500K	$1,500K	$2,000K	$2,000K	$2,000K	$2,000K
CAPEX	$10K										
Maintenance costs		$20K	$20K	$20K	$20K	$20K	$20K	$20K	$20K	$20K	$20K
Cashflow		$388K	$1,523K	$2,473K	$2,860K	$4,180K	$4,180K	$5,580K	$5,580K	$5,580K	$5,580K
DCF		$337K	$1,151K	$1,626K	$1,635K	$2,078K	$1,807K	$2,098K	$1,824K	$1,586K	$1,379K
Present value of cashflow	$15,523K										
Net present value	$15,513K										

The NPV is increased to $15.5 million as the best option. More distribution exploration would be helpful to measure the outcome values for comparison.

8.8. *Statistical Comparison for Different Models*

For each model examined, the statistics are collected for Expected NPV (ENPV), standard deviation, 5 percentile (P5), and 95 percentile (P95) as shown in Table 11. The numbers represent the improvement of the flexible options over the base case with uncertainties.

Table 11. NPV Statistical Comparison for Different Models

Case	P_5	ENPV	St. Dev	P_{95}	CAPEX	ENPV/CAPEX
Base Case with Uncertainties	$4,848K	$5,222K	$196K	$5,474K	$10K	52222.0%
Flexible Producivity Option	$4,845K	$5,508K	$355K	$5,938K	$10K	55084.9%
Flexible Hirings Option	$7,718K	$12,268K	$3,012K	$17,050K	$10K	122675.3%
Flexibility Hiring+Productivity	$7,677K	$13,483K	$3,784K	$19,421K	$10K	134831.7%

The improvement of the flexible options from the base case is summarized in Table 12.

Table 12. Improvement of Flexible Options

Alternative Case	P_5	ENPV	St. Dev	P_{95}	CAPEX	Value of Option
Flexible Producivity Option	0%	5%	81%	8%	0%	$286,294
Flexible Hirings Option	59%	135%	1438%	211%	0%	$7,045,336
Flexibility Hiring+Productivity	58%	158%	1832%	255%	0%	$8,260,974

The corresponding Cumulative Distribution Function (CDF) graph for each model are displayed in Figure 19, which also shows substantial improvement of the flexible option models. The combined Flexible Hiring + Productivity Option is the dominant model.

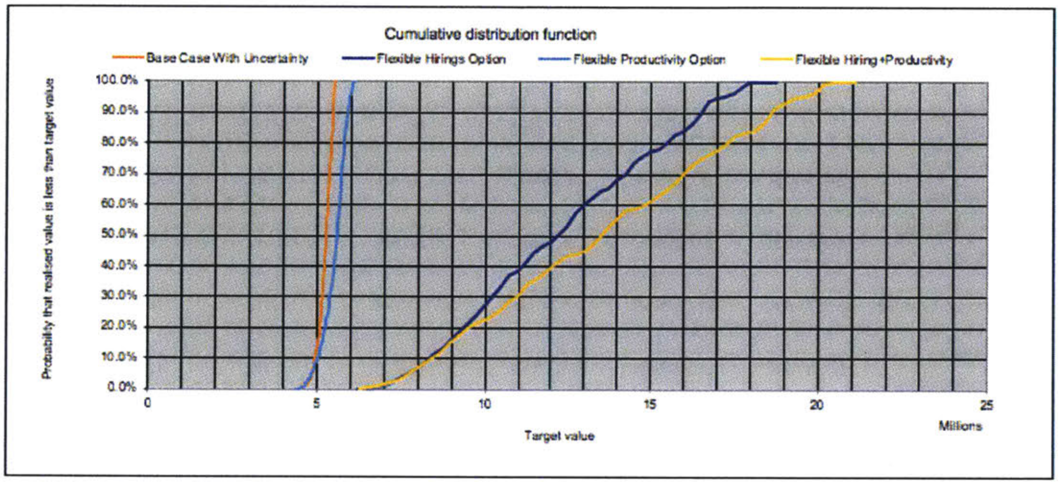


Figure 19. Comparison of Corporate Open Source Project Model Distributions

8.9. Implementation Strategy and Recommendations

Potential obstacles exist between strategy and implementation. Good implementation strategy would help overcome the obstacles to fill the gap between strategy and implementation.

8.9.1. Potential Obstacles

The obstacles are characterized by Ignorance, Inattention, Plan Failure, Stakeholder Block, and External Development.

1) **Ignorance**

   Ignorance often affect the natural growth of an open source project in adopting hiring related flexible options. Project managers are unaware of the need to expand internal teams to handling the increasing care of external development growth such as addressing issues in the forum, reviewing commit submissions, and fixing bugs introduced by external developers.

2) **Inattention**

All flexible options require close monitoring of project progress such as product design and implementation, testing and rework. Adjust hiring and productivity for the progress demand to attract more external developers. The flexible option analysis is illustrated on yearly basis but in reality, changes might happen more frequently.

3) **Failure to plan ahead**

Failure to plan ahead would affect hiring related options. The demand for team growth often requires sufficient funding budget. Failure to plan ahead would limit the capacity for internal and external contribution growth.

4) **Stakeholder block**

Due to IP and other sensitive issues, open source projects may face many types stakeholder block. Certain code might be prevented to be open-sourced that would potentially affect the flexible productivity options.

5) **External Developments**

As mentioned in uncertainty sensitivity analysis, external competition and economy environment all play roles affecting external interests in the open source projects. They all affect hiring and productivity flexibilities.

8.9.2. Implementation Recommendations

Based on the potential strategy and implementation gap analysis, the following actions are recommended.

1) **Initial Planning and Preventative Actions**

Integrated project delivery would require all the internal and external project organization stakeholders to work together collaboratively in IP and code sharing, product design and implementation, testing and rework, which would reduce ignorance, failure to plan ahead, and stakeholder block.

2) **Game Plan for Changes**

   The project managers should have a **game plan** to implement the flexible options as illustrated. The steps vary depending on individual project setting and external demands. Also **anticipate external development** and be adaptive to the changing environment, for example, merging projects with competitors to leverage advantages from either project for a win-win outcome for project rapid expansion.

3) **Ongoing Operational Actions**

   In addition to initial planning and preventative actions, ongoing operational actions would help the implementation of the flexible option.

4) **Rights to Change**

   Maintain **the rights to implement the flexible options**. Project managers should obtain HR permission to hire and fire internal developers whenever needed, and have the authority to enforce good productivity performance.

5) **Know How**

   Learn how to **implement and use the flexible options**. Managers need to know the project progress stage and act on the principles provided by the flexible options in term of hiring ahead of time and encouraging higher productivity practice.

6) **Attention! Attention! Attention!**

   Pay close attention to monitor the environment and ongoing project status. Project managers must verify and adjust flexible options assumptions and re-calculate proper actions to execute the options.

8.10. Chapter Summary

This chapter targets research question **RQ9** on Flexible Strategy design, especially in cross-organizational teamwork. Uncertainty is addressed through sensitivity analysis. Based on the framework, a Flexible Hiring + Productivity Strategy design is proposed using Flexible Options for corporate decision making that leverages corporate internal resources and investments to optimize strategy implementation across organizations. Google open source software development models are examined. Through scenario simulation of different flexible options, the combined Flexible Hiring + Productivity Option is the dominant model.

9. Conclusions

Principle of Holism 欲穷千里目，更上一层楼

- ***Chinese Poem:*** Enjoy a grander sight by climbing to a greater height.
- ***My System Thinking:*** See more insights of a system as a whole when position self or observer to better angle.

9.1. *Insights*

This thesis brings a fourth dimension of teamwork human factor to three dimensional constraints of project scope, time, and cost in project management frameworks. New sociotechnical sensors are introduced as Project Emergent Value (PEV), Project Utilization Value (PUV), and Project Utilization Ratio to measure complex projects in the four dimensions. These sociotechnical sensors can be instrumented at micro-scale, meso-scale, and macro-scale levels by different management frameworks. The Strategy-V Model framework is proposed by injecting the Agile framework activities into the Waterfall framework based on the sociotechnical sensors. PEV helps to identify framework patterns. PUV brings out the Strategy-V Project Utilization Theorem as a flexible strategy. The Strategy-V Model has the advantage of adaptability and strategy alignment over Waterfall and Agile frameworks proved by the theorem and shown in the first case study. The theorem can be generalized to the Theory of Project Framework Utilization as a Flexible Strategy guideline to choose effective program management framework. The new framework is extensible to organizational strategy management and other flexible options as shown in the last two case studies. Strategy-V would achieve better system in scope, faster time to develop, cheaper in cost, and more rewarding for teamwork.

9.2. Key Findings

9.2.1. Hypotheses Testing

The hypotheses have been tested with the following findings.

- **H1**: Would high project complexity require more planning activities on project dependencies in conforming the Strategy-V Model?

  Answer: From the sensitivity analysis in Case Study I, there is evidence from GitHub open source projects that high project complexity represented by PEV would require more planning activities on project wiki actions for project dependencies which conforms the Strategy-V Model. However, the correlation is not strong due to some projects host planning and communication elsewhere.

- **H2**: Does the Strategy-V Model with sociotechnical sensors for show project development S-curve trend over time?

  Answer: Based on the trend analysis in Case Study I, PUV as a sociotechnical sensor for the Strategy-V Model could show project development S-curve trend over time at certain level from the historical data for two GitHub projects.

- **H3**: Would any project sociotechnical sensor for the Strategy-V Model reflect empirical project popularity or success in project comparison?

  Answer: Based on the trend analysis in Case Study I, PUV as a sociotechnical sensor for the Strategy-V Model would also reflect empirical project popularity or success in project comparison to some degree.

- **H4**: Could the Strategy-V Model as a management framework be generalized from project management to organization management in broader scope by more sociotechnical sensors?

  Answer: From Case Study II, the Strategy-V Model can be generalized from project management to organization management by instrumentation of different sociotechnical sensors at each layer of the Strategy V.

- **H5**: Could the Strategy-V Model as a Flexible Strategy be generalized to other Flexible Option sensors to optimize corporate strategies?

  Answer: Base on Case Study III, the Strategy-V Model as a Flexible Strategy can be generalized using other Flexible Option sensors such as the Flexible Hiring + Productivity Option to optimize corporate Open Source strategy.

9.2.2. Answers to Research Questions

- **RQ1:** What are the causes of the gap between strategy and implementation in project management, especially in software projects?

  Answer: Due to project complexity with human factor under uncertainty, each project step might lead to deviation from strategy intent in activities that result in "bad move".

- **RQ2:** What are the key factors in Project Management and how to quantify them in regards to project performance?

Answer: Currently Project Management comprises a body of methods and tools that facilitate the achievement of project objectives within time, cost, and scope three dimensions measurable at desired performance.

- **RQ3:** How to measure project complexity and its relation to project scope, time, and cost dimensions?

  Answer: Project scope is represented by project complexity. Project Complexity involves the dynamics between Structural Complexity and Behavioral Complexity, which could be measured by sociotechnical sensors.

- **RQ4:** How can teamwork be reflected in project dimensions as sociotechnical sensors in theory?

  Answer: Project Emergent Value is the project scope value achieved through teamwork. This PEV measure is based on a combination of technical and social systems characteristics: the product of system architectural or structural complexity and human team creativity reward to produce the system.

- **RQ5:** How to measure project performances in context of Waterfall, V-Model, Agile frameworks?

  Answer: Project Utilization Value is the difference between Project Emergent Value and the product of project time and cost. The value can be computed for Waterfall, Strategy-V Model, Agile frameworks.

- **RQ6:** Why Agile framework might go wrong in strategy alignment? Would project complexity require more strategy planning and system decomposition?

Answer: Project Emergent Value measures the project complexity in both system architecture and teamwork. The value changes by time as more system complexity is discovered. The Agile project emergent value would start small but increase over time as more complexity are discovered. The rewards are lower or the cost is higher due to more iterations are needed. For Waterfall and Strategy-V frameworks, project initial scoping and resource estimation efforts are more thorough in system modules decomposition with dependency analysis and teamwork allocation. The project emergent value is high for both frameworks in the early stage if the scoping is correctly aligned with the project strategy goal.

- **RQ7:** Any better frameworks? Any theoretical proof? Any guideline on how to use the frameworks?

  Answer: The Strategy-V framework has advantage under the conditions formulated in the Strategy-V Project Utilization Theorem as a Flexible Strategy leveraging Waterfall and Agile frameworks. The Theorem is proved mathematically given the flexible option conditions.

  Use a Flexible Strategy guideline as the Theory of Project Framework Utilization in framework decision choice: At any framework decision making time of a project, choose the framework methodology that has the best Project Utilization where the scope complexity rewards are higher or cost is lower for any subset of project domain constrained by scope, time schedule, cost and human resource.

- **RQ8:** How would theoretical sociotechnical sensors compare to empirical evidence such as project popularity? Would the evidence show S-curve pattern over time? Any evidence on why project complexity would require more strategy planning and system decomposition?

Answer: From the experiments in the Case Study I, there are some empirical evidences that could be outlined by the following hypotheses testing results.

- From the sensitivity analysis, there is evidence from GitHub open source projects that high complexity represented by PEV would require more planning activities on project wiki actions for project dependencies which conforms the Strategy-V Model. However, the correlation is not strong due to some projects host planning and communication elsewhere.
- Based on the trend analysis, PUV as sociotechnical sensors for the Strategy-V Model could show project development S-curve trend over time in certain level from historical data for two GitHub projects.
- The project sociotechnical sensor PUV for the Strategy-V Model also could reflect empirical project popularity or success in project comparison to some degree by the trend comparison.

- **RQ9:** How to transform System Thinking from Project Management to Organization Management?

Answer: From the Strategy-V framework, organization teamwork would ease adaption to new strategy adding feedback loops to make changes possible at multiple implementation layers. The team can escalate implementation to the formulation feedback up a layer if could not be resolved at current layer. The organization can translate strategy better with vision checked by close engagement feedback at higher level and detailed design refined by articulation activities at lower level. The project leaders can sustain strategy longer by building consensus through the iterative design and interpretive implementation with multi-layer feedbacks reinforcing Strategy Implementation to conform with Strategy Formulation perpetually.

- **RQ10:** Any other Flexible Strategy design for the frameworks, especially in cross-organizational teamwork?

  Answer: Uncertainty is addressed through sensitivity analysis. Based on the framework, a Flexible Hiring + Productivity Strategy design is proposed using Flexible Options for corporate decision making that leverages corporate internal resources and investments to optimize strategy implementation across organizations. Google open source software development models are examined. Through scenario simulation of different flexible options, the combined Flexible Hiring + Productivity Option is the dominant model.

9.3. Limitations

Even though GitHub started to roll-out project management functions such as the Project tab with Kanban and other methods, the usage is sparse due to the ad-hoc nature of many GitHub projects. Certain key knowledges are missing online from the decomposition of project structure and component dependencies. As a result, the correlation is weak to reveal planning activities and their mapping to implementation activities in the sensitivity analysis. The power of the Strategy-V framework theory is not fully demonstrated by the GitHub project management analysis.

The choice of sociotechnical sensors is critical to determine the outcome of the experimental case studies. Due to limited time constraint, the thesis work only explores some but not fully the choices of project complexity and teamwork reward metrics with cost benefit analysis.

9.4. Future Work

Each project development framework could be expressed in certain functions of Scope, Time schedule, Cost, and Human teamwork among which another utility ratio $\frac{S \cdot H}{T \cdot C}$ might also reveal a spread of the gain over cost. Many other project complexity measures could be examined to calculate emergent and utility values. Also explore how the propose sensors change by time stochastically that helps value predication and framework projection.

10. Appendix

10.1. "Complexity vs. Planning" GitHub BigQuery SQL

```
WITH ProjectData AS
  (SELECT *
   FROM `githubarchive.day.2018*`
   WHERE repo.name LIKE 'google/%'),
     GhtData AS
  (SELECT p.name AS project_name,
          l.id AS label_count
   FROM `ghtorrent-bq.ght_2018_04_01.issue_labels` l,
        `ghtorrent-bq.ght_2018_04_01.repo_labels` r,
        `ghtorrent-bq.ght_2018_04_01.projects` p
   WHERE l.repo_id = p.id
     AND l.id = r.id
     AND r.name NOT IN ('bug',
                        'duplicate',
                        'wontfix',
                        'invalid',
                        'Bug',
                        'question',
                        'imported')
     AND (REGEXP_CONTAINS(p.url, r"repos/google/"))
)
SELECT ROUND((Ve - Vc)/(Ve + Vc), 2) AS Ru,
       ROUND(Ve - Vc, 2) AS Vu,
       *
FROM
  (SELECT ROUND(PullRequests * Committers + IssueComments * ClosedIssues
/TotalIssues, 2) AS Ve,
          ROUND(IssueComments *(OpenedIssues + ReopenedIssues)
/TotalIssues, 2) AS Vc,
```

```
            *
    FROM
      (SELECT repo.name AS ProjectName,
              rp.repo.id,

         (SELECT count(label_count)
          FROM GhtData
          WHERE CONCAT('google/', project_name) = rp.repo.name) AS
label_count,

         (SELECT COUNT(*)
          FROM ProjectData
          WHERE TYPE = 'WatchEvent'
            AND repo.name = rp.repo.name) AS Stars,
              COUNT(DISTINCT actor.login) AS Contributors,

         (SELECT COUNT(*)
          FROM ProjectData
          WHERE TYPE = 'PullRequestEvent'
            AND repo.name = rp.repo.name
            AND JSON_EXTRACT(payload, '$.pull_request.merged') IN ('true')
            AND JSON_EXTRACT(payload, '$.pull_request.head.repo.has_wiki')
IN ('true')) AS WikiCount,

         (SELECT COUNT(*)
          FROM ProjectData
          WHERE TYPE = 'PullRequestEvent'
            AND repo.name = rp.repo.name
            AND JSON_EXTRACT(payload, '$.pull_request.merged') IN ('true')
            AND JSON_EXTRACT(payload,
'$.pull_request.head.repo.has_projects') IN ('true')) AS
ProjectsTabCount,

         (SELECT COUNT(*)
```

```
        FROM ProjectData
        WHERE TYPE = 'PullRequestEvent'
          AND repo.name = rp.repo.name
          AND JSON_EXTRACT(payload, '$.pull_request.merged') IN
('true')) AS PullRequests,


       (SELECT ROUND(SUM(CASE
                              WHEN JSON_EXTRACT(payload,
'$.pull_request.merged') IN ('true') THEN 1
                              ELSE 0
                         END)/COUNT(*), 2)
        FROM ProjectData
        WHERE TYPE = 'PullRequestEvent'
          AND repo.name = rp.repo.name) AS MergeRatio,


       (SELECT COUNT(*)
        FROM ProjectData AS f
        WHERE TYPE = 'ForkEvent'
          AND repo.name = rp.repo.name) AS ForkCount,


       (SELECT COUNT(DISTINCT JSON_EXTRACT(payload,
'$.pull_request.user.login'))
        FROM ProjectData AS c
        WHERE TYPE = 'PullRequestEvent'
          AND repo.name = rp.repo.name
          AND JSON_EXTRACT(payload, '$.pull_request.merged') IN
('true')) AS Committers,


       (SELECT COUNT(DISTINCT actor.id)
        FROM ProjectData
        WHERE TYPE = 'PullRequestReviewCommentEvent'
          AND repo.name = rp.repo.name) AS ReviewComments,


       (SELECT COUNT(DISTINCT actor.id)
```

```
        FROM ProjectData
        WHERE TYPE = 'IssueCommentEvent'
          AND repo.name = rp.repo.name) AS IssueComments,

        (SELECT COUNT(*)
        FROM ProjectData
        WHERE TYPE = 'IssuesEvent'
          AND repo.name = rp.repo.name) AS TotalIssues,

        (SELECT COUNT(*)
        FROM ProjectData
        WHERE TYPE = 'IssuesEvent'
          AND repo.name = rp.repo.name
          AND JSON_EXTRACT_SCALAR(payload, '$.action') IN ('opened')) AS
OpenedIssues,

        (SELECT COUNT(*)
        FROM ProjectData
        WHERE TYPE = 'IssuesEvent'
          AND repo.name = rp.repo.name
          AND JSON_EXTRACT_SCALAR(payload, '$.action') IN ('reopened'))
AS ReopenedIssues,

        (SELECT COUNT(*)
        FROM ProjectData
        WHERE TYPE = 'IssuesEvent'
          AND repo.name = rp.repo.name
          AND JSON_EXTRACT_SCALAR(payload, '$.action') IN ('closed')) AS
ClosedIssues
      FROM ProjectData AS rp
      GROUP BY 1,
               2)
   WHERE PullRequests > 20
```

```
    AND IssueComments > 0
    AND TotalIssues > 0 )
WHERE (Ve + Vc > 0)
ORDER BY PullRequests DESC
```

10.2. 2015-2018 "Trend of Project Utilization Value" GitHub BigQuery SQL

```
WITH ProjectData AS
  (SELECT *,
          EXTRACT(YEAR
                  FROM created_at) AS YEAR
   FROM `githubarchive.year.*`
   WHERE repo.name IN ('dotnet/roslyn',
                       'tensorflow/tensorflow')
     AND _TABLE_SUFFIX BETWEEN '2015' AND '2018')
SELECT ROUND(Ve - Vc, 2) AS Vu,
       ROUND((Ve - Vc)/(Ve + Vc), 2) AS Ru,
       *
FROM
  (SELECT ROUND(PullRequests * Committers + IssueComments * ClosedIssues
/TotalIssues, 2) AS Ve,
          ROUND(IssueComments *(OpenedIssues + ReopenedIssues)
/TotalIssues, 2) AS Vc,
          *
   FROM
     (SELECT repo.name AS ProjectName,
             YEAR,

        (SELECT COUNT(*)
         FROM ProjectData AS w
         WHERE TYPE = 'WatchEvent'
           AND repo.name = rp.repo.name
```

```
    AND EXTRACT(YEAR
                FROM created_at) = rp.year) AS Stars,
      COUNT(DISTINCT actor.login) AS Contributors,

(SELECT COUNT(*)
 FROM ProjectData AS f
 WHERE TYPE = 'ForkEvent'
    AND repo.name = rp.repo.name
    AND EXTRACT(YEAR
                FROM created_at) = rp.year) AS ForkCount,

(SELECT COUNT(DISTINCT JSON_EXTRACT(payload,
'$.pull_request.user.login'))
 FROM ProjectData AS c
 WHERE TYPE = 'PullRequestEvent'
    AND repo.name = rp.repo.name
    AND JSON_EXTRACT(payload, '$.pull_request.merged') IN ('true')
    AND EXTRACT(YEAR
                FROM created_at) = rp.year) AS Committers,

(SELECT COUNT(*)
 FROM ProjectData AS p
 WHERE TYPE = 'PullRequestEvent'
    AND repo.name = rp.repo.name
    AND JSON_EXTRACT(payload, '$.pull_request.merged') IN ('true')
    AND EXTRACT(YEAR
                FROM created_at) = rp.year) AS PullRequests,

(SELECT COUNT(DISTINCT actor.id)
 FROM ProjectData
 WHERE TYPE = 'PullRequestReviewCommentEvent'
    AND repo.name = rp.repo.name
    AND EXTRACT(YEAR
```

```
                FROM created_at) = rp.year) AS ReviewComments,

(SELECT COUNT(DISTINCT actor.id)
 FROM ProjectData
 WHERE TYPE = 'IssueCommentEvent'
   AND repo.name = rp.repo.name
   AND EXTRACT(YEAR
                FROM created_at) = rp.year) AS IssueComments,

(SELECT COUNT(*)
 FROM ProjectData
 WHERE TYPE = 'IssuesEvent'
   AND repo.name = rp.repo.name
   AND EXTRACT(YEAR
                FROM created_at) = rp.year) AS TotalIssues,

(SELECT COUNT(*)
 FROM ProjectData
 WHERE TYPE = 'IssuesEvent'
   AND repo.name = rp.repo.name
   AND JSON_EXTRACT_SCALAR(payload, '$.action') IN ('opened')
   AND EXTRACT(YEAR
                FROM created_at) = rp.year) AS OpenedIssues,

(SELECT COUNT(*)
 FROM ProjectData
 WHERE TYPE = 'IssuesEvent'
   AND repo.name = rp.repo.name
   AND JSON_EXTRACT_SCALAR(payload, '$.action') IN ('reopened')
   AND EXTRACT(YEAR
                FROM created_at) = rp.year) AS ReopenedIssues,
```

```
        (SELECT COUNT(*)
         FROM ProjectData
         WHERE TYPE = 'IssuesEvent'
           AND repo.name = rp.repo.name
           AND JSON_EXTRACT_SCALAR(payload, '$.action') IN ('closed')
           AND EXTRACT(YEAR
                       FROM created_at) = rp.year) AS ClosedIssues
      FROM ProjectData AS rp
      GROUP BY 1,
               2)
   WHERE PullRequests > 0
     AND IssueComments > 0
     AND TotalIssues > 0 )
WHERE Ve + Vc > 0
ORDER BY ProjectName DESC,
         YEAR
```

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