Innovation Project Funding: A Framework for Rapid Evaluation of Innovation Projects for Implementation Using a System Approach

by

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M.B.A. University of Denver 2021

Submitted to the System Design and Management Program
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN ENGINEERING AND MANAGEMENT

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

September 2023

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Abstract

Success rates of corporate innovation are notoriously low. Improving corporate innovation success rates increases investment efficiency and enables progress toward an improved future. A literature review was completed to develop an understanding of innovation strengths and weaknesses often present in corporations. System engineering and quantitative analysis tools were explored to address the common weaknesses present in corporate innovation investment. The investment step was targeted as a critical decision point for progressing proposals forward for further implementation. The framework mitigates common pitfalls of corporate innovation while enabling the corporation to architect the innovation process to fit its needs. The framework is a five-step process: risk rank to define the predictors of innovation project success, establish a success function to calculate innovation success likelihood, solicit project proposals from the entire employee base, plot a tradespace to visualize the tradeoffs between all possible innovation projects, and finally select the portfolio of projects for investment.

Thesis Supervisor: Joan Rubin
Title: Executive Director, System Design & Management Program

Acknowledgements

First, I would like to thank my thesis advisor, Joan Rubin. The way you continuously support the cohort and me in academics and our careers has been very much appreciated and does not go unnoticed. Thank you for always making time for me and consistently demonstrating your tremendous care about this thesis, me as a student, and me as a person.

I'd also like to thank the other advisors who supported me. Reza Rahaman, thank you for being a role model. You never ceased to impress me with your knowledge, but I was most impressed with how you carry yourself and treat people. I hope to know as much as you about innovation one day. Still, more importantly, I strive to be as impactful of a leader as you have demonstrated you are. Chris Boone, I will forever challenge myself to rethink and unlearn because of what you have taught me. I appreciate our friendship and your unwavering willingness to help when I asked for it. I am also very appreciative of the parenting tips! Marco Bonilla, thank you for the encouragement through every step. I'm unsure if you know how much it helped, but it always has. Sometimes, I lacked confidence in my next move, and you've had a way of helping me through, even if you were unaware you were doing so. I have learned a lot from you in the classroom, but I have learned equally as many lessons from you about life outside the classroom. Finally, thank you to Akshay Sahni. You demonstrated how to pursue constant learning and you helped me believe that addressing this issue would be impactful.

To my parents, thank you for your patience and support. I can rely on you in my time of need, which is a comfort I cannot state my thanks enough for. Mom, the effort and commitment you put into caring for our family is something I hope to provide for my family. You've always been my rock, and you're the reason I have been able to do the things I have done. Dad, thank you for showing me what hard work can accomplish, and that change can occur. My belief in change is what fuels my passion for innovation.

Finally, and most importantly, this would not have been possible without the support of my wife, Kimberly, and my children, Gabriel and Grace. Kimmy, you are the most impressive person that I have ever met. You inspire me to do more and be better. I am so grateful to spend each day with you; you are my best friend. Thank you for all the hard work, sacrifice, and effort you have put into this last year. I could not have done this without you. Gabe and Grace, I am lucky to be your father, and I'm blessed to watch you grow up each day. I admire each of you for the people that you are, and I look forward to exploring what life has to offer both of you. Follow your heart, have fun, just be you, and know that I love you both with everything I have.

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Acronyms

4P: four dimensions of innovation space (product, process, position, and paradigm)
H: hypothesis
IRR/NPV: internal rate of return / net present value
MASF: multi-attribute success function
MATE: multi-attribute tradespace exploration
MIT: Massachusetts Institute of Technology
NASA: National Aeronautics and Space Administration
PR/FAQ: press release / frequently asked questions
RAT: risk aversion tax
RQ: research question
SMR: Sloan Management Review

Chapter 1

Introduction

1.1 Objective

The primary goal of this thesis is to expedite progress toward an improved future resulting from innovative improvements across industries. There are three key components to accomplish this goal:

- Establish that corporations can and should be leaders of innovation
- Enable an increased volume of innovation proposals to be put forward within an organization
- Increase the likelihood of successful outcomes of the innovation proposals selected for implementation

The framework proposed in this thesis demonstrates that a few key critical key parameters may be established to successfully evaluate innovation proposals in a corporate setting. The framework leverages an analytical tool known as a tradespace to visualize the data and enable improved decision-making.

1.2 Motivation

The success rates of innovative projects could be much higher. According to Clayton Christensen, a professor at Harvard Business School, of the ~30,000 new products introduced each year, roughly 95% of them fail. The success rate of innovation projects needs to improve to reduce resource waste and accelerate progress across industries. Applying systems engineering tools and viewing the entire system of innovation project possibilities may deliver these necessary improved results.

1.3 Research Questions and Hypotheses

Current innovation project proposal evaluations in corporations may need to be revised, as evidenced by these projects' relatively high failure rates. The decisions to approve/deny further action may be biased by previously developed beliefs, or the

proposals may be inadequately assessed due to focus on certain aspects of the proposal while missing other key components for consideration. Developing a framework to evaluate the proposal, with a system perspective, could enable business leaders to optimize decision-making and thus optimize the deployment of resources provided to support these programs/projects. This thesis seeks to answer the research questions below to understand how decision-making may be improved:

RQ1: What are the key indicators of success for innovation projects?

RQ2: What tools may be used to generate meaningful insights into complex investment decisions while reducing bias?

RQ3: Is a tradeoff of analysis “depth” for “speed” appropriate for corporate teams?

RQ4: What size organization benefits from the use of a system approach to innovation most?

The hypotheses to be explored in this thesis in answer to the research questions are as follows:

H1: The key indicators of success for innovation projects include: product-market-fit resulting from understanding customer needs and meeting them in a desirable manner, financial metrics that align with the business unit financial metric targets (IRR/NPV), technology readiness, and competitive positioning resulting from the innovation being able to be protectable into the future.

H2: A multi-attribute tradespace exploration (MATE) can and should be used to enable visualization of all proposals ranked against one another on some established criteria. This tool will need an appropriately developed function to establish the weighting of the multiple attributes.

H3: The tradeoff of analysis depth for speed is appropriate, especially if the framework is built such that revisiting the analysis can occur relatively quickly when new information is acquired.

H4: A mid-market or larger organization with funding to enable several innovation investments are expected to be the most aided by an innovation framework that uses a system approach.

1.4 Research Approach

The research approach can be broken into three phases:

- Complete a literature review – the literature review was focused on researching current methods for innovation project and program proposals from various industries and determining what factors enabled and inhibited their success
- Discuss with experienced leaders in the industry – four advisors with extensive backgrounds in research, development, innovation, and investment were used to learn about best practices, learnings, and common themes present in the industry
- Validate against case studies, where applicable – case studies and examples were sought to confirm perspectives from the advisors and to validate the legitimacy of the points raised in discussions
- Review proposal with experienced leaders in the industry – the final step of the research was to seek feedback from the leaders in the industry on the proposed framework

This research approach was purposeful in its intent to balance insights from academia and industry on innovation.

1.5 Thesis Structure

The thesis is organized in the following structure:

Chapter 1: Introduction

This chapter covers the objective and motivation for the research of applying systems engineering tools for innovation investment. It also shares the research questions, hypotheses, approach, and scope.

Chapter 2: Literature Review

This chapter presents the relevant research regarding corporate innovation, including factors that enable and inhibit successful corporate innovation.

Chapter 3: System Definition

This chapter defines the types of innovation and organizations most appropriately suited for utilizing the framework. Innovation process models are also shared to identify what step in the innovation process this framework is most applicable.

Chapter 4: Innovation Risks

This chapter presents two methods for establishing the most impactful corporate innovation success predictors. One method relies on company insight and leveraging a list of common risks to innovation projects generated through extensive research. The second method utilizes analytics to predict success factors quantitatively and includes an example analysis.

Chapter 5: Analysis

This chapter covers two tools that can be used together to predict innovation project outcomes quantitatively. A weighting function and tradespace examples have been provided for insight into how these analytic tools may be used to evaluate innovation proposals quantitatively.

Chapter 6: Portfolio Development

This chapter discusses the importance of viewing innovation as a portfolio and not a one-off project. Innovation portfolio models are presented and discussed as examples of how they can be paired with the output of the other tools utilized for innovation project evaluation.

Chapter 7: Framework

This chapter summarizes the various steps that can be taken to develop an innovation project process that will overcome common barriers to success in organizations and improve innovation investment performance.

Chapter 8: Conclusion

This chapter summarizes the findings of the research. The scope limitations of the research are also discussed while providing considerations for future research.

Chapter 2

Literature Review

2.1 Terminology

The topic of corporate innovation requires use of common terminology. For purpose of this research, the following terms are assigned these meanings:

Sustaining technologies: incremental improvements on established products

Disruptive technologies: deliver features a few customers value at a lower performance

Organizational culture: the values and basic assumptions that typify an organization

Adjustment and anchoring bias: the bias that results in insufficient adjustment from a starting (anchoring) point

Availability bias: the bias that causes probability estimations to be influenced by the ease with which an occurrence can be recalled

Representativeness bias: the bias that causes the probability of an event's outcome to be frequently estimated as the same outcome of the most similar event

Short-termism: the concentration on near-term objectives at the sacrifice of long-term outcomes

Product innovation: Changes in the things an organization offers

Process innovation: Changes in the process that products are created and delivered

Position innovation: Changes in the context in which the products/services are introduced

Paradigm innovation: Changes in the underlying mental models which frame what the organization does

Architectural innovation: Innovation targeting a new market with existing technology

Incremental innovation: Innovation targeting an existing market with existing technology

Radical innovation: Innovation targeting a new market with new technology

Disruptive innovation: Innovation targeting an existing market with new technology

Mid-market enterprise: A company with annual revenues between $10 million and $1 billion

Portfolio theory: The diversification of investments to reduce risk

2.2 Innovator's Dilemma

One belief that large corporations may lose the ability to innovate as they grow is supported by the research in *The Innovator's Dilemma*. In this book, Christensen introduces the concept of sustaining and disruptive technologies. Sustaining technologies are incremental, and "they improve the performance of established products, along the dimensions of performance that mainstream customers in major markets have historically valued" (Christensen, 1997). Established firms develop competence and strengths in sustaining technologies. Disruptive technologies, on the other hand, typically garner poorer initial performance, "but they have other features that a few fringe (and generally new) customers value" (Christensen, 1997). Disruptive technologies tend not to be the focus of established firms because the origins of disruptive technologies are in insignificant markets with lower profit margins and not what the established firms' customers want (Christensen, 1997). These opposing technologies are the center of the innovator's dilemma, highlighting an existing firm's failure to retain market share due to its focus on existing customers. A graphic demonstrating sustaining versus disruptive technology trajectory is shown below:

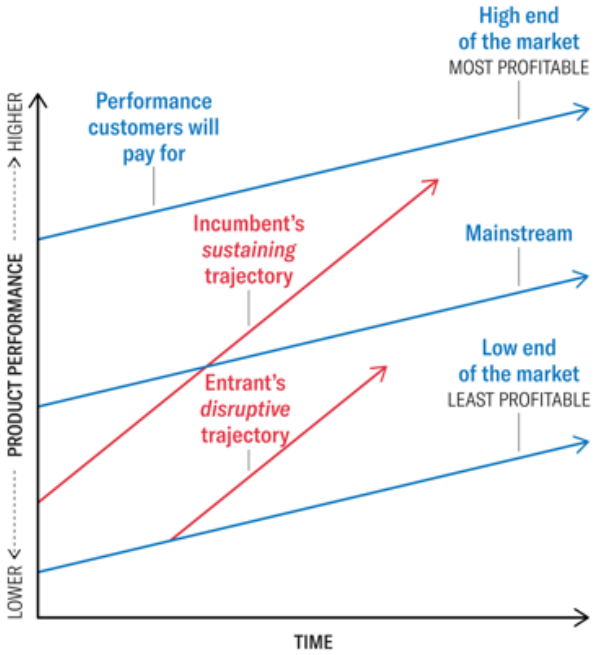

Figure 1: Product Performance Over Time (Christensen et al., 2015)

"Disruptive innovations are made possible because they get started in two types of markets that incumbents overlook" (Christensen et al., 2015): low-end or new. As emerging markets grow, the disruptor may overtake the existing firm in market share as their offering better meets the performance demanded. This dynamic is the source of disruptive innovation, often used to describe new products from startup companies looking to compete with large corporations.

Christensen goes on to propose five principles of disruptive technology. The five principles are:

Number	Principle of Disruptive Technology
1	Companies depend on customers and investors for resources
2	Small markets don't solve the growth needs of large companies
3	Markets that don't exist can't be analyzed
4	An organizations capabilities define its disabilities
5	Technology supply may not equal market demand

Table 1: Five Principles of Disruptive Technology (Christensen, 1997)

The first principle, alternately stated, is that companies that do not meet the needs of their customers and investors do not survive. The investors and customers' needs are being met, usually quite well in the case of successful companies, through sustaining innovations and not disruptive innovations. The innovator's dilemma is an example of how a corporation may lose the ability to innovate as they grow larger and highlights some of the factors in tension that inhibit investment by existing firms into innovation projects.

2.3 Organizations Using Assets to Win

Andrew Binns, Charles O'Reilly, and Michael Tushman argue in *Corporate Explorer* that "big companies are learning to use their assets to beat the odds of disruption." ~~They~~ Conventional wisdom aligns with Christensen's conclusion about disruptive innovation

that it is “almost impossible for an established firm to lead disruption” (Binns et al., 2022). However, existing firms are now using their assets to create an innovation advantage in a way they did not over twenty years ago when Christensen published this conclusion.

One example cited is Microsoft’s development of Office 365 which allowed the existing firm to combat the disruptive innovation from the software-as-a-service era. Microsoft was strategic in developing and distributing a new product that could have easily been viewed as competition to its existing line of products and thus survived the transition to software-as-a-service without losing its leading market share position. These existing firms’ assets, which can be used to compete with startups, provide a stronger initial financial position, existing technological assets, a significant number of skilled employees, production capacity, and established relationships with customers and the overall market. The recent development of existing firms creating innovation advantages by using their assets opens the door for additional innovation investment by these existing firms.

2.4 Organizational Culture

Existing firms may have assets that allow them to compete with startups, but something the existing firms have that may impede innovation is the existing organizational culture. Organizational culture is defined as “the values and basic assumptions that typify an organization. It refers to the most basic elements of an organization, or “just the way things are around here”” (Whetten et al., 2016). Organizational culture is a strong force that may be difficult to overcome, which is why Peter Drucker is credited with famously stating, “Culture eats strategy for breakfast.”

Research on Chinese companies has recently demonstrated the correlation of culture to innovation. One study found that “using all listed firms on both the Shanghai and Shenzhen stock exchanges between 2008 and 2017, we find strong and consistent evidence that a creation culture positively affects innovation” (Wang et al., 2021). This finding suggests that those cultures that are not creation cultures (ex: status quo, sustaining, or incremental innovation cultures) may negatively affect innovation. This

finding and the Innovator's Dilemma demonstrate how a sustaining culture common in existing firms may negatively affect innovation.

Another example of the correlation between culture and innovation can be found in SpaceX and Tesla. *MIT's SMR Culture 500* has ranked SpaceX and Tesla as the number two and three leaders in innovation. Innovation is heavily encouraged and incentivized in these companies, which is one reason they have become leaders in this category. Elon Musk has stated that the "incentive structure is set up that innovation is rewarded, but failure to try to innovate comes with a big penalty." If a company looking to innovate does not have established practices and procedures in place to support innovating, understanding the common negative impacts of organizational culture on innovation is critically important to enable successful innovation in the future.

2.4.1 Risk Aversion and Bias

Risk aversion and bias are common impediments to innovation and may be prevalent in existing firms. Daniel Kahneman won a Nobel Prize in 2002 for his work connecting economics and psychology. Through his economic model, prospect theory, he showed that when complex decisions are being made, people fail to make decisions using rational analysis. The concept states that "our decision-making is not rational, it is deeply affected by an emotional fear of loss" (Binns et al., 2022) and highlights an opportunity to utilize systems engineering tools to mitigate the impact of the biases that cloud our judgment.

Risk aversion may be driven directly by biases held by company leadership. Daniel Kahneman worked with Amos Tversky to introduce cognitive biases in the early 1970s. In their paper, *Judgement under Uncertainty: Heuristics and Biases,* they introduced three heuristics influencing decision-making: adjustment and anchoring, availability, and representativeness. The anchoring and adjustment bias was defined once the research identified that there was often insufficient adjustment from a starting point (anchor point), regardless of whether the starting point was given or generated by the subject. Once an initial estimate is made, there is often insufficient adjustment away from this point. The availability bias states that probability estimations are influenced by

the ease with which an occurrence can be recalled. A typical example is the fear of flying that some people hold, even though data suggest that driving in cars is much less safe. The probability of a plane crash is believed to be higher because the occurrence of a catastrophic plane crash is more easily recalled. Finally, the representativeness bias demonstrates that the probability of an event's outcome is frequently estimated to be the same as the outcome of the most similar event regardless of other information that may suggest an alternate outcome is likely.

The adjustment and anchoring bias highlight an opportunity for a framework to be used where frequent adjustment, using quantitative data, can be facilitated to battle a common bias. The availability bias may be present in innovation funding decisions and cloud decision-makers' judgment depending on if the most easily recalled analog is a fair analogy to use for evaluation. The representativeness bias may also be present in innovation funding decisions by incorrectly attributing the probability of success for an innovative project to be like another similar innovative project. In the absence of other decision-making tools, both the availability bias and representativeness bias may result in sub-optimal decision-making.

In practice, these biases have been shown to be pervasive in organizations. In 2012, a McKinsey global survey presented a fictitious investment scenario to managers and asked for their highest chance of loss tolerated. The risk-neutral manager would in theory be willing to accept a 75% chance of loss, but "most of the surveyed managers (…) demonstrated extreme loss aversion [and] they were willing to accept only an 18% chance of loss" (Lovallo et al., 2020). The same study found that only 9% of managers would exceed a 40% chance of loss. The lost value from this "safe" approach has been defined as the Risk Aversion Tax (RAT). The researchers tracked "one high-performing company [they] worked with, [they] assessed all investments made in a given year and calculated that its RAT was 32%" (Lovallo et al., 2020). The calculated RAT of 32% demonstrates that risk aversion is reducing the company performance by significant amount. The framework in this thesis leverages quantitative modeling that helps organizations combat risk aversion and biases to improve the quality of their decision-making.

2.4.2 Near-term Optimization

Short-termism, as defined by Oxford Languages, is the "concentration on short-term projects or objectives for immediate profit at the expense of long-term security" (Simpson, 1991). Research analyzing the impact of short-termism has been inconclusive in determining with certainty that short-termism negatively impacts long-term value, and proponents of both sides of the argument can be easily identified. Proponents of retaining near-term targets and the associated pressure that comes with them believe that investor oversight "is a substantially beneficial mechanism that serves the interest of investors and the economy" (Bebchuk, 2021). These near-term supporters believe that eliminating the near-term focus, in its entirety, would negate the benefits realized by capital markets over the last few decades. Those who oppose near-term focus, like Michael Porter, believe that "that short-termism [is] causing underinvestment in long-term R&D projects" (Bebchuk, 2021). The difficulty in demonstrating that short-termism detracts from long-term value creation may be partly due to the difficulty of accurately measuring the impact of an action on a lengthy timeline.

While the long-term impacts of short-termism may not be fully agreed upon, the immediate impacts of short-termism can be more readily understood. McKinsey looked at 615 prominent and mid-cap US publicly listed companies from 2001-2015 and "created a five-factor Corporate Horizon Index based on patterns of investment, growth, earnings quality, and earnings management" (Barton et al., 2017). This analysis established consensus on a few items: short-termism is increasing, firms with a long-term horizon exhibit stronger fundamentals than those with short-term horizons, and long-term companies deliver superior financial performance. The surveys also demonstrate that short-termism is a source of pressure for decision-makers, as shown in the figure below:

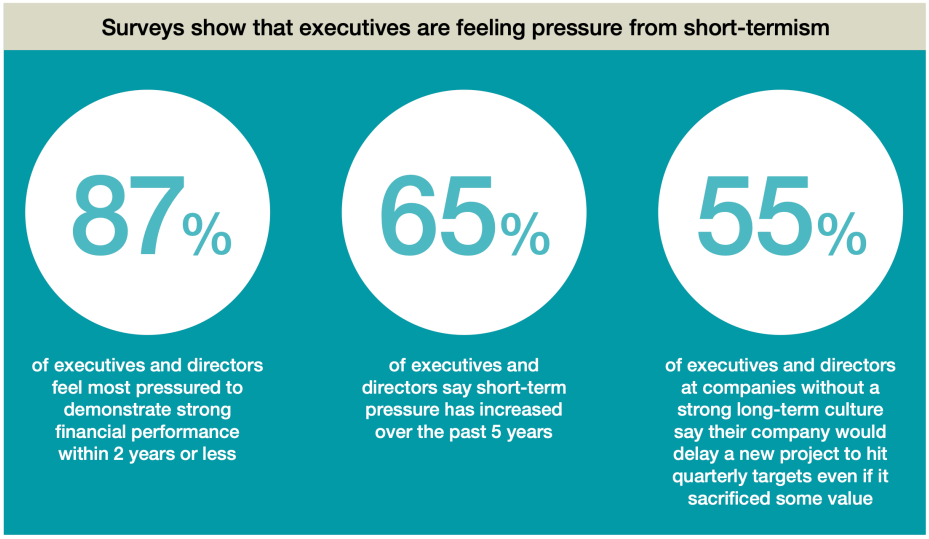

Figure 2: Impacts of Short-Termism on Executives (Barton et al., 2017)

The McKinsey study suggests that short-term pressures impact decision-making in a direction that may oppose long-term-based decision-making and that long-term-based decision-making may lead to stronger fundamentals and financial performance. Thus, an innovation investment process focused on quantifiable returns over a longer horizon should mitigate some of the short-term pressure and enable long-term-based decision-making to be more easily completed. The framework presented in this thesis aims to move decision-making away from short-term pressures and towards optimal solutions that consider the entire system and product lifecycle.

2.5 Pace of Change

The global trend of the increased pace of technological advancement impacts an organization's ability to innovate successfully. Successful innovation requires successful commercialization for investments to be recovered. Successful commercialization requires both value creation and value capture of the products in the portfolio of investments. It is possible to miss the opportunity for value creation or capture if the innovative development timeline is too great. Reaching an optimal solution is only acceptable if the solution is reached at the user's required pace.

A commonly held view is that there is a worldwide rapid pace of technological change. However, the pace of change for specific industries and technologies is more nuanced. Early research at MIT found that “Moore’s exponential law appears to be more fundamental than Wright’s power law” (Magee et al., 2016) when studying 28 technology domains. Their findings were that technology change is more often expected to be exponential than linear. A more recent follow-up study has explored 1757 domains to understand the average pace of change in technologies (Singh et al., 2021). This study identifies nuances that highlight that the pace of change is both technology-specific and varies from year to year. The technology changes realized ranged from 2% - 216%, with 80% improving at less than 25% per year. While less than 25% per year may not sound rapid, a 20% improvement year over year will still yield a technological landscape of 200% growth in a 4-year timeframe. Technology is changing, and customers’ needs are constantly evolving. An opportunity exists for a framework that allows for rapid evaluation of concepts to meet the demanding timelines for innovation progress and for staying well aligned with the users’ needs. The framework presented in this thesis is built such that rapid evaluation can be completed, and revisiting for updates with new information can be easily accommodated.

2.6 Democratizing Innovation

MIT Professor Eric von Hippel introduced the concept of democratizing innovation in 2005. The concept is based on the findings that “empirical studies show that many users – from 10 percent to nearly 40 percent – engage in developing or modifying products” (Hippel, 2006). These individuals responsible for new product development are often labeled lead users and are attributed to being early and active participants in shaping the future of a given domain. For example, one study found that sports equipment manufacturing companies were not the primary source of innovations in sporting equipment. Manufacturers, instead, relied on lead users to generate ideas for improvements to sporting goods. Lead users exist in all domains, and the one key to improving the odds of successful innovation is locating these lead users and delivering their needs (Aulet, 2015).

Existing organizations may have a competitive advantage in identifying lead users since they already have a product with a market presence. Their established customer base, relationships, and commercial availability create a group readily accessible that understands the products and should be leveraged. The company understands where its products are going and how they are being used to help identify lead users to solicit improvement ideas.

Another source of competitive advantage is the large employee base of established companies. The employees are likely familiar with the products, often users of the products themselves, and likely know others who use them. Enabling the employee base to submit innovation project proposals increases the likelihood of identifying potential product innovation ideas since these employees are often lead users and their needs when compared to a traditional route of a relatively small research and development team leading the charge of developing innovation project proposals. An example of an employee base that is likely full of innovative ideas because they are users of the products themselves is GoPro. GoPro has a program they call “Live It. Eat It. Love It.” and “The program gets employees out from behind desks and into the wild to use, test, and enjoy their GoPros on Thursday afternoons from 1 to 3 p.m.” (GoPro, n.d.). Gathering the insights and ideas from the large base of employee users can be a source of competitive advantage existing firms have over new firms. Democratizing innovation can be realized by enabling the entire employee base to submit concepts for consideration, which is possible using the framework provided in this thesis.

Chapter 3

System Definition

3.1 Innovation

As defined by Oxford Languages, innovation is “the action or processes of innovating” (Simpson, 1991). This definition is broad, and the term “innovation” is often used in industry with varying meanings. The following two sections are used to define innovation for this thesis. The definition of innovation used in this thesis is intended to align well with existing organizations’ strengths and to enable these firms to limit risks while attempting to innovate.

3.1.1 Product Innovation

The framework in this thesis has been developed with a focus on product innovation. Bessant and Tidd established four dimensions of the innovation space in their paper *Managing Innovation*. The four dimensions are product, process, position, and paradigm (4P). The definitions of each of these types of innovation, provided by Bessant and Tidd, are below:

Product Innovation	Changes in things (products/services) which an organization offers
Process Innovation	Changes in the ways in which they are created and delivered
Position Innovation	Changes in the context in which the products/services are introduced
Paradigm Innovation	Changes in the underlying mental models which frame what the organization does

Table 2: Four Dimensions of Innovation (Tidd et al., 2013)

Product innovation aligns well with research of understanding lead user insights and customer needs. The premise of this thesis is that focusing on product innovation

may lower the risk of unsuccessful innovation as product innovation emergent outcomes may be more easily predicted and tested than process, position, or paradigm innovation outcomes. Additionally, the change management aspect of delivering the innovation is expected to be lower for product innovation than for other innovation types.

Innovation proposals are still likely to contain multiple aspects of the 4P framework. One example in *Managing Innovation* mapped different innovation activities on the 4P framework spectrum and demonstrated that innovation rarely resides entirely in a single category of the 4P framework (Tidd et al., 2013). Proposals that span two or more areas, for example, product and position (or other) type innovations, may still fit within the framework for evaluation. An example of activity mapping across the 4P spectrum is shown below:

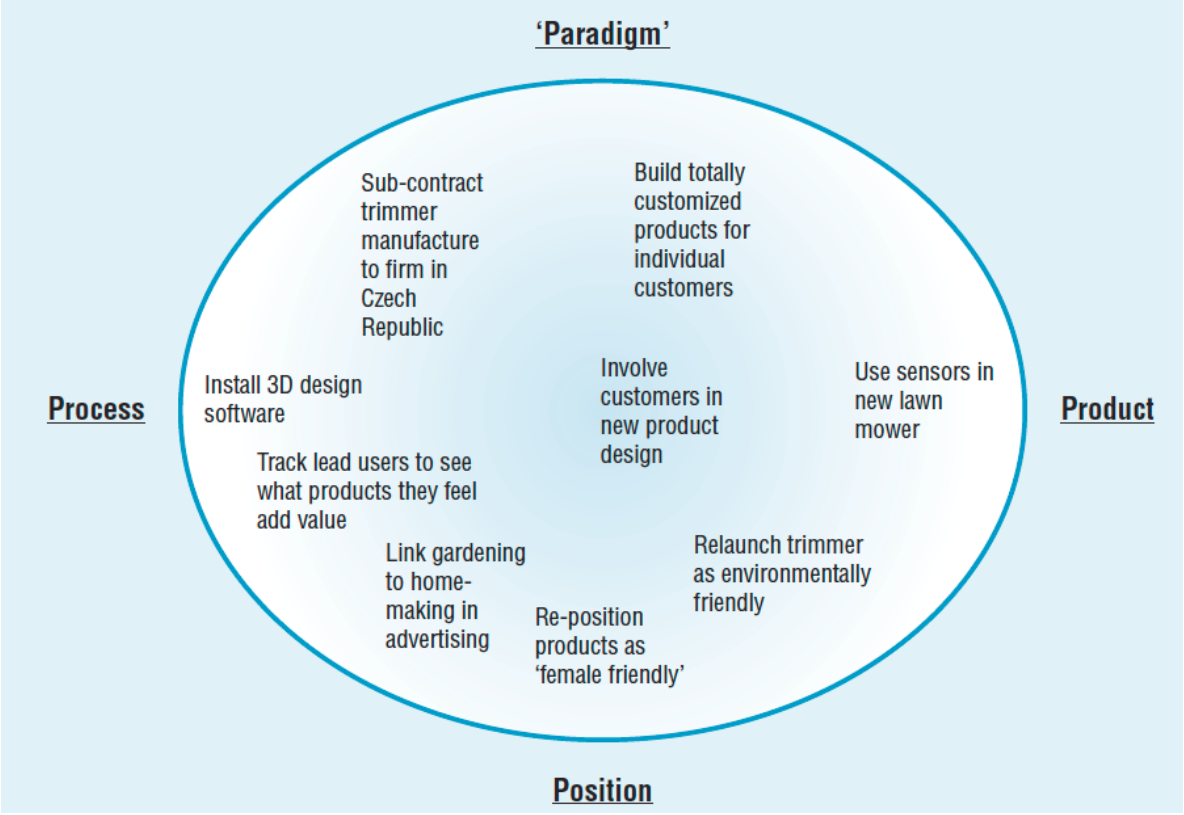

Figure 3: 4P Framework (Tidd et al., 2013)

3.1.2 Architectural Innovation

The framework in this thesis is also focused on architectural innovation. In *Strategic Management*, the four types of innovation discussed are: incremental, disruptive, architectural, and radical. The combination of technology level and market maturity defines the type of innovation.

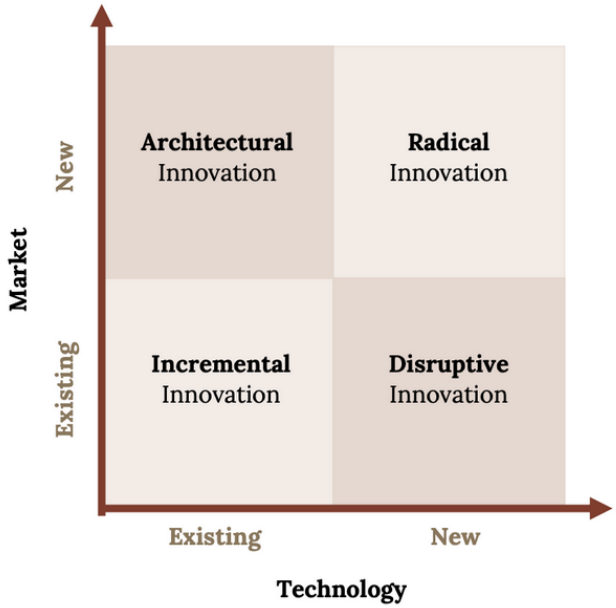

Figure 4: Innovation Types (Market vs. Technology) (Kennedy, 2020)

This innovation type is intended to minimize risk for an existing enterprise of relative scale. Focusing on existing technology can eliminate many unknowns accompanying entirely new technologies while accepting risk in new markets where an existing firm is expected to hold a greater understanding than others. It is also important to change focus away from only incremental innovation for the reasons discussed prior regarding The Innovator's Dilemma. The framework can easily adapt to incremental innovation (existing market and technologies). However, incremental innovation will likely not adequately address the issue of meeting the requirements created by the pace of change for specific markets.

3.2 Innovation Process Model

There are several innovation process models available from both research and practice. “The first generation (processes) were developed by NASA in the 1960s” (Herstatt et al., 2005). These early phase-review processes were continually built upon to capture more phases and focus innovation efforts further. The innovation process model below is from Pleschak and Sabisch in 1996:

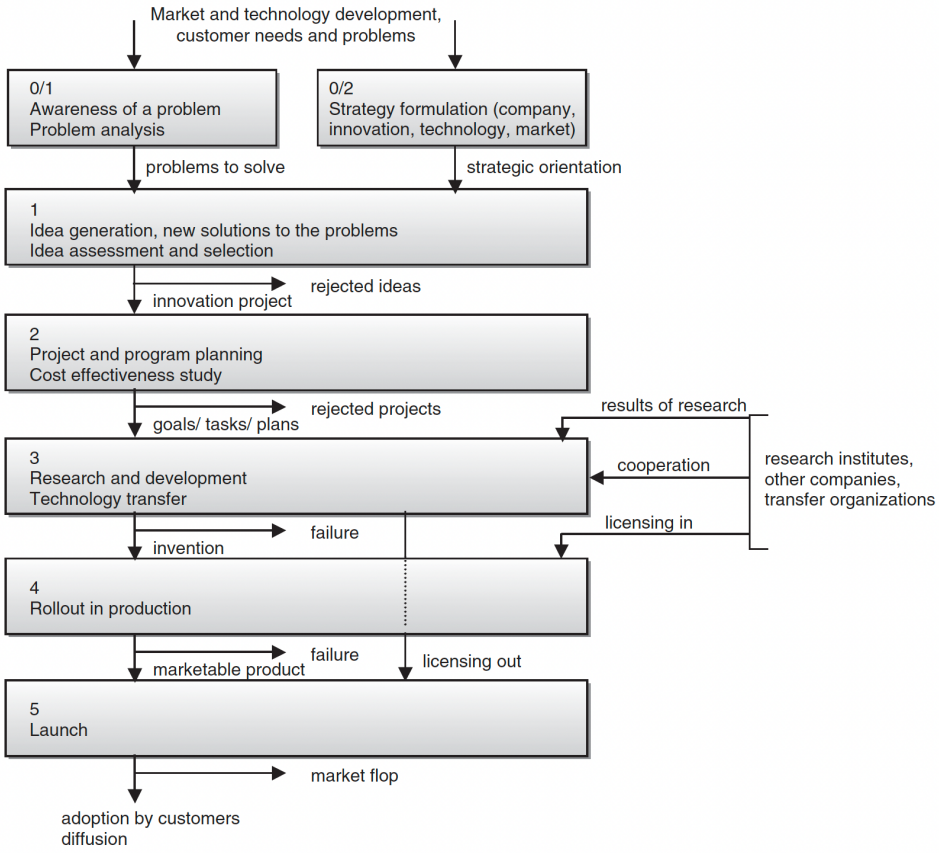

Figure 5: Process Model Including Failures (Pleschak et al., 1996)

This model details various phases of an innovation project, and “it intentionally includes the possibility of project termination during every stage of the innovation process due to the rejection of an idea, or technical or economic failure” (Herstatt et al., 2005). Although from 1996, the model demonstrates the importance of early detection of failures for companies in a fast-changing environment, a concept that remains relevant in today’s environment.

This thesis framework is focused on the step of idea assessment and selection. The idea assessment and selection step is an investment step where a corporation decides which proposals secure resources to move forward toward planning, development, and implementation. The intent is to provide a framework to filter the many potential innovation opportunities to a reduced amount where success, as defined by the individual company, is more likely due to a reduction of bias and risk aversion that may be present when utilizing other methods for proposal evaluation.

3.3 Organization Size

One hypothesis of this thesis is that the ideal organization size for utilization of this framework would be a mid-market enterprise or larger. The specific characteristics that mid-market and larger enterprises exhibit to enable this framework's optimal utilization are their large employee bases, their likelihood of having multiple locations in different geographical areas, and adequate resources for diversified innovation investment. A recent Harvard Business Review article defined a U.S. mid-market enterprise as a company "with annual revenues between $10 million and $1 billion" (Farren et al., 2021). The most critical factor for the framework in this thesis to be applied is the availability of resources for diversified innovation investment. Innovation projects require funding, and small companies may not have the resources to sustain several projects with uncertain financial outcomes. If a company, small or large, must decide about complex tradeoffs amongst various innovation proposals, this framework will apply.

The adequately large employee base may indicate a resource capacity to support the exploration of innovation proposals, including research, evaluation, and investment. The employee base also provides the potential for a significant source of innovation proposals from the organization's employees. Operating in multiple locations lends to having a greater possibility of identifying lead users and their requirements, as well as an understanding of varying market needs in general. When combined, these factors allow mid-market or larger enterprises to put forth various innovation proposals aligned with customer needs.

Chapter 4

Innovation Risks

4.1 Risk Reduction

Reducing risk, where possible, is imperative to optimizing outcomes of innovation investments. In the context of this thesis, risks are the various factors that may lead an innovation project to fail to meet expected financial outcomes. The base expected financial outcome is for the financial investment to be recovered through the commercialization of the innovative solution. This section will provide a list of common risks for innovation projects, highlight those considered critical risks for any industry, and propose a quantitative method for identifying key risks for evaluation.

4.2 Common Risks

The risk reference framework below was developed to diagnose risks in technology-based projects in the global company Unilever (Keizera et al., 2002). The 12 risk categories and 142 connected critical innovation issues result from 114 interviews with professionals in innovation, in-depth risk analyses for eight breakthrough projects, and input from a panel with experts in product innovation. The purpose of referencing this framework is to demonstrate the vast considerations made for innovation projects. Below are the 12 risk categories and 142 critical innovation issues as defined by Keizera, Halman, and Song:

1	**Product Family and Brand Positioning Risks**
1.1	New product helps to achieve business strategy
1.2	Project is important for project portfolio
1.3	New product contributes to brand name position
1.4	Project includes global roll out potential and schedule
1.5	New product fits within existing brand
1.6	New product fits with brand image
1.7	New product enhances potential of product family development
1.8	New product provides opportunities for platform deployment

1.9	New product supports company reputation
1.10	New product has brand recovery potential
1.11	New product has brand development potential
1.12	New product's platform will be accepted by consumers
2	**Product Technology Risks**
2.1	New product's intended functions are known and specified
2.2	New product fulfils intended functions
2.3	In-use conditions are known and specified
2.4	Interactions of product in-use with sustaining materials, tools, etc. are understood
2.5	Components' properties, function and behavior are known
2.6	Correct balance between product components is established
2.7	Assembled product meets safety and technical requirements
2.8	Alternatives to realize intended product functions are available
2.9	New product shows parity in performance compared to other products
2.10	New product shows stability while in storage (factory, shop/warehouse, transportation, at home)
2.11	New product format meets functional requirements
3	**Manufacturing Technology Risks**
3.1	Raw materials available that meet technical requirements
3.2	Process steps to realize the new product are known and specified
3.3	Conditions (temperature, energy, safety, etc.) to guarantee processing of good product quality known and specified
3.4	Production means (equipment and tools) necessary to guarantee good product quality are available
3.5	Scale up potential is possible according to production yield standards
3.6	Production system requirements (quality and safety standards, training of human resources, facilities, etc.) will be met
3.7	Product packaging implications are known and specified
3.8	Manufacturing efficiency standards will be met
3.9	Alternative approaches to process the intended product will be available
3.10	Adequate production capacity available
3.11	Adequate production start up assured
3.12	Reusability of rejects in production foreseen
4	**Intellectual Property Risks**
4.1	Original know-how will be protected
4.2	Required external licenses or know how known and available
4.3	Relation to legal and patent rights of competitors known and arranged
4.4	Relevant patent issues are understood
4.5	Patent crossing potential known and arranged
4.6	Trade mark registration potential known and arranged

5	**Supply Chain & Sourcing Risks**
5.1	Suppliers will meet required quality
5.2	Capacity available to meet peak demands
5.3	Appropriate after sales services available
5.4	Contingency options available for each of the selected suppliers
5.5	Financial position of each supplier is sound
5.6	Past experiences with each of the suppliers are positive
5.7	Suppliers are ready to accept modifications if required
5.8	Supply contracts can be canceled
5.9	Each supplier will be reliable in delivering according to requirements
5.10	Required quantities will be produced against acceptable prices
5.11	Appropriate contract arrangements with suppliers will be settled
6	**Consumer Acceptance Risks**
6.1	Product specifications meeting consumer standards and demands
6.2	New product fits consumer habits and/or user conditions
6.3	New product offers unique features or attributes to the customer
6.4	Consumers will be convinced that they get value for money, compared to competitive products
6.5	New product appeals to generally accepted values (e.g. health, safety, nature, environment)
6.6	New product offers additional enjoyment, compared to competitive products
6.7	New product will reduce consumer's costs, compared to competitive products
6.8	Non-intended product use by consumers is adequately anticipated
6.9	Target consumer's attitudes will remain stable during the development period
6.10	New product will be communicated successfully with target consumers
6.11	New product will provide easy-in-use advantages, compared to competitive products
6.12	Primary consumer requirements are known
6.13	Target consumers will accept the new product's key product ingredients
6.14	Niche marketing capabilities available if required
6.15	Communication about new product is based on realistic product claim
6.16	Advertising will be effective
6.17	Product claims will stimulate target consumers to buy
6.18	New product has repeat sales potential
7	**Trade Customer Risks**
7.1	Product specifications will meet trade customer standards and demands
7.2	Trade customers will welcome the new product from the perspective of potential sales
7.3	Trade customers will welcome the new product from the perspective of profit margin
7.4	Trade customers will welcome the new product given required surface and volume on shelf and storage facilities
7.5	Trade customer's attitude will remain stable during the development period

7.6	New product will be communicated successfully to trade customers
7.7	Right distribution channels will be used
7.8	Trade will give new product proper care
7.9	Trade supporting persons will endorse the new product
7.10	Stock demands will be met
8	**Competitor Risks**
8.1	Product will provide clear competitive advantages
8.2	Introduction of new product will change existing market share positions
8.3	Introduction of the new product will have impact on market prices
8.4	New product will be launched before competitors launch comparable product
8.5	Response actions towards public and media expected from competitors will be anticipated
8.6	New product enables the creation of potential barriers for competitors
8.7	Implications of being technology leader or follower for this project have been identified
8.8	Competitor's actions will be monitored and followed with adequate response
8.9	Competitor's challenges will be monitored adequately
9	**Commercial Viability Risks**
9.1	The market target is clearly defined and agreed
9.2	Market targets are selected based on convincing research data
9.3	Capital cost projection for new product is feasible
9.4	Delays in product launch will leave the commercial viability of the new product untouched
9.5	Sales projections for new product are realistic
9.6	Estimated profit margin are based on convincing research data
9.7	Profit margin will meet the company's standards
9.8	The estimated return on investment will meet the company's standards
9.9	Volume estimates are based on clear and reliable estimates
9.10	Product viability will be supported by repeat sales
9.11	Supplier will get attractive purchasing agreements
9.12	Knowledge of pricing sensitivity is available
9.13	Adequate investments to secure safety in production will be made
9.14	Long term market potential is to be expected
9.15	Financing of capital investment is secured
9.16	Fall back to prior product concept is feasible
9.17	New product is commercially viable in case of market restrictions
10	**Organization and Project Management Risks**
10.1	Internal political climate is in favor of this project
10.2	Top management actively supports this project
10.3	Project goals and objectives are feasible
10.4	Project team is sufficiently authorized and qualified for the project

10.5	Project team will effectively utilize the knowledge and experience of (internal) experts
10.6	Roles, tasks, and responsibilities of all team members are defined and appropriate
10.7	Decision making process in project is effective
10.8	Communication between members in the project team is effective
10.9	Required money, time, and (human) resources estimations are reliable and feasible
10.10	Required money, time, and (human) resources will be available when required
10.11	Project team will be informed in time about project progress
10.12	External development partners will deliver in time, conform budget, and technical specifications
10.13	Sound alternatives are available to external development partners
10.14	Collaboration within the project team is effective
10.15	Sponsor's interest for the project is secured
10.16	Project will effectively be organized and managed
10.17	Collaboration with external parties is effective
10.18	Collaboration between project team and the parent organization is effective
10.19	Project team is highly motivated and committed
10.20	Project team is paying attention to the right issues
10.21	Project team has an effective planning and contingency planning
10.22	Project team is learning from past experiences
11	**Public Acceptance Risks**
11.1	It is clearly understood who is responsible for PR of the project
11.2	The key opinion formers for the new product are known
11.3	Support of key opinion formers will be assured
11.4	Legal and political restrictions will be adequately anticipated
11.5	Environmental issues will be adequately anticipated
11.6	Safety issues will be adequately anticipated
11.7	Possible negative external reactions will be effectively anticipated
11.8	In case of new technology prior (external) experience will be consulted
12	**Screening and Appraisal**
12.1	New product performance targets will be tested and measured adequately
12.2	Trade customer appreciation will be tested and measured adequately
12.3	Consumer appreciation will be tested and measured adequately
12.4	Adverse properties as a consequence of the technological change will be tested and measured adequately
12.5	Credibility of the (internal) measures to external agencies is warranted
12.6	Tests will provide reliable evidence

Table 3: Critical Innovation Issues (Keizera et al., 2002)

The complete list of critical innovation issues in the table above is extensive and reflective of innovation projects along their entire implementation lifecycle. This thesis, however, focuses on the idea assessment and selection stage of the innovation projects and thus reduces the number of applicable considerations. These can further be reduced by applying the Pareto principle or the law of the vital few and trivial many. As previously stated, one essential element to address with any innovation framework is to meet the needs of the increased pace of change. Utilizing the Pareto principle enables both evaluations of the current landscape at a rapid pace and revisiting assumptions frequently, which are both necessary for operating in current environments.

After discussing various innovation projects with advisors across different industries, there is consensus that several key innovation project risks are present regardless of the industry in which the project is progressing. These risks are summarized in the table below:

1.1	New product helps to achieve business strategy
4.2	Required external licenses or know how known and available
6.12	Primary consumer requirements are known
9.7	Profit margin will meet the company's standards
9.8	The estimated return on investment will meet the company's standards

Table 4: List of Key Innovation Project Risks

The new product must help achieve business strategy because both in the literature review and discussion with advisors, the pressure from investors or the board will likely have a substantial impact on what projects are supported with resources. There is little reason to invest in a project that will not receive adequate support in the later stages of the innovation process. The focus of this thesis on architectural innovation supports the criticality of understanding external licenses and the availability of know-how. Pursuing existing technology requires that the existing technology be available for alternative uses and may be repurposed by the innovation project. Understanding customer requirements (and then meeting them) is likely the most critical consideration for an innovation project. This concept is supported in the literature review through the

concepts of lead users (Hippel, 2006), entrepreneurial best practices (Aulet, 2015), and Amazon's PR/FAQ innovation process (Binns et al., 2022). Finally, the success criterion is for the financial investment to be recovered through the commercialization of the innovative solution, so the financial metrics must forecast this possibility as the most probable outcome.

4.3 Applying Advanced Analytics

An alternate approach to utilizing common risks to evaluate an innovation project is to establish the most impactful predictors of success utilizing the firm's available data. Mid-sized or larger companies may have this dataset available or may be able to generate the dataset for evaluation. Suppose this data was not tracked in the past. In that case, it is still possible for the project evaluation teams to rank the various risk factors/success criteria for past projects to develop the dataset. This section will briefly discuss an approach to utilize a dataset of innovation project risk rankings and outcomes to establish which critical success criteria have been most reliable in predicting innovation success for the specific firm.

A straightforward but effective method to "classify to which category a new observation belongs" is to use a logistic regression (Simchi-Levi, 2023). For this example, the category shall be defined as successfully recovering the financial investment (A) or failing to recover the financial investment (B). The success versus failure case can be redefined, as needed, to understand the variability between moderate and tremendous successes better. The variables can then be listed and evaluated to understand their ability to predict success. The logit function is:

$$logit\big(P(A)\big) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \varepsilon$$

P(A) is the probability of a given classification (A) occurring, β_0 is the intercept, $\beta_n x_n$ are predictor variables, and ε are random deviations. Solving for (P(A)) gives the following logistic function:

$$P(A) = \frac{e^{\beta_0+\beta_1 x_1+\beta_2 x_2+\cdots+\beta_n x_n}}{1 + e^{\beta_0+\beta_1 x_1+\beta_2 x_2+\cdots+\beta_n x_n}}$$

In this example, the logistic regression model's purpose is to determine which success criteria may be most important in predicting whether an innovative project will be successful. To do this, solving for the various b coefficients and keeping only those with p-values below 0.05 will yield a short list of the most impactful criteria. The p-values greater than 0.05 are typically removed to avoid overfitting in a logistic regression model (Simchi-Levi, 2023).

The dataset will provide P(A), and each variable (risks/success criteria) from the dataset would represent an x value in each $\beta_n x_n$ pair. XLMiner can be used to classify a logistic regression, and the output will provide a list of p-values associated with each risk that should be used to reduce the number of risks used for project evaluation.

4.3.1 Example Analysis

The thesis author could not source innovation data from a mid-cap or larger firm to analyze. Therefore, a publicly available dataset was used as an analog to demonstrate the application of analytics to establish the most impactful predictors of success. The *Student Performance* dataset provides 30 attributes and three grade outcomes for 349 Gabriel Pereira school students. The attributes are analogous to the risks identified in Section 4.2, and the grade outcomes are analogous to success outcomes for innovation projects. The full dataset and subsequent analysis are provided in the appendix.

To analyze attributes, they must be recorded in a form that enables the completion of the regression. Therefore, the first step is to transform the available attribute data for use in the regression. The attributes were transformed into ordinal, binary, or categorical variables. An ordinal variable assumes that an explicit ordering of the category exists. For example, in the analysis of student performance, an ordinal variable was the mother's education level, ranging from one to five, with each greater integer representing a higher level of completed education. In analyzing past innovation project success, Risk 6.12 (primary consumer requirements are known) can be written as an ordinal variable with the value one meaning completely unknown and five being wholly established and understood. Binary variables are clear yes or no answers to

attributes. In the analysis of student performance, an example of a binary attribute was an address that indicated if a student's home address was urban or rural. In analyzing past innovation project success, Risk 9.7 (profit margin will meet company's standards) is a binary variable. Finally, categorical variables can also be used if specific categories are expected to influence success. In the example dataset, attributes were removed that contained broad "other" categories and students listed with a guardian as "other" were also removed. After completing the data cleanse, there were 26 attributes, a defined success criterion, and 323 cases to consider. A summary table of the original values and final variable type is below:

Attribute	Title	Description	Value	Variable Type
1	School	Student's school	Gabriel Pereira or Mousinho de Silveira	Binary
2	Sex	Student's sex	Female or male	Binary
3	Age	Age	15 – 22	Ordinal
4	Address	Student's home address	Urban or rural	Binary
5	FamSize	Family size	>3 or <=3	Binary
6	PStatus	Parent's cohabitation status	Living together or apart	Binary
7	MEdu	Mother's education	1 (none) – 5 (higher education)	Ordinal
8	FEdu	Father's education	1 (none) – 5 (higher education)	Ordinal
9	MJob	Mother's job	Teacher, health care, civil services, at home, or other	Categorical
10	FJob	Father's job	Teacher, health care, civil services, at home, or other	Categorical
11	Reason	Reason to choose this school	Close to home, reputation, course preference, or other	Categorical
12	Guardian	Student's guardian	Mother, father, or other	Categorical
13	TravelTime	Home to school travel time	1 (<15 min) – 5 (>60 min)	Ordinal
14	StudyTime	Weekly study time	1 (<2 hr) – 4 (>10 hr)	Ordinal
15	Failures	Number of past class failures	1, 2, 3, or 4 (for all >3)	Ordinal

16	SchoolSup	Extra educational support	Yes or no	Binary
17	FamSup	Family educational support	Yes or no	Binary
18	Paid	Extra paid classes in the course subject	Yes or no	Binary
19	Activities	Extra-curricular activities	Yes or no	Binary
20	Nursery	Attended nursery school	Yes or no	Binary
21	Higher	Wants to take higher education	Yes or no	Binary
22	Internet	Internet access at home	Yes or no	Binary
23	Romantic	With a romantic relationship	Yes or no	Binary
24	FamRel	Quality of family relationships	1 (very bad) – 5 (excellent)	Ordinal
25	FreeTime	Free time after school	1 (very low) – 5 (very high)	Ordinal
26	GoOut	Going out with friends	1 (very low) – 5 (very high)	Ordinal
27	DAlc	Workday alcohol consumption	1 (very low) – 5 (very high)	Ordinal
28	WAlc	Weekend alcohol consumption	1 (very low) – 5 (very high)	Ordinal
29	Health	Current health status	1 (very bad) – 5 (very good)	Ordinal
30	Absences	Number of school absences	0 – 93	Ordinal

Table 5: Sample Dataset Atributes and Variable Types

Once all data has been transformed to variable types suitable for running a regression, the regression can be run, and attributes that are insignificant for outcome prediction can be removed. Standard practice is to split the dataset 60/20/20, meaning 60% (or ~194 cases) are used to train, 20% are used for cross-validation, and a final 20% are used to test accuracy. Iteratively running the logistic regression on 60% of the cases and removing the variable with the greatest p-value begins to narrow toward a model with only statistically significant attributes. In this case, the intent of running this regression is not to develop a model to predict success. Instead, the intended outcome is a narrowed list of attributes that may be used for consideration. For purposes of this thesis 60% of data was used for training and the remaining data used for evaluation.

The table below shows the quantitative analysis of which predictors may be most impactful for predicting success:

Attribute	Title	Predictor Strength (1 = best, 26 = worst)	P-Value (when eliminated from model)
1	School	N/A	N/A – only used one school
2	Sex	9	0.31830
3	Age	20	0.94013
4	Address	5	0.11115
5	FamSize	21	0.94944
6	PStatus	8	0.37105
7	MEdu	1	0.00053
8	FEdu	18	0.82333
9	MJob	N/A	N/A – removed due to excessive “other”
10	FJob	N/A	N/A – removed due to excessive “other”
11	Reason	N/A	N/A – removed due to excessive “other”
12	Guardian	22	0.98354
13	TravelTime	26	0.99927
14	StudyTime	19	0.91733
15	Failures	6	0.13910
16	SchoolSup	24	0.99762
17	FamSup	10	0.39193
18	Paid	2	0.00961
19	Activities	23	0.99600
20	Nursery	14	0.62588
21	Higher	25	0.99908
22	Internet	4	0.09315
23	Romantic	3	0.08285
24	FamRel	11	0.43564
25	FreeTime	12	0.49916
26	GoOut	16	0.77588
27	DAlc	7	0.22969
28	WAlc	17	0.73382
29	Health	13	0.51845
30	Absences	15	0.69692

Table 6: Summary of Prediction Strength Analysis

The regression is used to apply the Pareto principle and utilizes a quantitative method to determine the most impactful success factors rather than the more typically used qualitative methods. Utilizing a quantitative approach may open the conversation beyond traditionally held views of what factors are most impactful. The traditionally held views may have been developed with bias, and this method attempts to mitigate these biases.

In the case of the sample data, iterating through until only p-values returned of less than 0.05 resulted in two attributes being the most impactful predictors of success. The two most impactful predictions were the mother's education level and if extra paid classes within the course subject were taken. While these may seem like good predictors in retrospect, they may not have jumped out as the most prominent when looking at the list of 26 available. The intent of applying this method for innovation success is to identify impactful predictors that may otherwise be ignored. The issue of narrowing down the factors considerably, from 26 to only two, is that the final model predicts success for no student because the criterion for success was set so high in the model. Developing a model that predicts success in no cases is a risk for modeling success in innovation and sticking to only quantitative methods for prediction. Innovation tends to have low success rates, so an overly simplified model may predict zero success and return accuracies greater than 90%, as seen in this test data.

Innovation is complex, and simplifying to only two factors to predict success may take the Pareto principle too far. Iterating through until there were five factors with p-values of roughly 0.05 resulted in a model with slightly lower accuracy but returned a model that predicts success for some cases. The table below is a summary of the model accuracy versus total attributes considered for the cases described:

Model Title	**Number of Attributes**	**Accuracy** (against 1st remaining 20%)	**Accuracy** (against 2nd remaining 20%)	**Average Accuracy**
Full	26	83.07%	82.81%	82.94%
80/20	5	86.15%	87.50%	86.83%
Overly simplified	2	90.77%	85.94%	88.36%

Table 7: Summary of Model Accuracy for Varying Attribute Counts

The reduction of attributes for consideration from 26 to five is a roughly 80% reduction in predictors to consider and meets the intent of applying quantitative analysis for this thesis. Ultimately, the five attributes that were quantitatively determined to be the most impactful predictors of success can now be carried forward to evaluate the new proposal's likelihood of success or, at a minimum, be entered into the conversation for consideration against the established predictors of success the company believes to be the most impactful.

Chapter 5

Analysis

5.1 Weighting Function

Once the key risks to success have been finalized, the evaluation moves to a multi-attribute tradespace exploration (MATE). A MATE can be used as "a decision-making framework" to help progress the various projects toward funding decisions (MIT, n.d.). The first step is aggregating variables into a single metric using an aggregation function. The generalized form (Keeney-Raiffa function) is:

$$KU + 1 = \prod_{i=1}^{n} (Kk_i U_i + 1)$$

Aggregating the multiple variables into one does not need to be complicated. This aggregation may be simple (Rebentisch, 2022) and take the form of the following equations:

Weighted sum

$$U = \sum_{i=1}^{n} k_i U_i$$

Multiplicative function

$$U = \prod_{i=1}^{n} U_i$$

Inverse multiplicative function

$$1 - U = \prod_{i=1}^{n} 1 - U_i$$

This thesis will move forward using the weighted sum aggregation function to normalize values across any selected risks while enabling weighting for risks deemed to be a higher priority over other risks. In practice, certain factors are expected to be deemed more critical to the business beyond just the likelihood of success, and this is a way to incorporate these additional considerations.

5.1.1 Example Weighting Function

The *Student Performance* dataset will be used again to demonstrate the application of the weighted sum aggregation. The MASF (multi-attribute success function) will be used to calculate each project's composite likelihood of success. The top five key risks previously identified using the quantitative analysis were Attributes 7, 18, 23, 22, and 4. Although the data would suggest these are the strongest predictors of success, the organization applying this framework likely has experience or reason to believe other factors may be predictors of success worth considering. In this example, Attributes 8 and 29 will also be considered in projections of success due to the fictitious belief that the organization has strong qualitative reasoning for including these factors.

To use a weighted sum aggregation, each attribute (synonymous with risk factor) will be weighted and mapped to estimate success likelihood. The success likelihood will be on a scale of zero to one. A success likelihood of zero represents a very low likelihood, while a one represents a very high likelihood. The weighting is intended to allow factors the company may regard more highly than others to be appropriately accounted for. An example weighting structure using the sample data is below:

Attribute	Weight
7	25%
18	20%
23	5%
22	15%
4	10%
8	15%
29	10%

Table 8: Example MASF Weighting Structure

Mapping the attributes to an estimate of success likelihood allows normalizing the data for input into the MASF. Each attribute can have unique mapping, depending on how the available data or information is expected to impact the likelihood of success. For this example, the attribute mapping to success likelihood is as follows:

Attribute 7	
Mother's Education	**Success Likelihood**
0	0
1	0.25
2	0.5
3	0.75
4	1
Attribute 18	
Paid	**Success Likelihood**
No (0)	0.25
Yes (1)	1
Attribute 23	
Romantic	**Success Likelihood**
Yes (1)	0.2
No (0)	1
Attribute 22	
Internet	**Success Likelihood**
No (0)	0.1
Yes (1)	1
Attribute 4	
Address	**Success Likelihood**
Rural (0)	0.2
Urban (1)	1
Attribute 8	
Father's Education	**Success Likelihood**
0	0
1	0.2
2	0.4
3	0.6
4	1
Attribute 29	
Health	**Success Likelihood**
1	0
2	0.2
3	0.4
4	0.6
5	1

Table 9: Example Attribute to Success Likelihood Mapping

Upon completion of the weighting and success likelihood mapping, the MASF can calculate a likelihood of success for a given instance (ex: project or, in this example, student). The success likelihood of individual attributes for Case 195 in the dataset is:

Case 195			
Attribute	**Attribute Weight**	**Dataset Value**	**Success Likelihood (SL)**
7	25%	4	1
18	20%	0	0.25
23	5%	0	1
22	15%	1	1
4	10%	1	1
8	15%	3	0.6
29	10%	2	0.2

Table 10: Summary Results for Case 195

A sample calculation for the MASF for Case 195 from the dataset is:

$$Case\ 195 = (1 * 0.25) + (0.25 * 0.2) + (1 * 0.05) + (1 * 0.15) + (1 * 0.1) + (0.6 * 0.15) + (0.2 * 0.1) = 0.71$$

5.2 Tradespace

The tradespace is a summary of the information that has been assembled to this point (Rebentisch, 2022) on a two-axis plot. The two axes should be parameters that are in tension with one another to allow the visualization of tradeoffs most effectively amongst all options. The primary axis should be a metric of significant interest for evaluation, such as the sum of the proposed investment (cost). The secondary axis could be the total risk (or stated as the opposite: the likelihood of success) which would be the aggregate value calculated in the previous step from the weighting function. Plotting these two against one another allows for a utopia point to be identified and all the various projects or proposals to be seen together. An example tradespace is shown below:

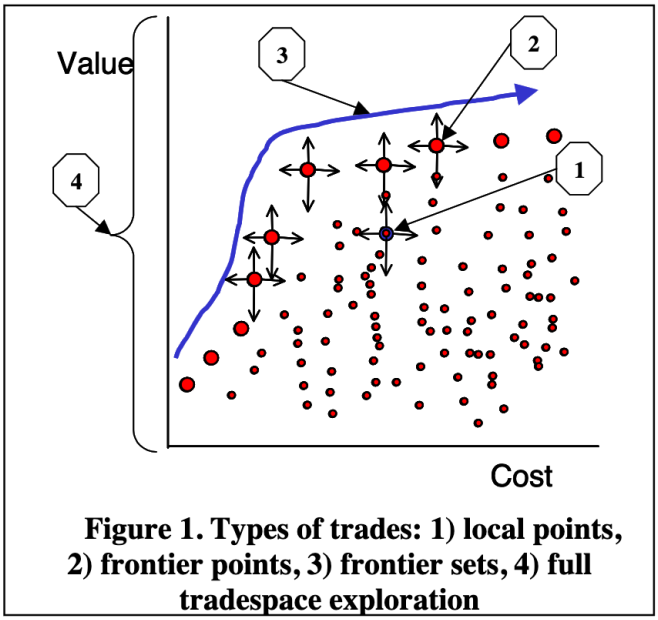

Figure 6: Tradespace Example (Ross et al., 2005)

The key components of understanding a trade space are local points, frontier points, frontier sets, and the utopia point. The local points are points that represent a single solution or, in the case of this thesis, a representation of a project forecast. The scattering of points plotted to show the range of outcomes for the various innovation projects. The utopia point is a fictitious local point that shows the ideal case. In the figure above, a point in the top left corner (near the #3 callout) would be the ideal case. This fictitious local point would be a point of low cost and maximum value, which is the utopian case. The utopia point aids in the visualization of which local points are closest to this perfect case. Frontier points have no point closer to the utopia point at the same value (i.e., no greater value possible at the same cost). The frontier set is the set of all frontier points. The other points in the trade space are dominated points and are not optimal solutions. The trade space should be used to visualize which innovation projects are optimal along the entire spectrum of investment options.

5.2.1 Example Tradespace Development

The Student Performance dataset will be used to demonstrate how to develop a tradespace. Investment amounts are a common metric in tension with success

outcomes for innovation projects. The publicly available data for this thesis only provides attributes for consideration and does not contain investment values or anything similar. To demonstrate how success attributes/risks could be compared to investment amounts required to evaluate, the thesis author used a random number generator to generate investment information for comparison to the existing dataset. The random numbers were generated with an average of $750,000 and a standard deviation of $100,000 using a Microsoft Excel function with normal distribution.

The tradespace is a plot of the MASF values against the investment amount of each case. The first 194 cases (60%) were used as training data while analyzing the most impactful success predictors, so the remaining 129 cases are being used to develop the tradespace. Below is an example of the data being used to generate points on the tradespace:

Case	Calculated Success Likelihood	Required Investment
195	0.71	$848,704
196	0.64	$671,011
197	0.4575	$633,608
198	0.4950	$705,219
199	0.7050	$726,929

Table 11: Example Dataset for Tradespace Generation

Plotting the data for all cases generates the tradespace below:

Figure 7: Example Tradespace

The tradespace above allows for all project proposals to be viewed against one another through a quantitative lens that reduces bias and risk aversion. The utopia point is shown on the graph (star) at the lowest investment possible with the highest likelihood of success possible. The cases shown by blue points are all the dominated cases from the analysis. Each case has an alternate case that is lower cost for the same or greater success likelihood. The cases that are shown by red points are along the Pareto frontier. These cases have no alternate case that is lower cost for the same or greater success likelihood and thus should be the first cases to consider for investment. This analysis demonstrates that the best cases to pursue are these:

Case	Calculated Success Likelihood	Required Investment
284	0.5425	$515,077
224	0.6900	$562,865
291	0.8500	$616,366
288	0.8600	$657,851
227	0.9000	$676,400
307	0.9200	$700,642
306	0.9600	$742,118
290	1.0000	$933,814

Table 12: Summary of Best Cases Evaluated

The traditional approach of applying the tradespace as a tool can be modified to fit the needs of corporations. In traditional tradespace analyses, all dominated points are removed from consideration. However, utilizing a tradespace for investment decisions is different. The decision-making will all depend on the amount of money available for investment and the lowest likelihood of success acceptable for an organization. A minimum calculated success likelihood can be defined to remove all cases from consideration that do not meet the requirement. Once the Pareto frontier has been established, the best available projects can be put into a category and removed from

the dataset. An example of using the tradespace tool with a cutoff of 0.75 as the calculated success likelihood and defining three tiers of potential investment would yield results like those shown below:

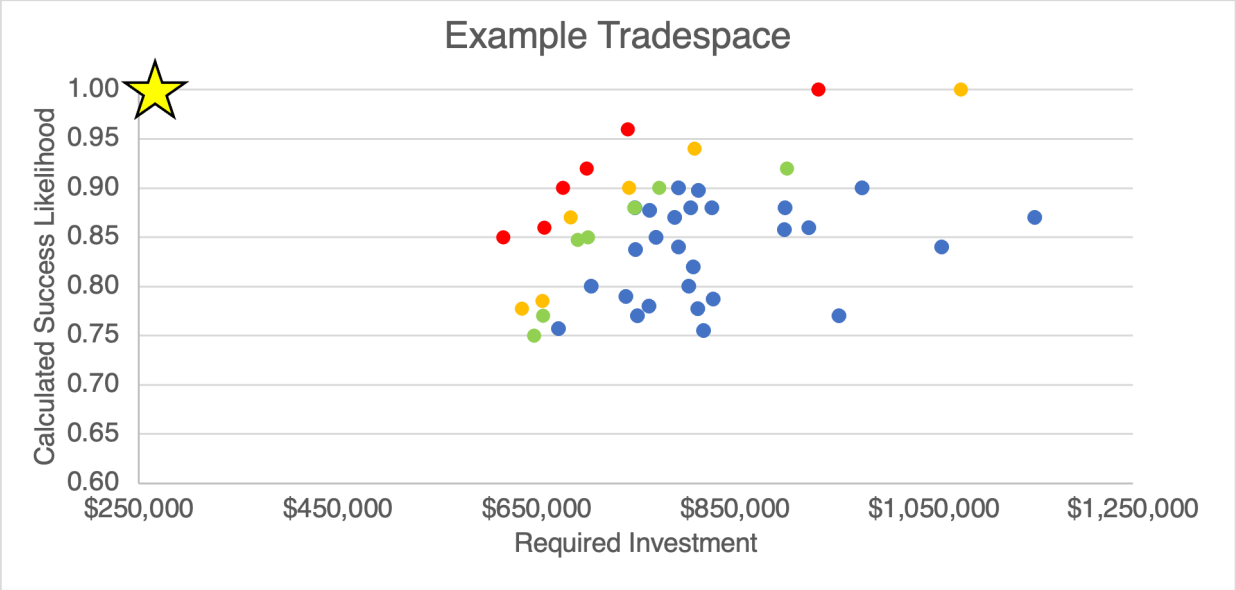

Figure 8: Example Tradespace with Investment Tier Optionality

Case	Calculated Success Likelihood	Required Investment
Tier I Investment Options		
291	0.8500	$616,366
288	0.8600	$657,851
227	0.9000	$676,400
307	0.9200	$700,642
306	0.9600	$742,118
290	1.0000	$933,814
Tier II Investment Options		
258	0.7775	$635,091
207	0.7850	$656,075
248	0.8700	$684,432
205	0.9000	$742,900
268	0.9400	$808,752
297	1.0000	$1,076,923
Tier III Investment Options		
234	0.7500	$647,399
316	0.7700	$656,459
292	0.8475	$691,195
237	0.8500	$701,466
235	0.8800	$748,726
298	0.9000	$773,460
268	0.9400	$808,752

Table 13: Summary of Tiered Investment Opportunity Analysis

These cases (ex: innovation projects) should be considered for investment before others. The tradespace expedites decision-making by quantitatively establishing the most promising projects. It also allows for the rapid elimination of projects by removing those far away from the Pareto frontier for consideration, as these projects are the least competitive options being evaluated.

Finally, the tradespace example above demonstrates proposals being evaluated against one another based on required investment. It is possible to iterate through the

analysis again and compare proposals based on expected returns. The expectation is that adding a view of expected returns can show the organization's most significant financial upside while simultaneously eliminating the high cost and low likelihood of success projects relative to the other options available. The analysis, taken to this second step, would provide decision-makers with more information to optimize their investment decisions.

Chapter 6

Portfolio Development

6.1 Markowitz

Originated by Harry Markowitz, portfolio theory, specifically the diversification of investments to reduce risk, is widely understood by investors in 2023. Markowitz first published the theory that a diversified portfolio is less volatile than the sum of its parts in 1952 in the paper *Portfolio Selection*. He later won the Nobel Prize in Economics for the theory. This theory is applicable in the case of investment in innovation projects because innovation projects have uncertain futures. This thesis attempts to minimize risks through bias reduction, quantitative analysis of key success factors, and to visualize the optimal projects. While these steps are taken to make the future more certain, there will always be uncertainties when trying something new, which is common in innovation projects.

6.2 Innovation as a Portfolio

Diversification of investments in the financial industry has proven effective in mitigating risk. Investments that were diversified (stocks and bonds) outperformed non-diversified investments between 2000 and 2015. The graphic below from Charles Schwab summarizes this point:

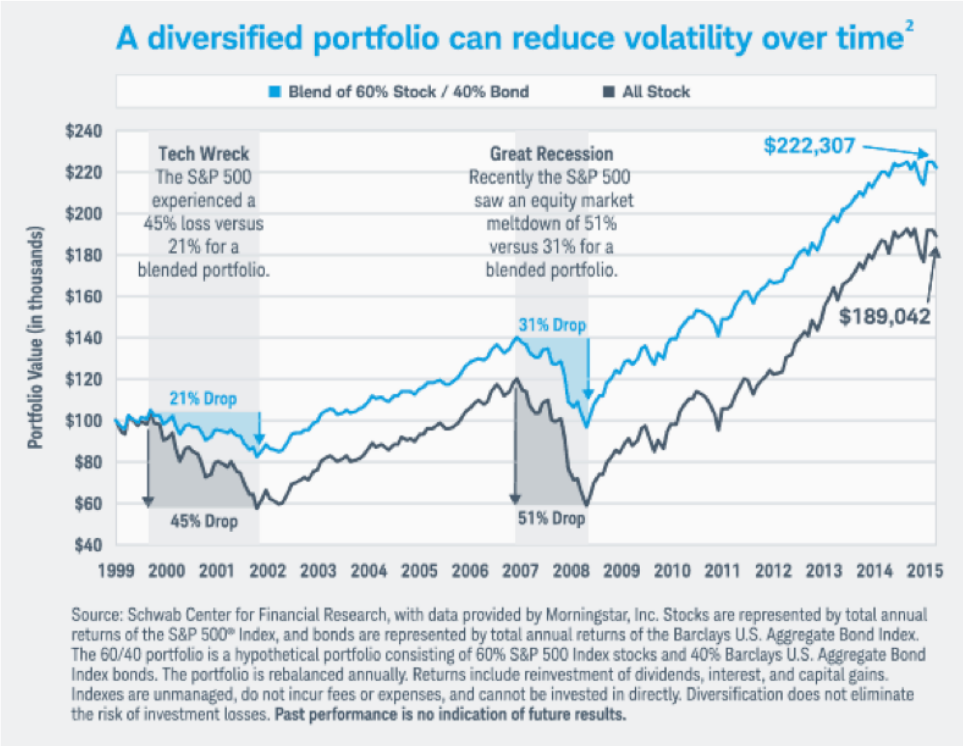

Figure 9: Diversified Portfolio Performance Over Time (Charles Schwab, 2018)

There are benefits to approaching innovation through a portfolio-driven approach. These benefits are:

Benefit 1	See the impacts of easily implemented innovations while simultaneously exploring future disruptive technologies
Benefit 2	Justify taking on longer-horizon, higher-risk initiatives because they are offset by shorter-term, more certain projects
Benefit 3	Manage innovation budgets and justify budget requests
Benefit 4	Ensure that innovation efforts are complementary to each other, but not redundant

Table 14: Benefits of Approaching Innovation as a Portfolio (Holden et al., 2018)

However, organizations may struggle to establish a portfolio of innovation investments because "funding streams are often decentralized across various offices or divisions (…) "big bets" are often managed either at an agency level or through a

dedicated internal group [while incremental innovations are] managed by the individual offices" (Holden et al., 2018). This decentralization causes innovation projects to be viewed as one-offs and not appropriately encompassed into an innovation portfolio. The tradespace combats this hurdle by allowing all projects to be viewed as a full picture of the potential innovation portfolio.

There are existing innovation portfolio models. The models are shown below: The Ambition Matrix

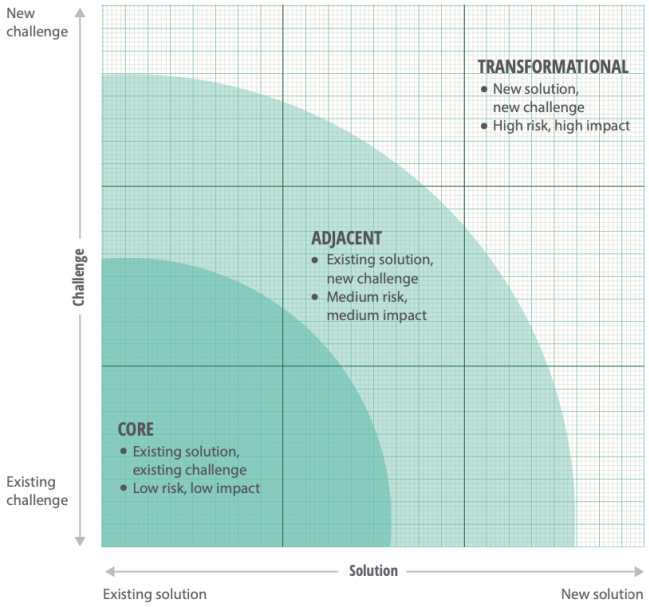

Figure 10: The Ambition Matrix (Holden et al., 2018)

U.S. Agency for International Development Innovation Portfolio

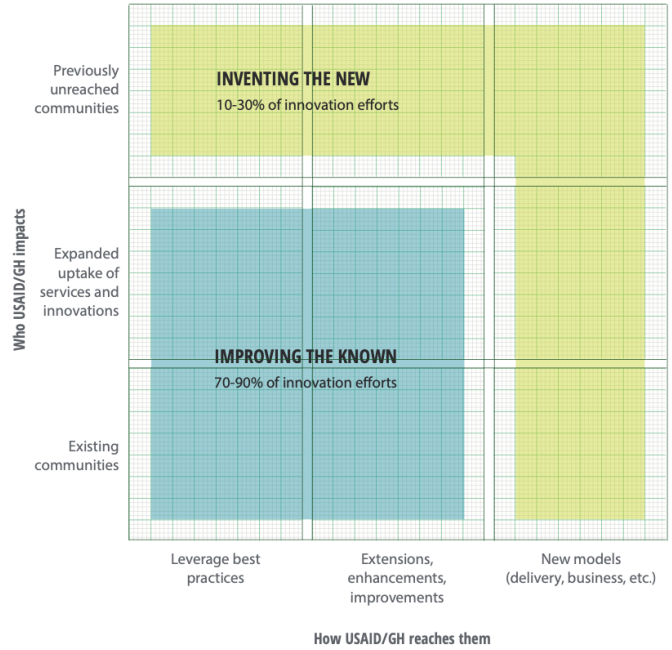

Figure 11: USAID Innovation Portfolio (Holden et al., 2018)

Options Portfolio Model

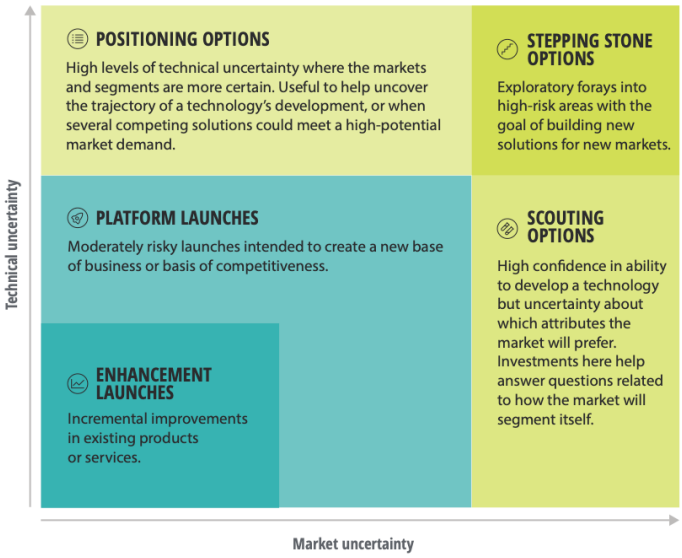

Figure 12: Options Portfolio Model (Holden et al., 2018)

Pairing the ideology which these models are based with the tradespace analysis enables decision-makers to develop a diversified portfolio of the best projects.

Chapter 7

Framework

7.1 Process Summary

The framework in this thesis is intended to overcome several factors that negatively impact corporate innovation. The factors that inhibit innovation are difficulty identifying lead users, the inherent risk aversion and biases in nearly all companies, near-term optimization, and the fast pace of technological change. Although there are factors that inhibit the success of corporate innovation, other factors aid in the success of corporate innovation. The factors that aid in the success of corporate innovation are their stronger financial position compared to potential competitors, technological assets, number of skilled employees, production capacity, and established relationships with customers. The framework developed leverages these strengths in innovation while minimizing the negative implications of the factors that inhibit innovation. The framework can be summarized into a five-step process. The process diagram is shown below:

Figure 13: Framework Summary

7.2 Risk Rank

The first step in analyzing the innovation proposals is to develop the risk ranking that will serve as key indicators for the success of the innovation investment. The three methods for establishing these indicators are standard key indicators (Section 4.2), quantitatively determining the most impactful predictors (Section 4.3), or a hybrid of the two methods. Establishing a shortened list of risks enables the evaluation of projects to be more quickly completed, which is required to meet the rapid pace of technology change and evolving customer needs (Section 2.5).

7.3 Establish Success Function

The second step toward evaluating innovation proposals using this framework is establishing the weighting function. The weighting function provides flexibility in its application to ensure the organization can appropriately value the metrics and drivers most critical to the business while mitigating biases and overcoming innovation inhibitors that stem from the organizational culture. However, investor and market pressures influence company actions (Section 2.4.2), and it is unreasonable to expect this influence to be eliminated.

This framework accommodates these pressures by allowing specific predictors to be weighted more influentially than others. For example, in an operating environment where capital efficiency is critical for a company's operations, the weight applied to Risk 9.8 (estimated return on investment will meet the company's standards) can be much greater than other factors for consideration. Once established, the attribute weighting is the same for all evaluated projects.

Finally, the multi-attribute success function comprised of the sum of attribute weightings and calculated success likelihoods are used to characterize each case. Approaching this calculation from a quantitative perspective significantly reduces the impacts of the adjustment and anchoring, availability, and representative biases (Section 2.4.1). This approach also enables overcoming hurdles that may be present due to the organizational culture (Section 2.4).

7.4 Project Proposal Generation

The Chairman of Hellman & Friedman LLC, a private equity group with $80 billion in assets under management, stated, "Listen to your partners and associates – surround yourself with smart people and listen intently to their views" (Finkel et al., 2010). Expanding innovation proposals to include as many proposers as possible addresses the point being made by Hellman. Allowing employees to propose innovation projects ensures they are heard and democratizes innovation by increasing the likelihood that lead users are identified (Section 2.6). However, expanding the total number of proposals could slow the progression of innovation due to the increased volume of

evaluations to be completed. This framework uses the Pareto principle to benefit from the increased input for proposals while balancing the expediency required to keep up with the pace of technological change experienced in today's environment (Section 2.5).

Sourcing innovation proposals must occur at a frequency that meets or exceeds the pace of change realized in the industry where the innovation projects will be implemented. Many templates for innovation proposal documents are available online, like the MIT SMART Innovation Centre template. The key indicators for the success of the innovation investment have already been established in the risk ranking step, and these indicators must be added to the proposal template used. Project proposals should leverage the entire employee base and at minimum require values to be provided for the key indicators that the organization has established.

7.5 Plot the Tradespace

The fourth step is developing the visualization of the proposed projects against the metrics of success likelihood and required investment by plotting the tradespace. This perspective of the entire innovation landscape being evaluated helps combat the innovator's dilemma (Section 2.2) by focusing solely on projected outcomes and cost rather than on serving current markets. The tradespace is used to develop the list of the most promising investment opportunities (Section 5.2.1).

7.6 Develop a Portfolio of Projects

The final step is to develop a portfolio of projects to invest in. Innovation is inherently risky, and investments should be diversified to reduce risk (Section 6.1). In the context of this thesis, investment diversification primarily comes in the form of the tradespace representing all options on a single graph. This framework overcomes frequent hurdles for innovation portfolio development (Section 6.2). Selecting frontier points along the acceptable range of success likelihood for the company and applying the ideology of innovation portfolio models (Section 6.2) allows for optimal portfolio investment decisions. Various investment tiers may be established (Section 5.2.1) and expand innovation opportunities beyond the select few frontier points, thus increasing the

available options to generate a portfolio. At a minimum, this evaluation method establishes the uncompetitive nature of the local points opposite the utopia point. It enables the rapid removal of projects that are not suitable for funding.

Chapter 8

Conclusion

8.1 Research Summary

Opportunity exists for existing firms to improve their innovation success rates. Although these firms have factors that enable successful innovation compared to new enterprises, the success rate of delivered innovation projects from corporations still needs to improve. Applying a system approach to evaluate all innovation project proposals simultaneously reduces factors that inhibit successful innovation and enables a portfolio approach critical for reducing risk in uncertain activities.

The factors that may inhibit innovation are the organizational culture, innovator's dilemma, risk aversion, biases, near-term optimization, and the pace of change required by the users of the products. The factors that may enable innovation are large employee bases that can be leveraged to democratize innovation, their likelihood of having multiple locations in different geographical areas, and adequate resources for diversified innovation investment. The organization must understand the impacts that each of the factors above may have on innovation to reduce the negative factors and maximize the impact of the positive factors.

System engineering tools, rooted in quantitative analysis, can be applied to various steps of innovation investment assessments to aid in the reduction of common negative impacts present in organizations. The tools used are advanced analytics, weighting functions that enable multiple factors to be considered simultaneously, and a multi-attribute tradespace exploration. Utilizing a portfolio approach is the final tool necessary to improve outcomes when decision-making with imperfect information about unknown futures. The process summary is below:

8.2 Scope Limitations

Innovation is a broad term that is applied in several different manners. This thesis took a narrowed approach to investigating innovation from the perspective of an existing organization of relative scale. The other narrowing features were to focus on architectural innovation and product innovation. The framework put forth may not be appropriate for radical innovation or paradigm innovation. Further information about the application of the term innovation can be found in Chapter 3.

The use of non-innovation investment data also limits this thesis. The premise of the thesis is for innovation investment, but student performance data was used instead. When applying the framework, principles, and tools to investment data, additional considerations may need to be made. For example, the MASF is a calculation based on each proposal's underlying assumptions or analysis. There is likely to be bias in these assumptions or analyses, and it may be difficult to calibrate the various attribute metrics across an entire organization to ensure projects are appropriately compared to one another. There are best practices that can be used, such as not having proposers be the people ranking the success likelihood of a specific attribute (Finkel et al., 2010), and these practices to eliminate bias and calibrate attribute rankings during the quantitative evaluation should be researched, understood, and applied when making the transition to using actual investment data. Investment data is expected to have greater uncertainty than student performance data, and that uncertainty should be addressed.

8.3 Future Research

The framework in this thesis is expected to be helpful but has yet to be trialed in practice or even with an innovation investment-specific dataset. Further analysis using innovation investment data may present the opportunity to refine the framework. The weighting function has been suggested to be applied across an entire organization. However, in organizations, there are often divisions with certain specialties within a business, and further research could identify the optimal application of the weighting function and size of the tradespace to be considered in large organizations. A single weighting function and tradespace for these large organizations may be insufficient to

address their innovation opportunities adequately. The framework proposed was intended to be applicable across many industries, so it is broad. Future research modifying this broad template may find opportunities to use the framework in new ventures and for the other types of innovation that were excluded from consideration in this thesis.

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Appendix

A.1 Original Dataset

Attribute 1 school	Attribute 2 sex	Attribute 3 age	Attribute 4 address	Attribute 5 famsize	Attribute 6 Pstatus	Attribute 7 Medu	Attribute 8 Fedu	Attribute 9 Mjob	Attribute 10 Fjob	Attribute 11 reason	Attribute 12 guardian	Attribute 13 traveltime	Attribute 14 studytime	Attribute 15 failures	Attribute 16 schoolsup
GP	F	18	U	GT3	A	4	4	at_home	teacher	course	mother	2	2	0	yes
GP	F	17	U	GT3	T	1	1	at_home	other	course	father	1	2	0	no
GP	F	15	U	LE3	T	1	1	at_home	other	other	mother	1	2	3	yes
GP	F	15	U	GT3	T	4	2	health	services	home	mother	1	3	0	no
GP	F	16	U	GT3	T	3	3	other	other	home	father	1	2	0	no
GP	M	16	U	LE3	T	4	3	services	other	reputation	mother	1	2	0	no
GP	M	16	U	LE3	T	2	2	other	other	home	mother	1	2	0	no
GP	F	17	U	GT3	A	4	4	other	teacher	home	mother	2	2	0	yes
GP	M	15	U	LE3	A	3	2	services	other	home	mother	1	2	0	no
GP	M	15	U	GT3	T	3	4	other	other	home	mother	1	2	0	no
GP	F	15	U	GT3	T	4	4	teacher	health	reputation	mother	1	2	0	no
GP	F	15	U	GT3	T	2	1	services	other	reputation	father	3	3	0	no
GP	M	15	U	LE3	T	4	4	health	services	course	father	1	1	0	no
GP	M	15	U	GT3	T	4	3	teacher	other	course	mother	2	2	0	no
GP	M	15	U	GT3	A	2	2	other	other	home	other	1	3	0	no
GP	F	16	U	GT3	T	4	4	health	other	home	mother	1	1	0	no
GP	F	16	U	GT3	T	4	4	services	services	reputation	mother	1	3	0	no
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GP	M	16	U	GT3	T	4	4	teacher	teacher	home	mother	1	2	0	no
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GP	M	15	R	GT3	T	4	3	teacher	at_home	course	mother	1	2	0	no
GP	M	15	U	LE3	T	3	3	other	other	course	mother	1	2	0	no
GP	M	16	U	GT3	T	3	2	other	other	home	mother	1	1	0	no
GP	F	15	U	GT3	T	2	3	other	other	other	father	2	1	0	no
GP	M	15	U	LE3	T	4	3	teacher	services	home	mother	1	3	0	no
GP	M	16	R	GT3	A	4	4	other	teacher	reputation	mother	2	3	0	no
GP	F	15	R	GT3	T	3	4	services	health	course	mother	1	3	0	yes
GP	F	15	R	GT3	T	2	2	at_home	other	reputation	mother	1	1	0	yes
GP	F	16	U	LE3	T	2	2	other	other	home	mother	2	2	1	no
GP	M	15	U	LE3	T	4	4	teacher	other	home	other	1	1	0	no
GP	M	15	U	GT3	T	4	4	services	teacher	course	father	1	2	0	no
GP	M	15	U	GT3	T	2	2	services	services	course	father	1	1	0	yes
GP	F	16	U	LE3	T	2	2	other	at_home	course	father	2	2	1	yes
GP	F	15	U	LE3	A	4	3	other	other	course	mother	1	2	0	yes
GP	F	16	U	LE3	A	3	3	other	services	home	mother	1	2	0	no
GP	M	16	U	GT3	T	4	3	health	services	reputation	mother	1	4	0	no
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GP	F	15	U	GT3	T	4	4	services	teacher	other	father	1	2	1	yes
GP	F	16	U	LE3	T	2	2	services	services	course	mother	3	2	0	no
GP	F	15	U	LE3	T	4	2	health	other	other	mother	1	2	0	no
GP	M	15	U	LE3	A	4	2	health	health	other	father	2	1	1	no
GP	F	15	U	GT3	T	4	4	services	services	course	mother	1	1	0	yes
GP	F	15	U	LE3	A	3	3	other	other	other	mother	1	1	0	no
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GP	M	15	U	GT3	T	4	4	teacher	health	reputation	mother	1	2	0	no
GP	M	15	U	LE3	T	1	2	other	at_home	home	father	1	2	0	yes
GP	F	16	U	GT3	T	4	2	services	other	course	mother	1	2	0	no
GP	F	16	R	GT3	T	4	4	health	teacher	other	mother	1	2	0	no
GP	F	16	U	GT3	T	1	1	services	services	course	father	4	1	0	yes
GP	F	16	U	LE3	T	1	2	other	services	reputation	father	1	2	0	yes
GP	F	16	U	GT3	T	4	3	teacher	health	home	mother	1	3	0	yes
GP	F	15	U	LE3	T	4	3	services	services	reputation	father	1	2	0	yes
GP	F	16	U	LE3	T	4	3	teacher	services	course	mother	3	2	0	no
GP	M	15	U	GT3	A	4	4	other	services	reputation	mother	1	4	0	no
GP	F	16	U	GT3	T	3	1	services	other	course	mother	1	4	0	yes
GP	F	15	R	LE3	T	2	2	health	services	reputation	mother	2	2	0	yes
GP	F	15	R	LE3	T	3	1	other	other	reputation	father	2	4	0	no
GP	M	16	U	GT3	T	3	1	other	other	reputation	father	2	4	0	no
GP	M	15	U	GT3	T	4	2	other	other	course	mother	1	4	0	no
GP	F	15	R	GT3	T	1	1	other	other	reputation	mother	1	2	2	yes
GP	M	16	U	GT3	T	3	1	other	other	reputation	mother	1	1	0	no
GP	F	16	U	GT3	T	3	3	other	services	home	mother	1	2	0	yes
GP	M	15	U	GT3	T	4	3	teacher	other	home	mother	1	2	0	no
GP	M	15	U	GT3	T	4	0	teacher	other	course	mother	2	4	0	no
GP	F	16	U	GT3	T	2	2	other	other	reputation	mother	1	4	0	no
GP	M	17	U	GT3	T	2	1	other	other	home	mother	2	1	3	yes
GP	F	16	U	GT3	T	3	4	at_home	other	course	mother	1	2	0	no
GP	M	15	U	GT3	T	2	3	other	services	course	father	1	1	0	yes
GP	M	15	U	GT3	T	2	3	other	other	home	mother	1	3	0	yes
GP	F	15	U	LE3	T	3	2	services	other	reputation	mother	1	2	0	no
GP	M	15	U	LE3	T	2	2	services	services	home	mother	2	2	0	no
GP	F	15	U	GT3	T	1	1	other	other	home	father	1	2	0	no
GP	F	15	U	GT3	T	4	4	services	services	reputation	father	2	2	2	no
GP	F	16	U	LE3	T	2	2	at_home	other	course	mother	1	2	0	no

GP	F	15	U	GT3	T	4	2	other	other	reputation	mother	1	3	0	no
GP	M	16	U	GT3	T	2	2	services	other	reputation	father	2	2	1	no
GP	M	16	U	LE3	A	4	4	teacher	health	reputation	mother	1	2	0	no
GP	F	16	U	GT3	T	3	3	other	other	home	mother	1	3	0	no
GP	F	15	U	GT3	T	4	3	services	other	reputation	mother	1	1	0	no
GP	F	16	U	LE3	T	3	1	other	other	home	father	1	2	0	yes
GP	F	16	U	GT3	T	4	2	teacher	services	home	mother	2	2	0	no
GP	M	15	U	LE3	T	2	2	services	health	reputation	mother	1	4	0	no
GP	F	15	R	GT3	T	1	1	at_home	other	home	mother	2	4	1	yes
GP	M	16	R	GT3	T	4	3	services	other	reputation	mother	2	1	0	yes
GP	F	16	U	GT3	T	2	1	other	other	course	mother	1	2	0	no
GP	F	16	U	GT3	T	4	4	other	other	reputation	mother	1	1	0	no
GP	F	16	U	GT3	T	4	3	other	at_home	course	mother	1	3	0	yes
GP	M	16	U	GT3	T	4	4	services	services	other	mother	1	1	0	yes
GP	M	16	U	GT3	T	4	4	services	teacher	other	father	1	3	0	no
GP	M	15	U	GT3	T	4	4	services	other	course	mother	1	1	0	no
GP	F	15	U	GT3	T	3	2	services	other	home	mother	2	2	0	yes
GP	M	15	U	GT3	A	3	4	services	other	course	mother	1	2	0	no
GP	F	15	U	GT3	A	3	3	other	health	reputation	father	1	4	0	yes
GP	F	15	U	GT3	T	2	2	other	other	course	mother	1	4	0	yes
GP	M	16	U	GT3	T	3	3	services	other	home	father	1	3	0	no
GP	M	15	R	GT3	T	4	4	other	other	home	father	4	4	0	no
GP	F	16	U	LE3	T	4	4	health	health	other	mother	1	3	0	no
GP	M	15	U	LE3	A	4	4	teacher	teacher	course	mother	1	1	0	no
GP	F	16	R	GT3	T	3	3	services	other	reputation	father	1	3	1	yes
GP	F	16	U	GT3	T	2	2	at_home	other	home	mother	1	2	1	yes
GP	M	15	U	LE3	T	4	2	teacher	other	course	mother	1	1	0	no
GP	M	15	R	GT3	T	2	1	health	services	reputation	mother	1	2	0	no
GP	M	16	U	GT3	T	4	4	teacher	teacher	course	father	1	2	0	no
GP	M	15	U	GT3	T	4	4	other	teacher	reputation	father	2	2	0	no
GP	M	16	U	GT3	T	3	3	other	services	home	father	2	1	0	no
GP	M	17	R	GT3	T	1	3	other	other	course	father	3	2	1	no
GP	M	15	U	GT3	T	3	4	other	other	reputation	father	1	1	0	no
GP	F	15	U	GT3	T	1	2	at_home	services	course	mother	1	2	0	no
GP	M	15	U	GT3	T	2	2	services	services	home	father	1	4	0	no
GP	F	16	U	LE3	T	2	4	other	health	course	father	2	2	0	no
GP	M	16	U	GT3	T	4	4	health	other	course	mother	1	1	0	no
GP	F	16	U	GT3	T	2	2	other	other	home	mother	1	2	0	no
GP	M	15	U	GT3	T	3	4	services	services	home	father	1	1	0	yes
GP	F	15	U	LE3	A	3	4	other	other	home	mother	1	2	0	yes
GP	F	19	U	GT3	T	0	1	at_home	other	course	other	1	2	3	no
GP	M	18	R	GT3	T	2	2	services	other	reputation	mother	1	1	2	no
GP	M	16	R	GT3	T	4	4	teacher	teacher	course	mother	1	1	0	no
GP	F	15	R	GT3	T	3	4	services	teacher	course	father	2	3	2	no
GP	F	15	U	GT3	T	1	1	at_home	other	course	mother	3	1	0	no
GP	F	17	U	LE3	T	2	2	other	other	course	father	1	1	0	no
GP	F	16	U	GT3	A	3	4	services	other	course	father	1	1	0	no
GP	M	15	R	GT3	T	3	4	at_home	teacher	course	mother	4	2	0	no
GP	F	15	U	GT3	T	4	4	services	at_home	course	mother	1	3	0	no
GP	M	17	R	GT3	T	3	4	at_home	other	course	mother	3	2	0	no
GP	F	16	U	GT3	A	3	3	other	other	course	other	2	1	2	no
GP	M	16	U	LE3	T	1	1	services	other	course	mother	1	2	1	no
GP	F	15	U	GT3	T	4	4	teacher	teacher	course	mother	2	1	0	no
GP	M	15	U	GT3	T	4	3	teacher	services	course	father	2	4	0	yes
GP	M	16	U	LE3	T	2	2	services	services	reputation	father	2	1	2	no
GP	F	15	U	GT3	T	4	4	teacher	services	course	mother	1	3	0	no
GP	F	16	U	LE3	T	1	1	at_home	at_home	course	mother	1	1	0	no
GP	M	17	U	GT3	T	2	1	other	other	home	mother	1	1	3	no
GP	F	15	U	GT3	T	1	1	other	services	course	father	1	2	0	no
GP	F	15	U	GT3	T	3	2	health	services	home	father	1	2	3	no
GP	F	15	U	GT3	T	1	2	at_home	other	course	mother	1	2	0	no
GP	M	16	U	GT3	T	4	4	teacher	teacher	course	mother	1	1	0	no
GP	M	15	U	LE3	A	2	1	services	other	course	mother	4	1	3	no
GP	M	18	U	LE3	T	1	1	other	other	course	mother	1	1	3	no
GP	M	16	U	LE3	T	2	1	at_home	other	course	mother	1	1	1	no
GP	F	15	R	GT3	T	3	3	services	services	reputation	other	2	3	2	no
GP	M	19	U	GT3	T	3	2	services	at_home	home	mother	1	1	3	no
GP	F	17	U	GT3	T	4	4	other	teacher	course	mother	1	1	0	yes
GP	M	15	R	GT3	T	2	3	at_home	services	course	mother	1	2	0	yes
GP	M	17	R	LE3	T	1	2	other	other	reputation	mother	1	1	0	no
GP	F	18	R	GT3	T	1	1	at_home	other	course	mother	3	1	3	no
GP	M	16	R	GT3	T	2	2	at_home	other	course	mother	3	1	0	no
GP	M	16	U	GT3	T	3	3	other	services	course	father	1	2	1	no
GP	M	17	R	LE3	T	2	1	at_home	other	course	mother	2	1	2	no
GP	M	15	R	GT3	T	3	2	other	other	course	mother	2	2	2	yes
GP	M	16	U	LE3	T	1	2	other	other	course	mother	2	1	1	no
GP	M	17	U	GT3	T	1	3	at_home	services	course	father	1	1	0	no
GP	M	17	R	LE3	T	1	1	other	services	course	mother	4	2	3	no
GP	M	16	U	GT3	T	3	2	services	services	course	mother	2	1	1	no
GP	M	16	U	GT3	T	2	2	other	other	course	father	1	2	0	no
GP	F	16	U	GT3	T	4	2	health	services	home	father	1	2	0	no
GP	F	16	U	GT3	T	2	2	other	other	home	mother	1	2	0	no
GP	F	16	U	GT3	T	4	4	health	health	reputation	mother	1	2	0	no
GP	M	16	U	GT3	T	3	4	other	other	course	father	3	1	2	no
GP	M	16	U	GT3	T	1	0	other	other	reputation	mother	2	2	0	no
GP	M	17	U	LE3	T	4	4	teacher	other	reputation	mother	1	2	0	no
GP	F	16	U	GT3	T	1	3	at_home	services	home	mother	1	2	3	no
GP	F	16	U	LE3	T	3	3	other	other	reputation	mother	2	2	0	no
GP	M	17	U	LE3	T	4	3	teacher	other	course	mother	2	2	0	no

GP	F	16	U	GT3	T	2	2	services	other	reputation	mother	2	2	0 no
GP	M	17	U	GT3	T	3	3	other	other	reputation	father	1	2	0 no
GP	M	16	R	GT3	T	4	2	teacher	services	other	mother	1	1	0 no
GP	M	17	U	GT3	T	4	3	other	other	course	mother	1	2	0 no
GP	M	16	U	GT3	T	4	3	teacher	other	home	mother	1	2	0 no
GP	M	16	U	GT3	T	3	3	services	other	home	mother	1	2	0 no
GP	F	17	U	GT3	T	2	4	services	services	reputation	father	1	2	0 no
GP	F	17	U	LE3	T	3	3	other	other	reputation	mother	1	2	0 no
GP	F	16	U	GT3	T	3	2	other	other	reputation	mother	1	2	0 no
GP	M	17	U	GT3	T	3	3	services	services	other	mother	1	2	0 no
GP	M	16	U	GT3	T	1	2	services	services	other	mother	1	1	0 no
GP	M	16	U	LE3	T	2	1	other	other	course	mother	1	2	0 no
GP	F	17	U	GT3	A	3	3	health	other	reputation	mother	1	2	0 no
GP	M	17	R	GT3	T	1	2	at_home	other	home	mother	1	2	0 no
GP	F	16	U	GT3	T	2	3	services	services	course	mother	1	2	0 no
GP	F	17	U	GT3	T	1	1	at_home	services	course	mother	1	2	0 no
GP	M	17	U	GT3	T	1	2	at_home	services	other	other	2	2	0 no
GP	M	16	R	GT3	T	3	3	services	services	reputation	mother	1	1	0 no
GP	M	16	U	GT3	T	2	3	other	other	home	father	2	1	0 no
GP	F	17	U	LE3	T	2	4	services	services	course	father	1	2	0 no
GP	M	17	U	GT3	T	4	4	services	teacher	home	mother	1	1	0 no
GP	M	16	R	LE3	T	3	3	teacher	other	home	father	3	1	0 no
GP	F	17	U	GT3	T	4	4	services	teacher	home	mother	2	1	1 no
GP	F	16	U	LE3	T	4	4	teacher	teacher	reputation	mother	1	2	0 no
GP	F	16	U	GT3	T	4	3	health	other	home	mother	1	2	0 no
GP	F	16	U	GT3	T	2	3	other	other	reputation	mother	1	2	0 yes
GP	F	17	U	GT3	T	1	1	other	other	course	mother	1	2	0 no
GP	F	17	R	GT3	T	2	2	other	other	reputation	mother	1	1	0 no
GP	F	16	R	GT3	T	2	2	services	services	reputation	mother	2	4	0 no
GP	F	17	U	GT3	T	3	4	at_home	services	home	mother	1	3	1 no
GP	F	16	U	GT3	A	3	1	services	other	course	mother	1	2	3 no
GP	F	16	U	GT3	T	4	3	teacher	other	other	mother	1	2	0 no
GP	F	16	U	GT3	T	1	1	at_home	other	home	mother	2	1	0 no
GP	F	17	R	GT3	T	4	3	teacher	other	reputation	mother	2	3	0 no
GP	F	19	U	GT3	T	3	3	other	other	reputation	other	1	4	0 no
GP	M	17	U	LE3	T	4	4	services	other	home	mother	1	2	0 no
GP	F	16	U	GT3	A	2	2	other	other	reputation	mother	1	2	0 yes
GP	M	18	U	GT3	T	2	2	services	other	home	mother	1	2	1 no
GP	F	17	R	LE3	T	4	4	services	other	other	mother	1	1	0 no
GP	F	17	U	LE3	T	3	2	other	other	reputation	mother	2	2	0 no
GP	F	17	U	GT3	T	4	3	other	other	reputation	mother	1	2	2 no
GP	M	18	U	LE3	T	3	3	services	health	home	father	1	2	1 no
GP	F	17	U	GT3	T	2	3	at_home	other	home	father	2	1	0 no
GP	F	17	U	GT3	T	2	2	at_home	at_home	course	mother	1	3	0 no
GP	F	17	R	GT3	T	2	1	at_home	services	reputation	mother	2	2	0 no
GP	F	17	U	GT3	T	1	1	at_home	other	reputation	mother	1	3	1 no
GP	F	16	U	GT3	T	2	3	services	teacher	other	mother	1	2	0 yes
GP	M	18	U	GT3	T	2	2	other	other	home	mother	2	2	0 no
GP	F	16	U	GT3	T	4	4	teacher	services	home	mother	1	3	0 no
GP	F	18	R	GT3	T	3	1	other	other	reputation	mother	1	2	1 no
GP	F	17	U	GT3	T	3	2	other	other	course	mother	1	2	0 no
GP	M	17	U	LE3	T	2	3	services	services	reputation	father	1	2	0 no
GP	M	18	U	LE3	T	2	1	at_home	other	course	mother	4	2	0 yes
GP	F	17	U	GT3	A	2	1	other	other	course	mother	2	3	0 no
GP	F	17	U	LE3	T	4	3	health	other	reputation	father	1	2	0 no
GP	M	17	R	GT3	T	2	2	other	other	course	father	2	2	0 no
GP	M	17	U	GT3	T	4	4	teacher	teacher	reputation	mother	1	2	0 yes
GP	M	16	U	GT3	T	4	4	health	other	reputation	father	1	2	0 no
GP	M	16	U	LE3	T	1	1	other	other	home	mother	2	2	0 no
GP	M	16	U	GT3	T	3	2	at_home	other	reputation	mother	2	3	0 no
GP	M	17	U	LE3	T	2	2	other	other	home	father	1	2	0 no
GP	F	16	U	GT3	T	2	1	other	other	home	mother	1	1	0 no
GP	F	17	R	GT3	T	2	1	at_home	services	course	mother	3	2	0 no
GP	M	18	U	GT3	T	2	2	other	services	reputation	father	1	2	1 no
GP	M	17	U	LE3	T	4	3	health	other	course	mother	2	2	0 no
GP	M	17	R	LE3	A	4	4	teacher	other	course	mother	2	2	0 no
GP	M	16	U	LE3	T	4	3	teacher	other	course	mother	1	1	0 no
GP	M	16	U	GT3	T	4	4	services	services	course	mother	1	1	0 no
GP	F	18	U	GT3	T	2	1	other	other	course	other	2	3	0 no
GP	M	16	U	GT3	T	2	1	other	other	course	mother	3	1	0 no
GP	M	17	U	GT3	T	2	3	other	other	course	father	2	1	0 no
GP	M	22	U	GT3	T	3	1	services	services	other	mother	1	1	3 no
GP	M	18	R	LE3	T	3	3	other	services	course	mother	1	2	1 no
GP	M	16	U	GT3	T	0	2	other	other	other	mother	1	1	0 no
GP	M	18	U	GT3	T	3	2	services	other	course	mother	2	1	1 no
GP	M	16	U	GT3	T	3	3	at_home	other	reputation	other	3	2	0 yes
GP	M	18	U	GT3	T	2	1	services	services	other	mother	1	1	1 no
GP	M	16	R	GT3	T	2	1	other	other	course	mother	2	1	0 no
GP	M	17	R	GT3	T	2	1	other	other	course	mother	1	1	0 no
GP	M	17	U	LE3	T	1	1	health	other	course	mother	2	1	1 no
GP	F	17	U	LE3	T	4	2	teacher	services	reputation	mother	1	4	0 no
GP	M	19	U	LE3	A	4	3	services	at_home	reputation	mother	1	2	0 no
GP	M	18	U	GT3	T	2	1	other	other	home	mother	1	2	0 no
GP	F	17	U	LE3	T	2	2	services	services	course	father	1	4	0 no
GP	F	18	U	GT3	T	4	3	services	other	home	father	1	2	0 no
GP	M	18	U	GT3	T	4	3	teacher	other	course	mother	1	2	0 no
GP	M	18	R	GT3	T	3	2	other	other	course	mother	1	3	0 no
GP	F	17	U	GT3	T	3	3	other	other	home	mother	1	3	0 no
GP	F	18	U	GT3	T	2	2	at_home	services	home	mother	1	3	0 no

GP	M	18	R	LE3	A	3	4	other	other	reputation	mother	2	2	0 no
GP	M	17	U	GT3	T	3	1	services	other	other	mother	1	2	0 no
GP	F	18	R	GT3	T	4	4	teacher	other	reputation	mother	2	2	0 no
GP	M	18	U	GT3	T	4	2	health	other	reputation	father	1	2	0 no
GP	F	18	R	GT3	T	2	1	other	other	reputation	mother	2	2	0 no
GP	F	19	U	GT3	T	3	3	other	services	home	other	1	2	2 no
GP	F	18	U	GT3	T	2	3	other	services	reputation	father	1	4	0 no
GP	F	18	U	LE3	T	1	1	other	other	home	mother	2	2	0 no
GP	M	17	R	GT3	T	1	2	at_home	at_home	home	mother	1	2	0 no
GP	F	17	U	GT3	T	2	4	at_home	health	reputation	mother	2	2	0 no
GP	F	17	U	LE3	T	2	2	services	other	course	mother	2	2	0 yes
GP	F	18	R	GT3	A	3	2	other	services	home	mother	2	2	0 no
GP	M	18	U	GT3	T	4	4	teacher	services	home	mother	2	1	0 no
GP	F	18	U	GT3	T	4	4	health	health	reputation	father	1	2	1 yes
GP	M	18	U	LE3	T	4	3	teacher	services	course	mother	2	1	0 no
GP	M	17	U	LE3	A	4	1	services	other	home	mother	2	1	0 no
GP	M	17	U	LE3	A	3	2	teacher	services	home	mother	1	1	1 no
GP	F	18	R	LE3	T	1	1	at_home	other	reputation	mother	2	4	0 no
GP	F	18	U	GT3	T	1	1	other	other	home	mother	2	2	0 yes
GP	F	17	U	GT3	T	2	2	other	other	course	mother	1	2	0 no
GP	M	17	U	GT3	T	1	1	other	other	reputation	father	1	2	0 no
GP	F	18	U	GT3	T	2	2	at_home	at_home	other	mother	1	3	0 no
GP	F	17	U	GT3	T	1	1	services	teacher	reputation	mother	1	3	0 no
GP	M	18	U	GT3	T	2	1	services	services	reputation	mother	1	3	0 no
GP	M	18	U	LE3	A	4	4	teacher	teacher	reputation	mother	1	2	0 no
GP	M	18	U	GT3	T	4	2	teacher	other	home	mother	1	2	0 no
GP	F	17	U	GT3	T	4	3	health	services	reputation	mother	1	3	0 no
GP	F	18	U	LE3	T	2	1	services	at_home	reputation	mother	1	2	1 no
GP	F	17	R	LE3	T	3	1	services	other	reputation	mother	2	4	0 no
GP	M	18	R	LE3	T	3	2	services	other	reputation	mother	2	3	0 no
GP	M	17	U	GT3	T	3	3	health	other	home	mother	1	1	0 no
GP	F	19	U	GT3	T	4	4	health	other	reputation	other	2	2	0 no
GP	F	18	U	LE3	T	4	3	other	other	home	other	2	2	0 no
GP	F	18	U	GT3	T	4	3	other	other	reputation	father	1	4	0 no
GP	M	18	U	LE3	T	4	4	teacher	teacher	home	mother	1	1	0 no
GP	F	18	U	LE3	A	4	4	health	other	home	mother	1	2	0 no
GP	M	17	U	LE3	T	4	4	other	teacher	home	father	2	1	0 no
GP	F	17	U	GT3	T	4	2	other	other	reputation	mother	2	3	0 no
GP	F	17	U	GT3	T	3	2	health	health	reputation	father	1	4	0 no
GP	M	19	U	GT3	T	3	3	other	other	home	other	1	2	1 no
GP	F	18	U	GT3	T	2	4	services	at_home	reputation	other	1	2	1 no
GP	M	20	U	GT3	A	3	2	services	other	course	other	1	1	0 no
GP	M	19	U	GT3	T	4	4	teacher	services	reputation	other	2	1	1 no
GP	M	19	R	GT3	T	3	3	other	services	reputation	father	1	2	1 no
GP	F	19	U	LE3	T	1	1	at_home	other	reputation	other	1	2	1 yes
GP	F	19	U	LE3	T	1	2	services	services	home	other	1	2	1 no
GP	F	19	U	GT3	T	2	1	at_home	other	other	other	3	2	0 no
GP	M	19	U	GT3	T	1	2	other	services	course	other	1	2	1 no
GP	F	19	U	LE3	T	3	2	services	other	reputation	other	2	2	1 no
GP	F	19	U	GT3	T	1	1	at_home	health	home	other	1	3	2 no
GP	F	19	R	GT3	T	2	3	other	other	reputation	other	1	3	1 no
GP	F	18	U	GT3	T	2	1	services	other	course	mother	2	2	0 no
GP	F	18	U	GT3	T	4	3	other	other	course	mother	1	3	0 no
GP	F	17	R	GT3	T	3	4	at_home	services	course	father	1	3	0 no
GP	F	18	U	GT3	T	4	4	teacher	other	course	mother	1	2	0 no
GP	F	17	U	GT3	A	4	3	services	services	course	mother	1	2	0 no
GP	F	17	U	GT3	T	2	2	other	other	course	mother	1	2	0 no
GP	F	17	R	LE3	T	2	2	services	services	course	mother	1	3	0 no
GP	F	17	U	GT3	T	3	1	services	services	course	father	1	3	0 no
GP	F	17	U	LE3	T	0	2	at_home	at_home	home	father	2	3	0 no
GP	M	18	U	GT3	T	4	4	other	other	course	mother	1	3	0 no
GP	M	17	U	GT3	T	3	3	other	services	reputation	mother	1	1	0 no
GP	M	17	R	GT3	T	2	2	services	other	course	mother	4	1	0 no
GP	F	17	U	GT3	T	4	4	teacher	services	course	mother	1	3	0 no
GP	F	17	U	GT3	T	4	4	teacher	teacher	course	mother	2	3	0 no
GP	M	18	U	LE3	T	2	2	other	other	course	mother	1	4	0 no
GP	F	17	R	GT3	T	2	4	at_home	other	course	father	1	3	0 no
GP	F	18	U	GT3	T	3	3	services	services	home	mother	1	2	0 no
GP	F	18	U	LE3	T	2	2	other	other	home	other	1	2	0 no
GP	F	18	R	GT3	T	2	2	at_home	other	course	mother	2	4	0 no
GP	F	17	U	GT3	T	3	4	services	other	course	mother	1	3	0 no
GP	F	19	R	GT3	A	3	1	services	at_home	home	other	1	3	1 no
GP	F	17	U	GT3	T	3	2	other	other	home	mother	1	2	0 no
GP	F	18	U	LE3	T	3	3	services	services	home	mother	1	4	0 no
GP	F	17	R	GT3	A	3	2	other	other	home	mother	1	2	0 no
GP	F	19	U	GT3	T	2	1	services	services	home	other	1	3	1 no
GP	M	18	U	GT3	T	4	4	teacher	services	home	father	1	2	1 no
GP	M	18	U	LE3	T	3	4	services	other	home	mother	1	2	0 no
GP	F	17	U	GT3	A	2	2	at_home	at_home	home	father	1	2	1 no
GP	F	18	U	GT3	T	2	3	at_home	other	course	mother	1	3	0 no
GP	F	18	U	GT3	T	3	2	other	services	other	mother	1	3	0 no
GP	M	18	R	GT3	T	4	3	teacher	services	course	mother	1	3	0 no
GP	M	18	U	GT3	T	4	3	teacher	other	course	mother	1	3	0 no
GP	F	17	U	GT3	T	4	3	health	other	reputation	mother	1	3	0 no
MS	M	18	R	GT3	T	3	2	other	other	course	mother	2	1	1 no
MS	M	19	R	GT3	T	1	1	other	services	home	other	3	2	3 no
MS	M	17	U	GT3	T	3	3	health	other	course	mother	2	2	0 no
MS	M	18	U	LE3	T	1	3	at_home	services	course	mother	1	1	1 no
MS	M	19	R	GT3	T	1	1	other	other	home	other	3	1	1 no

MS	M	17	R	GT3	T	4	3	services	other	home	mother	2	2	0	no
MS	F	18	U	GT3	T	3	3	services	services	course	father	1	2	0	no
MS	F	17	R	GT3	T	4	4	teacher	services	other	father	2	2	0	no
MS	F	17	U	LE3	A	3	2	services	other	reputation	mother	2	2	0	no
MS	M	18	U	LE3	T	1	1	other	services	home	father	2	1	0	no
MS	F	18	U	LE3	T	1	1	at_home	services	course	father	2	3	0	no
MS	F	18	R	LE3	A	1	4	at_home	other	course	mother	3	2	0	no
MS	M	18	R	LE3	T	1	1	at_home	other	other	mother	2	2	1	no
MS	F	18	U	GT3	T	3	3	services	services	other	mother	2	2	0	no
MS	F	17	U	LE3	T	4	4	at_home	at_home	course	mother	1	2	0	no
MS	F	17	R	GT3	T	1	2	other	services	course	father	2	2	0	no
MS	M	18	R	GT3	T	1	3	at_home	other	course	mother	2	2	0	no
MS	M	18	U	LE3	T	4	4	teacher	services	other	mother	2	3	0	no
MS	F	17	R	GT3	T	1	1	other	services	reputation	mother	3	1	1	no
MS	F	18	U	GT3	T	2	3	at_home	services	course	father	2	1	0	no
MS	F	18	R	GT3	T	4	4	other	teacher	other	father	3	2	0	no
MS	F	19	U	LE3	T	3	2	services	services	home	other	2	2	2	no
MS	M	18	R	LE3	T	1	2	at_home	services	other	father	3	1	0	no
MS	F	17	U	GT3	T	2	2	other	at_home	home	mother	1	3	0	no
MS	F	17	R	GT3	T	1	2	other	other	course	mother	1	1	0	no
MS	F	18	R	LE3	T	4	4	other	other	reputation	mother	2	3	0	no
MS	F	18	R	GT3	T	1	1	other	other	home	mother	4	3	0	no
MS	F	20	U	GT3	T	4	2	health	other	course	other	2	3	2	no
MS	F	18	R	LE3	T	4	4	teacher	services	course	mother	1	2	0	no
MS	F	18	U	GT3	T	3	3	other	other	home	mother	1	2	0	no
MS	F	17	R	GT3	T	3	1	at_home	other	reputation	mother	1	2	0	no
MS	M	18	U	GT3	T	4	4	teacher	teacher	home	father	1	2	0	no
MS	M	18	R	GT3	T	2	1	other	other	other	mother	2	1	0	no
MS	M	17	U	GT3	T	2	3	other	services	home	father	2	2	0	no
MS	M	19	R	GT3	T	1	1	other	services	other	mother	2	1	1	no
MS	M	18	R	GT3	T	4	2	other	other	home	father	2	1	1	no
MS	F	18	R	GT3	T	2	2	at_home	other	other	mother	2	3	0	no
MS	F	18	R	GT3	T	4	4	teacher	at_home	reputation	mother	3	1	0	no
MS	F	19	R	GT3	T	2	3	services	other	course	mother	1	3	1	no
MS	F	18	U	LE3	T	3	1	teacher	services	course	mother	1	2	0	no
MS	F	18	U	GT3	T	1	1	other	other	course	mother	2	2	1	no
MS	M	20	U	LE3	A	2	2	services	services	course	other	1	2	2	no
MS	M	17	U	LE3	T	3	1	services	services	course	mother	2	1	0	no
MS	M	21	R	GT3	T	1	1	other	other	course	other	1	1	3	no
MS	M	18	R	LE3	T	3	2	services	other	course	mother	3	1	0	no
MS	M	19	U	LE3	T	1	1	other	at_home	course	father	1	1	0	no

Attribute 17	Attribute 18	Attribute 19	Attribute 20	Attribute 21	Attribute 22	Attribute 23	Attribute 24	Attribute 25	Attribute 26	Attribute 27	Attribute 28	Attribute 29	Attribute 30			
famsup	paid	activities	nursery	higher	internet	romantic	famrel	freetime	goout	Dalc	Walc	health	absences	G1	G2	G3
no	no	no	yes	yes	no	no	4	3	4	1	1	3	6	5	6	6
yes	no	no	no	yes	yes	no	5	3	3	1	1	3	4	5	5	6
no	yes	no	yes	yes	yes	no	4	3	2	2	3	3	10	7	8	10
yes	yes	yes	yes	yes	yes	yes	3	2	2	1	1	5	2	15	14	15
yes	yes	no	yes	yes	no	no	4	3	2	1	2	5	4	6	10	10
yes	yes	yes	yes	yes	yes	no	5	4	2	1	2	5	10	15	15	15
no	no	no	yes	yes	yes	no	4	4	4	1	1	3	0	12	12	11
yes	no	no	yes	yes	no	no	4	1	4	1	1	1	6	6	5	6
yes	yes	no	yes	yes	yes	no	4	2	2	1	1	1	0	16	18	19
yes	yes	yes	yes	yes	yes	no	5	5	1	1	1	5	0	14	15	15
yes	yes	no	yes	yes	yes	no	3	3	3	1	2	2	0	10	8	9
yes	no	yes	yes	yes	yes	no	5	2	2	1	1	4	4	10	12	12
yes	yes	yes	yes	yes	yes	no	4	3	3	1	3	5	2	14	14	14
yes	yes	no	yes	yes	yes	no	5	4	3	1	2	3	2	10	10	11
yes	no	no	yes	yes	yes	yes	4	5	2	1	1	3	0	14	16	16
yes	no	no	yes	yes	yes	no	4	4	4	1	2	2	4	14	14	14
yes	yes	yes	yes	yes	yes	no	3	2	3	1	2	2	6	13	14	14
yes	no	yes	yes	yes	no	no	5	3	2	1	1	4	4	8	10	10
yes	no	yes	yes	yes	yes	no	5	5	5	2	4	5	16	6	5	5
no	yes	yes	yes	yes	yes	no	3	1	3	1	3	5	4	8	10	10
no	no	no	yes	yes	yes	no	4	4	1	1	1	1	0	13	14	15
yes	yes	no	yes	yes	yes	no	5	4	2	1	1	5	0	12	15	15
no	no	yes	yes	yes	yes	no	4	5	1	1	3	5	2	15	15	16
yes	no	yes	yes	yes	yes	no	5	4	4	2	4	5	0	13	13	12
yes	yes	yes	yes	yes	yes	no	4	3	2	1	1	5	2	10	9	8
yes	yes	no	no	yes	yes	no	1	2	2	1	3	5	14	6	9	8
yes	yes	no	yes	yes	yes	no	4	2	2	1	2	5	2	12	12	11
no	yes	no	yes	yes	yes	no	2	2	4	2	4	1	4	15	16	15
yes	no	yes	yes	yes	yes	no	5	3	3	1	1	5	4	11	11	11
yes	yes	yes	yes	yes	yes	yes	4	4	5	5	5	5	16	10	12	11
yes	yes	no	no	yes	yes	no	5	4	2	3	4	5	0	9	11	12
yes	no	yes	yes	yes	yes	no	4	3	1	1	1	5	0	17	16	17
yes	no	yes	yes	yes	yes	yes	4	5	2	1	1	5	0	17	16	16
no	no	yes	no	yes	yes	no	5	3	2	1	1	2	0	8	10	12
yes	yes	no	no	yes	yes	no	5	4	3	1	1	5	0	12	14	15
yes	no	yes	yes	yes	no	no	3	5	1	1	1	5	0	8	7	6
yes	no	yes	yes	yes	yes	no	5	4	3	1	1	4	2	15	16	18
yes	no	yes	yes	yes	yes	yes	2	4	3	1	1	5	7	15	16	15
yes	yes	yes	yes	yes	yes	no	4	3	2	1	1	5	2	12	12	11
yes	yes	yes	yes	yes	no	no	4	3	1	1	1	2	8	14	13	13
yes	no	yes	no	yes	yes	yes	3	3	3	1	2	3	25	7	10	11
yes	no	no	no	yes	yes	yes	5	4	3	2	4	5	8	12	12	12
yes	no	yes	yes	yes	yes	no	4	3	3	1	1	5	2	19	18	18
yes	no	no	yes	yes	yes	no	5	4	1	1	1	1	0	8	8	11
no	no	yes	yes	yes	yes	no	4	3	3	2	2	5	14	10	10	9
yes	yes	yes	yes	yes	yes	yes	5	2	2	1	1	5	8	8	8	6
yes	no	no	yes	yes	yes	no	2	3	5	1	4	3	12	11	12	11
no	no	yes	yes	yes	yes	no	4	2	2	1	1	2	4	19	19	20
yes	yes	no	yes	yes	no	no	4	3	3	2	2	5	2	15	15	14
yes	no	yes	no	yes	yes	no	4	4	4	1	1	3	2	7	7	7
yes	yes	no	yes	yes	yes	no	4	3	3	2	3	4	2	12	13	13
yes	yes	no	yes	yes	yes	no	4	3	3	1	1	5	2	11	13	13
no	no	no	yes	yes	no	no	5	5	5	3	4	5	6	11	11	10
yes	yes	no	yes	yes	yes	no	3	3	4	2	3	5	0	8	10	11
no	yes	no	yes	yes	yes	no	5	3	4	4	4	1	6	10	13	13
no	yes	yes	yes	yes	yes	yes	5	3	4	1	1	2	8	8	9	10
yes	yes	yes	yes	yes	yes	no	4	3	2	1	1	1	0	14	15	15
yes	no	yes	yes	yes	no	no	3	2	2	1	1	5	4	14	15	15
yes	no	yes	yes	yes	yes	no	4	3	2	1	1	5	2	9	10	9
yes	no	no	yes	yes	yes	no	4	2	3	1	1	5	2	15	16	16
yes	no	yes	yes	yes	no	no	2	4	4	2	3	4	6	10	11	11
yes	no	yes	no	yes	yes	yes	5	5	5	5	5	5	6	10	8	11
no	no	yes	yes	yes	yes	no	4	4	3	1	1	1	4	8	10	9
yes	yes	yes	yes	yes	yes	no	3	4	4	2	4	4	2	10	9	9
no	no	yes	yes	yes	yes	yes	4	4	4	2	4	2	0	10	10	10
yes	no	yes	yes	yes	yes	no	5	4	3	1	2	1	2	16	15	15
yes	no	yes	no	yes	yes	yes	1	3	3	5	5	3	4	13	13	12
yes	yes	no	yes	yes	yes	no	4	3	3	1	2	5	4	7	7	6
yes	yes	no	yes	yes	yes	no	4	1	3	1	3	4	2	8	9	8
yes	no	no	no	yes	yes	no	4	4	2	2	3	3	12	16	16	16
yes	yes	no	yes	yes	yes	no	4	3	2	1	1	5	0	13	15	15
no	no	no	yes	yes	yes	no	3	3	3	1	1	3	0	10	10	10
yes	no	no	no	yes	yes	yes	3	3	4	2	4	5	2	8	6	5
no	no	yes	yes	yes	no	no	5	3	2	2	2	5	2	12	12	14
yes	yes	yes	yes	yes	yes	no	4	3	3	2	4	5	54	11	12	11
yes	yes	yes	yes	yes	yes	no	4	3	3	2	3	5	6	9	9	10
no	no	yes	yes	yes	yes	no	3	4	3	1	1	1	8	11	11	10
no	yes	no	yes	yes	yes	yes	5	2	3	1	3	3	0	11	11	11
yes	no	yes	yes	no	yes	no	4	5	1	1	1	3	2	8	8	10
yes	no	no	yes	yes	yes	no	2	4	3	1	2	3	12	5	5	5
yes	yes	yes	no	yes	yes	yes	3	2	2	1	3	3	2	10	12	12
no	yes	no	no	yes	yes	no	5	3	2	1	2	5	4	11	10	11
yes	yes	no	yes	yes	yes	no	4	4	4	1	1	5	10	7	6	6
no	yes	yes	yes	yes	yes	no	5	3	3	1	3	4	4	15	15	15
yes	no	yes	no	yes	yes	no	4	3	2	2	3	4	2	9	10	10
no	yes	no	yes	yes	yes	yes	4	4	4	2	3	5	6	7	9	8
yes	no	no	yes	yes	no	no	4	3	4	1	2	2	4	8	7	6

yes	no	yes	yes	yes	yes	no	5	3	3	1	3	1	4	13	14	14
no	yes	yes	no	yes	yes	no	4	4	2	1	1	3	12	11	10	10
yes	no	no	yes	yes	no	no	4	1	3	3	5	5	18	8	6	7
yes	yes	no	yes	yes	yes	yes	4	3	3	1	3	4	0	7	7	8
no	yes	yes	yes	yes	yes	no	4	5	5	1	3	1	4	16	17	18
yes	no	no	yes	yes	no	no	3	3	3	2	3	2	4	7	6	6
yes	yes	yes	yes	yes	yes	no	5	3	3	1	1	1	0	11	10	10
yes	no	yes	yes	yes	yes	no	4	3	4	1	1	4	6	11	13	14
yes	yes	yes	yes	yes	yes	no	3	1	2	1	1	1	2	7	10	10
yes	no	yes	no	yes	yes	no	3	3	3	1	1	4	2	11	15	15
yes	yes	no	yes	yes	no	yes	4	3	5	1	1	5	2	8	9	10
no	no	yes	no	yes	yes	no	5	3	4	1	2	1	6	11	14	14
yes	yes	no	yes	yes	yes	no	5	3	5	1	1	3	0	7	9	8
yes	yes	yes	yes	yes	yes	no	4	5	5	5	5	4	14	7	7	5
yes	no	yes	yes	yes	yes	yes	4	4	3	1	1	4	0	16	17	17
yes	no	yes	no	yes	yes	no	5	3	3	1	1	5	4	10	13	14
yes	yes	no	yes	yes	yes	no	4	3	5	1	1	2	26	7	6	6
yes	yes	yes	yes	yes	yes	no	5	4	4	1	1	1	0	16	18	18
no	no	no	yes	yes	no	no	4	3	3	1	1	4	10	10	11	11
yes	yes	no	yes	yes	yes	no	5	1	2	1	1	3	8	7	8	8
yes	no	yes	yes	yes	yes	no	5	3	3	1	1	5	2	16	18	18
yes	yes	yes	yes	yes	yes	yes	1	3	5	3	5	1	6	10	13	13
yes	yes	yes	yes	yes	yes	yes	5	4	5	1	1	4	4	14	15	16
no	no	yes	yes	yes	yes	no	5	5	3	1	1	4	6	18	19	19
yes	no	yes	yes	yes	yes	no	4	1	2	1	1	2	0	7	10	10
no	no	yes	yes	yes	yes	no	3	1	2	1	1	5	6	10	13	13
no	no	no	yes	yes	yes	no	3	5	2	1	1	3	10	18	19	19
no	no	yes	yes	yes	yes	yes	5	4	2	1	1	5	8	9	9	9
yes	no	yes	yes	yes	yes	no	5	4	4	1	2	5	2	15	15	16
yes	no	yes	yes	yes	no	no	4	4	3	1	1	2	2	11	13	14
no	no	yes	yes	yes	yes	no	5	4	2	1	1	5	0	13	14	13
yes	no	yes	yes	yes	yes	no	5	2	4	1	4	5	20	9	7	8
no	no	no	yes	yes	yes	no	3	4	3	1	2	4	6	14	13	13
no	no	no	no	yes	yes	no	3	2	3	1	2	1	2	16	15	15
yes	yes	yes	yes	yes	yes	no	5	5	4	1	2	5	6	16	14	15
yes	yes	yes	yes	yes	yes	yes	4	2	2	1	2	5	2	13	13	13
yes	no	yes	yes	yes	yes	no	3	4	4	1	4	5	18	14	11	13
no	yes	no	yes	yes	yes	yes	5	4	4	1	1	5	0	8	7	8
no	no	no	yes	yes	yes	no	5	5	5	3	2	5	0	13	13	12
no	no	yes	yes	yes	yes	yes	5	3	2	1	1	1	0	7	10	11
yes	no	no	no	no	no	no	3	4	2	1	1	5	2	7	8	9
yes	no	yes	yes	yes	yes	no	3	3	3	1	2	4	0	7	4	0
no	yes	yes	yes	yes	yes	no	3	5	5	2	5	4	8	18	18	18
yes	no	no	yes	yes	yes	yes	4	2	2	2	2	5	0	12	0	0
yes	no	yes	no	yes	yes	yes	4	3	3	1	2	4	0	8	0	0
yes	no	no	yes	yes	yes	yes	3	4	4	1	3	5	12	10	13	12
no	no	no	yes	yes	yes	no	3	2	1	1	4	5	16	12	11	11
yes	no	no	yes	yes	no	yes	5	3	3	1	1	5	0	9	0	0
yes	no	yes	yes	yes	yes	yes	4	3	3	1	1	5	0	11	0	0
no	no	no	yes	yes	no	no	5	4	5	2	4	5	0	10	0	0
yes	no	yes	no	yes	yes	yes	4	3	2	1	1	5	0	4	0	0
no	no	no	yes	yes	no	yes	4	4	4	1	3	5	0	14	12	12
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yes	yes	no	no	yes	yes	yes	3	2	2	4	2	5	10	14	12	11
no	no	yes	yes	yes	no	yes	3	2	2	1	1	3	4	7	7	9
yes	yes	yes	yes	no	yes	yes	4	3	3	2	3	3	3	14	12	12
no	no	yes	yes	yes	no	yes	3	4	3	1	1	3	8	13	11	11
no	no	yes	yes	yes	yes	no	3	5	5	1	3	1	14	6	5	5
no	no	no	yes	yes	yes	no	5	4	4	1	1	1	0	19	18	19
no	no	no	yes	yes	yes	no	4	3	2	1	2	4	2	8	8	10
yes	yes	no	no	yes	yes	yes	5	4	3	1	1	3	4	15	14	15
no	yes	yes	yes	yes	yes	no	5	4	3	3	4	2	4	8	9	10
no	yes	no	yes	yes	yes	yes	4	1	3	1	2	1	0	15	15	15
yes	yes	yes	no	yes	yes	no	4	5	4	2	3	1	17	10	10	10
no	yes	yes	no	yes	yes	no	3	2	4	1	4	2	4	15	14	14
no	no	yes	no	yes	yes	yes	4	4	3	1	3	5	5	7	6	7
no	no	yes	yes	yes	yes	no	4	4	3	1	1	3	2	11	11	10
no	no	no	yes	yes	no	no	4	3	2	1	3	5	0	6	5	0
no	yes	no	yes	yes	no	no	5	4	3	4	3	3	14	6	5	5
no	yes	no	yes	yes	no	no	5	3	3	1	3	4	2	10	9	10
yes	yes	yes	yes	yes	yes	yes	4	4	3	2	2	5	7	6	5	6
no	no	yes	no	yes	yes	no	5	4	2	1	2	5	0	7	5	0
yes	yes	no	yes	yes	yes	no	4	3	4	1	1	1	0	7	9	8
no	no	yes	yes	yes	no	no	1	1	1	1	1	5	0	6	5	0
yes	yes	no	yes	yes	no	no	5	5	4	4	5	4	11	9	9	9
no	no	no	no	yes	yes	no	2	4	5	3	4	2	3	14	16	16
no	no	no	no	yes	no	no	5	5	3	3	3	3	3	10	8	7
no	no	no	no	yes	yes	no	4	4	1	3	4	5	0	11	12	10
no	no	no	yes	yes	yes	no	3	2	3	3	3	5	5	8	9	9

A.2 Fully Scrubbed Dataset

Attribute 1 School	Attribute 2 Sex	Attribute 3 age	Attribute 4 Address	Attribute 5 FamSize	Attribute 6 Pstatus	Attribute 7 Medu	Attribute 8 Fedu	Attribute 12 Guardian	Attribute 13 traveltime	Attribute 14 studytime	Attribute 15 failures	Attribute 16 SchoolSup	Attribute 17 FamSup	Attribute 18 Paid	Attribute 19 Activities	Attribute 20 Nursery	Attribute 21 Higher	Attribute 22 Internet
1	1	18	1	1	1	4	4	1	2	2	0	1	0	0	0	1	1	0
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1	1	16	1	1	0	3	3	0	1	2	0	0	1	1	0	1	1	0
1	0	16	1	0	0	4	3	1	1	2	0	0	1	1	1	1	1	1
1	0	16	1	0	0	2	2	1	1	2	0	0	0	0	0	1	1	1
1	1	17	1	1	1	4	4	1	2	2	0	1	1	0	0	1	1	0
1	0	15	1	0	1	3	2	1	1	2	0	0	1	1	0	1	1	1
1	0	15	1	1	0	3	4	1	1	2	0	0	1	1	1	1	1	1
1	1	15	1	1	0	4	4	1	1	2	0	0	1	1	0	1	1	1
1	1	15	1	1	0	2	1	0	3	3	0	0	1	0	1	1	1	1
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1	1	16	1	1	0	4	4	1	1	3	0	0	1	1	1	1	1	1
1	1	16	1	1	0	3	3	1	3	2	0	1	1	0	1	1	1	0
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Attribute 23 Romantic	Attribute 24 famrel	Attribute 25 freetime	Attribute 26 goout	Attribute 27 Dalc	Attribute 28 Walc	Attribute 29 health	Attribute 30 absences	Success
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0	2	3	3	2	2	2	8	0
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0	3	4	4	3	3	1	2	0
0	5	4	5	1	2	5	0	0
0	4	4	2	1	2	5	0	0
0	3	3	2	1	1	3	0	0
0	4	3	2	1	1	5	2	0
1	3	3	2	2	1	5	0	0
0	4	5	5	2	5	5	0	0
1	2	3	5	2	5	4	0	0
1	4	4	4	3	5	5	6	0
1	4	5	4	1	1	4	0	0
1	4	2	1	1	1	4	0	0
0	4	4	4	1	1	1	2	0
0	2	2	2	3	3	5	8	0
0	5	2	5	1	5	4	6	0
0	4	2	2	1	2	3	2	1
1	4	5	5	4	4	5	4	0
1	3	3	2	2	2	5	0	0
1	4	4	4	1	4	3	6	0
0	4	4	4	2	4	5	0	0
0	5	3	3	1	4	2	2	0
1	5	3	5	1	5	5	0	0
0	4	5	2	1	1	2	16	0
0	4	3	5	2	4	4	4	0
1	4	2	3	1	1	3	0	0
0	5	1	5	1	1	4	0	0
1	4	4	2	1	1	3	0	0
0	3	4	5	2	4	2	0	0
1	4	3	2	1	1	3	2	0
0	4	4	4	1	3	5	0	0
1	4	3	5	1	1	3	0	0
0	4	4	5	1	1	4	4	0
0	4	4	4	4	4	4	4	0
0	3	4	4	1	4	5	2	0
0	4	3	4	1	4	4	4	0
1	4	3	3	3	4	3	10	0
1	5	2	3	1	1	2	4	0
0	3	4	3	2	3	3	10	0
1	4	2	3	1	2	3	2	0
0	5	4	2	2	3	5	0	1
1	5	3	3	2	3	1	56	0
0	1	2	2	1	2	1	14	0
1	4	3	4	2	3	4	12	0
1	3	3	3	1	2	3	2	0
1	4	2	3	1	2	5	0	0
1	3	3	3	1	3	3	6	0
0	3	1	3	1	5	3	4	0
0	4	3	3	1	1	2	10	0
0	5	3	3	1	1	3	0	0
0	4	3	2	3	4	5	8	0
0	5	3	3	1	1	3	0	0
1	4	3	2	1	1	5	0	0
0	5	2	3	1	2	5	4	1
0	3	3	4	3	5	3	8	0
0	4	2	4	2	3	2	24	1
0	4	5	2	1	2	3	0	0
0	4	3	5	1	5	2	2	1
0	4	4	3	1	3	4	6	0
0	4	4	4	1	3	1	4	0
0	5	3	2	1	2	3	18	0
0	5	3	5	1	1	5	6	0
1	4	4	3	3	4	5	28	0
0	2	3	3	2	2	4	5	0
1	1	3	2	1	1	1	10	0
0	4	3	2	1	4	5	6	0
1	4	4	2	1	1	4	6	0
1	5	3	5	4	5	3	13	0
0	3	3	4	1	1	4	0	0
0	4	4	4	2	4	5	15	0
0	5	2	1	1	2	3	12	0
0	4	4	4	1	3	1	2	0
1	3	4	5	2	4	1	22	0
0	3	2	4	2	4	4	13	0
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0	4	3	3	1	1	4	4	0
0	4	2	5	1	2	5	2	0
1	4	3	4	1	1	5	0	0
0	2	3	1	1	1	3	2	1
0	3	3	3	5	5	4	0	0
0	5	3	2	1	1	5	0	0
1	5	3	3	1	1	4	16	0
0	5	3	4	1	3	3	10	1
0	5	3	3	1	3	3	2	0
1	4	3	2	4	5	3	14	0
1	3	2	3	1	2	3	10	0
1	3	2	3	1	2	3	14	0
0	4	5	2	1	1	1	4	0
1	4	5	5	1	3	2	14	0
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0	3	4	2	1	1	5	18	0
1	5	3	3	1	3	2	10	0
1	4	4	2	5	5	4	4	0

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0	2	1	1	1	1	3	2	0
0	5	5	4	3	5	2	0	0
1	2	5	5	1	4	5	14	0
0	3	3	3	2	3	4	2	0
0	5	4	5	1	1	3	0	0
0	5	3	2	1	2	5	0	0
0	4	3	3	1	1	4	6	1
0	5	2	2	1	1	2	4	0
1	5	4	5	5	5	1	16	0
1	4	3	3	1	3	5	8	0
0	4	3	2	2	4	5	0	0
0	4	4	5	2	4	5	0	0
0	3	2	5	2	5	5	4	0
0	3	3	2	1	3	3	0	0
0	4	4	2	2	4	5	0	0
0	4	4	4	1	2	5	2	0
0	4	2	3	1	1	4	6	0
0	4	3	1	1	1	1	12	0
0	5	2	4	1	2	4	8	0
1	3	4	1	1	1	2	0	0
1	3	1	2	1	3	2	21	1
0	4	3	2	1	1	3	2	0
0	5	3	2	1	1	3	1	0
0	3	2	3	1	1	4	4	0
1	4	3	3	1	1	3	0	0
0	4	2	5	3	4	1	13	1
1	5	4	4	3	4	5	2	0
0	4	3	4	2	2	4	8	0
1	5	4	5	1	3	5	10	0
1	4	3	5	1	2	3	0	0
1	4	5	5	1	3	2	4	0
0	4	4	3	1	1	3	2	0
1	3	5	2	2	2	1	2	0
1	4	3	3	1	1	1	2	0
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1	4	1	1	1	1	5	75	0
0	3	2	4	1	4	3	22	0
1	2	4	4	1	1	4	15	0
0	4	2	3	1	2	1	8	0
1	4	5	4	2	4	5	30	0
0	4	4	4	3	4	3	19	0
0	5	2	2	1	1	3	1	0
0	5	4	4	1	1	4	4	0
0	5	4	5	1	2	5	4	0
0	4	3	3	1	2	4	2	0
0	4	3	3	1	2	2	5	1
0	4	3	3	1	1	3	6	0
0	4	2	4	1	3	2	6	0
0	5	4	3	1	1	2	9	0
1	4	3	2	1	4	5	11	0
0	4	2	2	1	2	3	0	0
1	5	4	3	1	1	5	12	0
0	3	1	2	1	1	3	6	1
0	5	4	2	1	1	4	8	0
0	4	4	3	1	3	5	4	0
0	4	3	3	1	1	3	0	0
1	1	4	2	2	2	1	5	1
1	4	2	4	1	1	4	14	0
0	4	1	1	2	2	5	0	0
0	4	3	3	1	1	3	0	0
0	5	2	2	1	2	5	0	1
1	4	5	3	1	2	5	0	0
0	5	3	3	1	2	1	0	0
1	4	3	4	1	1	5	9	0
0	4	3	4	2	5	5	0	0
0	4	4	4	3	3	5	2	0
1	5	2	2	1	2	5	23	0
1	4	2	2	1	1	3	12	0
0	3	3	2	2	2	3	3	0
0	3	4	3	2	3	5	1	0
0	3	3	3	2	3	2	0	1
0	4	3	3	2	2	3	3	0
0	4	3	5	3	5	5	3	0
0	4	4	5	5	5	4	8	0
0	5	4	4	1	3	4	7	0
1	4	3	3	1	2	4	4	0
0	4	5	5	2	4	5	2	0
1	4	4	3	1	1	5	7	0
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0	4	4	4	1	1	4	0	0
0	4	4	5	1	3	5	16	1
1	4	3	2	2	3	2	0	0
0	5	3	3	1	1	1	7	1
0	4	3	3	2	3	2	4	0
0	4	3	3	2	2	2	0	0
1	4	3	3	1	3	5	11	1
1	3	3	1	1	2	4	0	0
0	4	3	3	1	2	3	4	0
1	5	4	3	2	3	1	7	0
1	5	3	2	1	2	4	9	1
1	5	4	5	2	3	5	0	0
1	4	4	3	1	3	4	0	0

A.3 All Attribute Model

SUMMARY OUTPUT								
Regression Statistics								
Chi Square	59.2219681							
Residual Dev.	93.6340805							
# of iterations	21							
Observations	194							
	Coefficients	Standard Err	P-value	Odd Ratio	Lower 95%	Upper 95%	Lower 95%	Upper 95%
Intercept	-22.590802	16759.9808	0.99892453	1.545E-10	0	infinity	0	infinity
Sex	-0.198561	0.62489791	0.75067491	0.81990972	0.24090841	2.79048763	0.24090841	2.79048763
age	0.10862307	0.47577823	0.81940828	1.1147421	0.43872384	2.83241945	0.43872384	2.83241945
Address	-2.498225	1.03439901	0.01572889	0.08223083	0.01082811	0.62447739	0.01082811	0.62447739
FamSize	-0.2578775	0.67396103	0.70199441	0.77268992	0.20621895	2.89522228	0.20621895	2.89522228
Pstatus	1.32604478	0.91266005	0.14623905	3.76611807	0.62955879	22.529501	0.62955879	22.529501
Medu	0.94736796	0.43336149	0.0288089	2.57891291	1.10295733	6.02996292	1.10295733	6.02996292
Fedu	0.16607655	0.3504758	0.63559957	1.18066348	0.59401935	2.34666808	0.59401935	2.34666808
Guardian	-0.3639677	0.67934752	0.59212396	0.69491365	0.183514	2.63143409	0.183514	2.63143409
traveltime	-0.0004225	0.46375836	0.99927318	0.99957764	0.40277704	2.48066638	0.40277704	2.48066638
studytime	-0.0509228	0.36490831	0.88901582	0.95035201	0.46480841	1.94309939	0.46480841	1.94309939
failures	-0.9976019	0.87050899	0.25179581	0.36876271	0.06695275	2.03107327	0.06695275	2.03107327
SchoolSup	-22.039826	7446.61404	0.9976385	2.6806E-10	0	infinity	0	infinity
FamSup	-0.2981028	0.63606979	0.63931004	0.74222502	0.21335951	2.58201746	0.21335951	2.58201746
Paid	-1.7609025	0.71896762	0.014317	0.17188966	0.04200136	0.70345464	0.04200136	0.70345464
Activities	0.01026619	0.59243855	0.98617438	1.01031907	0.31635445	3.22658535	0.31635445	3.22658535
Nursery	0.22011269	0.87596521	0.8015975	1.24621716	0.22385706	6.93771839	0.22385706	6.93771839
Higher	19.3981926	16759.9789	0.99907652	265783505	0	infinity	0	infinity
Internet	1.67400812	1.04912229	0.11057204	5.33350233	0.68233551	41.6895303	0.68233551	41.6895303
Romantic	-1.9531982	0.9570602	0.04126762	0.14181978	0.0217313	0.92552448	0.0217313	0.92552448
famrel	0.10152241	0.3464433	0.76949012	1.10685472	0.56130324	2.18264796	0.56130324	2.18264796
freetime	0.01104283	0.3145849	0.97199771	1.01110403	0.54578386	1.87314328	0.54578386	1.87314328
goout	-0.0094339	0.31138781	0.9758307	0.99061044	0.53808281	1.8237138	0.53808281	1.8237138
Dalc	-0.4208046	0.61903313	0.49664553	0.65651836	0.19513039	2.20886323	0.19513039	2.20886323
Walc	-0.2453825	0.38539366	0.52431634	0.78240524	0.36760725	1.66524993	0.36760725	1.66524993
health	-0.1821153	0.21538265	0.39780774	0.83350524	0.54648002	1.27128341	0.54648002	1.27128341
absences	-0.0511148	0.07338313	0.48608676	0.95016963	0.82288152	1.09714741	0.82288152	1.09714741

A.4 80/20 Model

SUMMARY OUTPUT								
Regression Statistics								
Chi Square	32.8203345							
Residual Dev.	120.035714							
# of iterations	7							
Observations	194							
	Coefficients	Standard Err	P-value	Odd Ratio	Lower 95%	Upper 95%	Lower 95%	Upper 95%
Intercept	-5.0985131	1.33913961	0.00014049	0.00610582	0.00044245	0.08426003	0.00044245	0.08426003
Address	-1.0371442	0.65104361	0.11114925	0.35446552	0.09894746	1.26982337	0.09894746	1.26982337
Medu	1.10569525	0.31579776	0.00046304	3.02132431	1.62700844	5.61054284	1.62700844	5.61054284
Paid	-1.6263077	0.56098031	0.003743	0.19665435	0.06549321	0.59048771	0.06549321	0.59048771
Internet	1.48656847	0.82559088	0.07176413	4.4218956	0.87672674	22.3024572	0.87672674	22.3024572
Romantic	-1.558674	0.72242547	0.03096231	0.2104149	0.05106776	0.86697419	0.05106776	0.86697419

A.5 Overly Simplified Model

SUMMARY OUTPUT								
Regression Statistics								
Chi Square	23.1780316							
Residual Dev.	129.678017							
# of iterations	6							
Observations	194							
	Coefficients	Standard Err	P-value	Odd Ratio	Lower 95%	Upper 95%	Lower 95%	Upper 95%
Intercept	-4.7363619	1.05039966	6.5102E-06	0.0087705	0.00111924	0.06872677	0.00111924	0.06872677
Medu	1.0240872	0.29533454	0.00052523	2.78455255	1.56086809	4.96757731	1.56086809	4.96757731
Paid	-1.3961108	0.53909714	0.00960539	0.2475579	0.08605904	0.71212643	0.08605904	0.71212643

A.6 Tradespace Dataset

Project	Address	Medu	Fedu	Paid	Internet	Romantic	Health	Random Cost	Likelihood
195	1	1	0.6	0.25	1	1	0.2	$ 848,703.98	0.71
196	1	0.5	0.6	1	0.1	1	0.6	$ 671,011.28	0.64
197	1	0.25	0.2	1	0.1	1	0	$ 663,607.93	0.4575
198	0.2	0.5	0.4	0.25	1	1	0.4	$ 705,219.17	0.495
199	0.2	0.5	0.4	1	1	1	1	$ 726,929.33	0.705
200	1	0.75	1	1	1	0.2	1	$ 812,908.66	0.8975
201	1	0.75	0.2	1	1	1	0.6	$ 812,399.03	0.7775
202	1	1	0.6	1	1	0.2	0	$ 704,956.71	0.8
203	1	0.25	0.2	1	0.1	1	1	$ 692,491.15	0.5575
204	0.2	1	0.6	1	1	0.2	0.6	$ 762,837.59	0.78
205	1	1	1	1	1	0.2	0.4	$ 742,900.31	0.9
206	1	0.5	0.4	1	1	1	0.6	$ 616,057.84	0.745
207	1	0.5	0.4	1	1	1	1	$ 656,074.82	0.785
208	0.2	1	1	1	0.1	1	0.4	$ 813,257.06	0.725
209	1	0.75	0.4	1	1	1	0	$ 790,408.85	0.7475
210	1	1	0.6	1	1	0.2	0	$ 802,991.24	0.8
211	1	0.75	0.6	1	1	1	0.6	$ 749,564.23	0.8375
212	1	0.5	0.6	1	0.1	1	0.4	$ 632,341.14	0.62
213	1	0.5	0.4	1	1	1	0.6	$ 878,487.89	0.745
214	0.2	0.5	0.2	0.25	1	1	1	$ 782,339.66	0.525
215	1	0.25	0.2	0.25	0.1	0.2	1	$ 582,176.84	0.3675
216	1	0.5	0.6	0.25	1	1	0.4	$ 651,599.25	0.605
217	1	0.5	0.4	1	1	1	0.6	$ 810,250.07	0.745
218	1	1	1	0.25	1	1	1	$ 769,952.14	0.85
219	0.2	0.75	0.2	0.25	1	0.2	0.6	$ 588,585.22	0.5075
220	1	0.75	0.4	0.25	1	1	0.4	$ 572,788.92	0.6375
221	1	0.5	0.6	1	1	1	0.4	$ 818,059.77	0.755
222	1	0.5	0.2	1	1	0.2	0.4	$ 787,118.24	0.655
223	1	0.5	0.2	0.25	1	0.2	0.4	$ 605,505.18	0.505
224	1	1	0.6	0.25	1	0.2	0.4	$ 562,865.07	0.69
225	0.2	0.5	0.4	1	1	1	0	$ 789,187.01	0.605
226	1	1	1	0.25	1	0.2	0.2	$ 771,998.24	0.73
227	1	1	1	1	1	1	0	$ 676,399.84	0.9
228	1	0.25	0.2	1	1	1	1	$ 817,837.63	0.6925
229	1	0.75	0.4	0.25	1	0.2	0.2	$ 667,135.73	0.5775
230	1	0.5	0.4	1	1	0.2	0.6	$ 766,400.23	0.705
231	1	0.5	0.2	0.25	1	0.2	1	$ 760,461.07	0.565
232	0.2	0.5	0.2	0.25	0.1	1	0.4	$ 737,341.33	0.33
233	1	0.5	0.4	0.25	1	1	0.2	$ 683,505.53	0.555
234	1	1	0.6	0.25	1	0.2	1	$ 647,399.22	0.75
235	0.2	1	1	1	1	1	0.6	$ 748,725.77	0.88
236	1	1	0.6	0.25	1	1	0.4	$ 911,320.54	0.73
237	1	1	1	0.25	1	1	1	$ 701,466.11	0.85
238	1	0.5	0.2	0.25	1	1	0.6	$ 842,239.77	0.565
239	1	0.5	0.6	0.25	1	1	0.2	$ 751,156.68	0.585
240	1	0.75	0.2	0.25	1	0.2	0	$ 739,429.95	0.5275
241	0.2	0.75	0.6	0.25	1	0.2	1	$ 757,308.13	0.6075
242	1	0	0.4	1	1	1	1	$ 845,826.70	0.66
243	1	0.75	0.4	0.25	1	1	1	$ 842,502.38	0.6975
244	1	0.5	0.2	0.25	1	1	1	$ 855,037.31	0.605
245	0.2	0.5	0.2	0.25	0.1	1	0.4	$ 761,978.59	0.33
246	0.2	0.5	0.2	0.25	1	1	1	$ 709,475.80	0.525
247	1	0.25	0.2	0.25	1	1	1	$ 756,734.58	0.5425
248	1	1	0.4	1	1	1	0.6	$ 684,431.82	0.87
249	1	1	0.6	0.25	1	1	0	$ 748,472.45	0.69
250	1	0.5	0.2	0.25	1	1	0.6	$ 921,720.35	0.565
251	1	0.5	0.4	1	1	0.2	0.2	$ 748,184.26	0.665
252	1	1	0.6	1	1	0.2	0.2	$ 807,470.32	0.82
253	1	1	0.6	1	1	1	0.4	$ 899,774.94	0.88
254	0.2	0.75	0.4	0.25	0.1	1	0.4	$ 825,892.04	0.4225
255	1	0.75	0.6	0.25	0.1	1	0.6	$ 800,402.35	0.5525
256	1	0.5	0.4	1	1	0.2	0.4	$ 738,912.22	0.685
257	0.2	0.75	1	1	1	1	0	$ 671,937.89	0.7575
258	1	0.75	0.2	1	1	0.2	1	$ 635,091.50	0.7775
259	0.2	1	1	1	1	1	0.6	$ 804,980.09	0.88

260	1	1	0.4	1	1	0.2	1	$ 789,154.72	0.87
261	0.2	0.5	0.2	0.25	1	0.2	0.4	$ 863,143.88	0.425
262	1	0.5	0.6	1	1	0.2	0.2	$ 647,642.53	0.695
263	1	0.25	0.2	1	0.1	1	0.4	$ 662,105.73	0.4975
264	0.2	0.25	0.4	1	0.1	0.2	0	$ 729,972.63	0.3675
265	1	0.5	1	1	1	0.2	0	$ 817,274.82	0.735
266	1	0.5	0.4	1	1	0.2	1	$ 840,711.47	0.745
267	0.2	0.75	0.4	0.25	1	0.2	1	$ 701,781.60	0.5775
268	1	1	1	1	1	1	0.4	$ 808,751.95	0.94
269	1	1	1	0.25	1	0.2	0.6	$ 954,118.13	0.77
270	1	1	0.6	1	1	1	0	$ 1,057,437.19	0.84
271	1	1	0.2	1	1	0.2	1	$ 792,710.61	0.84
272	1	0.75	0.4	0.25	1	1	0.4	$ 583,420.19	0.6375
273	0.2	0.25	0.2	1	0.1	1	0.4	$ 624,375.47	0.4175
274	1	0.25	0.2	0.25	1	1	0.6	$ 943,990.25	0.5025
275	1	0.5	0.4	0.25	1	1	1	$ 754,230.97	0.635
276	1	0.25	0.2	1	1	1	0.6	$ 826,390.77	0.6525
277	1	0.5	0.4	1	1	1	0.2	$ 621,806.17	0.705
278	1	0.25	0.2	1	1	1	0.4	$ 803,329.86	0.6325
279	1	0.5	0.2	1	1	1	0.2	$ 864,353.90	0.675
280	1	1	1	1	1	1	0.2	$ 902,034.74	0.92
281	1	1	0.4	1	1	0.2	1	$ 1,151,468.01	0.87
282	1	1	0.6	1	1	1	0.4	$ 748,772.62	0.88
283	1	0.5	0.2	0.25	1	0.2	1	$ 703,479.78	0.565
284	0.2	0.75	0.2	1	0.1	1	0.4	$ 515,077.16	0.5425
285	0.2	0.75	0.4	1	1	1	0.6	$ 891,453.57	0.7275
286	1	0.75	0.6	1	1	1	1	$ 764,074.05	0.8775
287	1	1	0.6	1	1	1	0.4	$ 826,073.55	0.88
288	1	1	1	1	1	0.2	0	$ 657,850.66	0.86
289	1	1	1	0.25	1	0.2	0.6	$ 751,732.62	0.77
290	1	1	1	1	1	1	1	$ 933,813.84	1
291	1	1	0.4	1	1	1	0.4	$ 616,366.09	0.85
292	1	0.75	0.4	1	1	1	1	$ 691,194.96	0.8475
293	0.2	0.75	0.6	0.25	0.1	0.2	1	$ 1,049,803.50	0.4725
294	1	0.5	0.2	1	1	1	0	$ 828,505.86	0.655
295	1	1	0.6	1	1	0.2	1	$ 793,129.62	0.9
296	0.2	0.75	1	1	1	1	1	$ 899,153.92	0.8575
297	1	1	1	1	1	1	1	$ 1,076,922.77	1
298	1	1	0.6	1	1	0.2	1	$ 773,460.36	0.9
299	1	0.5	0.4	0.25	0.1	0.2	0.4	$ 660,683.55	0.4
300	0.2	0.5	0.4	1	1	1	0.4	$ 731,834.71	0.645
301	1	0.75	0.2	0.25	1	1	1	$ 739,866.80	0.6675
302	1	0	0.4	0.25	1	1	0.2	$ 758,573.03	0.43
303	1	1	1	0.25	1	1	0.4	$ 740,086.99	0.79
304	1	0.75	0.6	0.25	1	1	1	$ 859,586.33	0.7275
305	0.2	0.5	0.4	0.25	1	1	0.6	$ 723,349.31	0.515
306	1	1	1	1	1	1	0.6	$ 742,118.03	0.96
307	1	1	1	1	1	0.2	0.6	$ 700,641.86	0.92
308	1	0.5	0.4	0.25	1	1	1	$ 705,512.05	0.635
309	0.2	0.5	1	0.25	1	0.2	1	$ 816,854.32	0.605
310	1	0.75	0.6	0.25	1	1	0.6	$ 695,586.63	0.6875
311	0.2	0.5	0.4	0.25	0.1	1	0.6	$ 815,174.76	0.38
312	1	0.75	1	0.25	1	1	1	$ 827,577.63	0.7875
313	1	0.75	0.4	1	1	0.2	0.2	$ 713,122.21	0.7275
314	1	0.75	0.6	0.25	1	1	0	$ 581,158.63	0.6275
315	0.2	0.75	0.4	1	1	1	0.2	$ 646,134.30	0.6875
316	1	1	1	0.25	1	1	0.2	$ 656,459.14	0.77
317	1	0.75	1	0.25	1	0.2	1	$ 875,398.19	0.7475
318	1	0.5	0.4	0.25	1	0.2	0.6	$ 765,020.46	0.555
319	1	0.5	0.6	0.25	1	1	0.4	$ 779,143.14	0.605
320	1	0.75	0.4	0.25	1	0.2	0	$ 761,643.57	0.5575
321	0.2	1	0.6	0.25	1	0.2	0.6	$ 699,220.81	0.63
322	1	1	0.6	1	1	0.2	1	$ 977,518.02	0.9
323	1	1	0.6	1	1	0.2	0.6	$ 923,961.49	0.86

A.7 Cutoff Tradespace Dataset

Project	Address	Medu	Fedu	Paid	Internet	Romantic	Health	Random Cost	Likelihood
200	1	0.75	1	1	1	0.2	1	$ 812,908.66	0.8975
201	1	0.75	0.2	1	1	1	0.6	$ 812,399.03	0.7775
202	1	1	0.6	1	1	0.2	0	$ 704,956.71	0.8
204	0.2	1	0.6	1	1	0.2	0.6	$ 762,837.59	0.78
205	1	1	1	1	1	0.2	0.4	$ 742,900.31	0.9
207	1	0.5	0.4	1	1	1	1	$ 656,074.82	0.785
210	1	1	0.6	1	1	0.2	0	$ 802,991.24	0.8
211	1	0.75	0.6	1	1	1	0.6	$ 749,564.23	0.8375
218	1	1	1	0.25	1	1	1	$ 769,952.14	0.85
221	1	0.5	0.6	1	1	1	0.4	$ 818,059.77	0.755
227	1	1	1	1	1	1	0	$ 676,399.84	0.9
234	1	1	0.6	0.25	1	0.2	1	$ 647,399.22	0.75
235	0.2	1	1	1	1	1	0.6	$ 748,725.77	0.88
237	1	1	1	0.25	1	1	1	$ 701,466.11	0.85
248	1	1	0.4	1	1	1	0.6	$ 684,431.82	0.87
252	1	1	0.6	1	1	0.2	0.2	$ 807,470.32	0.82
253	1	1	0.6	1	1	1	0.4	$ 899,774.94	0.88
257	0.2	0.75	1	1	1	1	0	$ 671,937.89	0.7575
258	1	0.75	0.2	1	1	0.2	1	$ 635,091.50	0.7775
259	0.2	1	1	1	1	1	0.6	$ 804,980.09	0.88
260	1	1	0.4	1	1	0.2	1	$ 789,154.72	0.87
268	1	1	1	1	1	1	0.4	$ 808,751.95	0.94
269	1	1	1	0.25	1	0.2	0.6	$ 954,118.13	0.77
270	1	1	0.6	1	1	1	0	$ 1,057,437.19	0.84
271	1	1	0.2	1	1	0.2	1	$ 792,710.61	0.84
280	1	1	1	1	1	1	0.2	$ 902,034.74	0.92
281	1	1	0.4	1	1	0.2	1	$ 1,151,468.01	0.87
282	1	1	0.6	1	1	1	0.4	$ 748,772.62	0.88
286	1	0.75	0.6	1	1	1	1	$ 764,074.05	0.8775
287	1	1	0.6	1	1	1	0.4	$ 826,073.55	0.88
288	1	1	1	1	1	0.2	0	$ 657,850.66	0.86
289	1	1	1	0.25	1	0.2	0.6	$ 751,732.62	0.77
290	1	1	1	1	1	1	1	$ 933,813.84	1
291	1	1	0.4	1	1	1	0.4	$ 616,366.09	0.85
292	1	0.75	0.4	1	1	1	1	$ 691,194.96	0.8475
295	1	1	0.6	1	1	0.2	1	$ 793,129.62	0.9
296	0.2	0.75	1	1	1	1	1	$ 899,153.92	0.8575
297	1	1	1	1	1	1	1	$ 1,076,922.77	1
298	1	1	0.6	1	1	0.2	1	$ 773,460.36	0.9
303	1	1	1	0.25	1	1	0.4	$ 740,086.99	0.79
306	1	1	1	1	1	1	0.6	$ 742,118.03	0.96
307	1	1	1	1	1	0.2	0.6	$ 700,641.86	0.92
312	1	0.75	1	0.25	1	1	1	$ 827,577.63	0.7875
316	1	1	1	0.25	1	1	0.2	$ 656,459.14	0.77
322	1	1	0.6	1	1	0.2	1	$ 977,518.02	0.9
323	1	1	0.6	1	1	0.2	0.6	$ 923,961.49	0.86