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Real options analysis framework for agile projects

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***Abstract*—The literature proves that agile projects have a higher success rate in stakeholder satisfaction and overall success than projects managed with a plan-driven methodology such as waterfall. However, little corresponding literature examines whether that success extends to the target benefits. This study identifies the mechanisms—actions, decisions, or entities—that enable agile and plan-driven projects to deliver target benefits. It uses real options analysis to quantify and model the differences between project methods and builds a management decision-making framework. The framework includes real option types, mechanisms, and locations; project roles and processes; risk scores and failure rates; a computational model; and a binomial tree for visual analysis. The study contributes a novel framework to the project management literature on agile projects and benefits realization.**

***Index Terms*—Real options analysis, agile, risk failure rate, benefits realization.**

I. Introduction

BY initiating a project, organizations expect to realize a set of target benefits that are the reason for the investment and other tactical goals such as project efficiency [1]. There is proof that agile projects have a higher success rate in stakeholder satisfaction and overall success than projects managed with a plan-driven methodology such as waterfall [2, 3, 4]. However, little corresponding literature examines whether success with agile projects extends to the target benefits. In short, the two project approaches differ in planning and execution: plan-driven projects prefer a linear product development life cycle where an upfront plan defines the scope, schedule, and costs for delivery Lundin and Söderholm [5], and agile projects encourage an iterative and incremental life cycle, self-organizing teams, and evolutionary planning for product development [6, 7, 3].

Serrador and Pinto [3] proved that agile projects were successful at project efficiency, stakeholder satisfaction, and overall performance. Gemino et al. [4] determined that agile and plan-driven approaches have similar time, budget, and scope performance. Further, agile projects demonstrate a higher success rate in stakeholder satisfaction, which is attributed to successful communication. In a meta-analysis of 69 studies, [8] found that the cost-benefit of agile methods, as measured by return on investment, net present value, break-even point, and real options analysis, was on par with plan-driven methods.

The literature on the benefit realization of agile projects exists but is scarce in explaining the actions, decisions, or entities in agile projects that contribute to the target benefits. Marnewick and Marnewick [2] argues that agile projects' frequent and iterative delivery allows for earlier benefits than traditional methodologies. Moreover, the article states that benefits management is a continuous delivery cycle where benefits are inherently realized and provides empirical evidence.

This study analyzes the mechanisms agile projects use to deliver target benefits. "A mechanism is defined as an action, decision or entity that enables a real option" [9, p. 459]. Then, the study uses those mechanisms to compare the benefits realization between agile and plan-driven projects in a real options analysis framework. A real option is a right (but not an obligation) to invest in a real asset in the future [10].

This study contributes a novel framework that project owners and managers can use to determine the mechanisms within a project that can be optimized to deliver the target benefits. It furthermore contributes to the theory of benefits realization in projects.

The paper is structured as follows. Section Two provides a literature review and describes the related research. Section Three includes the conceptual framework and a description of the research methodology. Section Four describes the relevant project frameworks, and Section Five describes the characteristics of the real options. Section Six applies the method to an illustrative comparison case. Section Six also provides conclusions, including the study's contribution, implications, limitations, and considerations for future research.

II. Literature Review

A. Projects

Projects are "... a unique, transient endeavor, undertaken to achieve planned objectives, which could be defined in terms of outputs, outcomes or benefits" [11]. An important measure of project success is whether the project contributes the expected benefits to the sponsoring organization [1, 12]. Direct and indirect links between project and corporate success require "an effective benefits delivery and management process that involves the mutual co-operation of project management and line management functions" [12].

Project management success, also known as project efficiency or the iron triangle, is the performance of delivering on time, within budget, and to quality. It requires focusing on risk management, change control, limiting project duration, and assigning clear responsibilities [12]. However, delivering the right functionality is more important than finishing rigidly on time and within budget [13, 14].

B. Project Methodologies

Terminology within project management is evolving, so terms such as methodology, approach, framework, and life cycle are used inconsistently between project management standards, literature, and practitioners [15, 16]. This research synthesizes the terminology for project methodology and life cycle. A project methodology is a collection of processes, tools, techniques, methods, capability profiles, knowledge areas, and related understanding used to manage a project life cycle [15]. The term methodology is interchangeable with project approach or framework. A life cycle is a series of organizing phases or stages that a project passes through systematically to transform an idea at the start to reality at completion [11, 16].

Plan-driven methodologies, also known as traditional or waterfall methodologies, are linear life cycles that follow a stage-gate or phased approach. They create an upfront plan where the time is limited, the scope is defined, and the costs are estimated [5]. The output from one phase of the project is built on in the next phase, and the output is delivered in a single release.

Agile methodologies follow the four values and 12 principles described in the Agile Manifesto, a framework for managing projects in a flexible way that responds to dynamic situations [6, 7, 3]. Agile methodologies generally encourage iterative and incremental development life cycles, self-organizing teams, and evolutionary product development. The output is delivered in small, frequent releases to create more value than large mega-releases [17]. Multiple methodologies ascribe to the values and principles of the Agile Manifesto, such as Scrum, Extreme Programming (XP), Lean, and Kanban. They each have their own rules, events, and practices [18].

Hybrid methodologies mix elements of linear, iterative, incremental, and evolutionary life cycles or traditional and agile methodologies.

C. Real Options Analysis

A real option is the right to invest in a real asset in the future without an obligation to make the investment. The cost of an option on an asset is small relative to the cost of the total asset. Thus, by investing in an option to the asset instead of the total asset, an organization can defer investments until the uncertainty is reduced. Resources can be deployed on other opportunities. Switch, change scale, stage, abandon, and strategic growth are types of real options; the types are described in Table I.

TABLE I
REAL OPTIONS TYPES

Types	Description	References
Switch	Put asset to a different purpose from the original intentions.	[19, 20, 21]
Change scale: expand	Change the scope by reallocating resources. Resources can be expanded or systems can be scaled up with relative ease.	[20]
Change scale: reduce	Change the scope by reallocating resources. Resources can be reduced or systems scaled down with relative ease.	[19, 21]
Stage	When structured as a series of incremental outlays, terminate the project should conditions become unfavorable. This option overlaps with other options such as abandon, change scale, and strategic growth.	[21, 19, 20]
Abandon	If possible, without negative consequences, discontinue the project prior to completion and redeploy the remaining resources.	[19, 20, 21]
Strategic growth	Pursue a variety of follow-on investments when the initial baseline opens the opportunity to do so. This differs from other options, which reduce or limit potential losses from unfavorable circumstances, by increasing gains in the event of favorable circumstances.	[19, 21]
Defer with revenue leakage	Delay the decision on whether and how to invest for some period but imperil some aspect of the potential benefits.	[20]
Defer	Delay the decision on whether and how to invest for some period without imperiling the potential benefits	[19, 20, 21]

Real options analysis (ROA) "is most valuable when there is a high uncertainty with the underlying asset value and management has significant flexibility to change the course of the project in a favorable direction and is willing to exercise the options" [20, p. 94]. In a real options model, project opportunity is equated with the flexibility to acquire a payoff by making an investment before a project is completed [22].

Real options theory is derived from finance theories that value financial options contracts. "A financial option contract conveys the right, but not the obligation, on the purchaser to either buy or sell an underlying asset at some point in the future" [10, p. 2].

D. Real Options Use in Projects

Real options have been applied in many project situations, including the portfolio and project initiation [23], continuation and termination of projects [19], valuation of projects [24], planning and risk management [25, 26, 27], and performance monitoring [28]. Racheva et al. [29] conceptualized the use of real options within an agile project as a quantitative approach to determine when and how much to invest in software functionality.

Real options in project literature are based on different models. One model is based on defining the location where the real option occurs: "in" or "on" the project [9, 30]. Real options "in" projects are decisions or actions taken within the project, such as the system design. Real options "on" projects are decisions and actions that affect the project outcome. However, this characterization is ambiguous in a location where the option exists, with the project team or the project governance body[9].

Another model is the characterization of real options as mechanisms and types [9]. "A mechanism is an action, decision, or entity that enables a real option. It is a source of flexibility... A type is an action or decision that can be exercised by the owner of the real option. The type is therefore representative of the future flexibility" [9, p. 459–460]. Type is a method of managing uncertainty that can be exercised before the expiration date and after or as uncertainties are clarified.

This characterization was conceived to reconcile ambiguities in terminology between the classic application of real options analysis and the engineering application of real options. "In the classical application of ROA, the real option is used to describe the right but not the obligation to take a future action, which is then considered in the valuation of decisions under uncertainty. On the other hand, in engineering applications that actively synthesize options, the term real options is typically used to refer to a design feature that enables some flexibility" [9, p. 460].

In component options, exercising one option generates another. In this case, the value of the compound option is derived from the values from another option and not the underlying asset. For example, in a multistage project, the design is one project, and the development is a separate project [20]. Compound options are out of the scope of this study.

III. Methodology

A. Conceptual Framework

The study compares how agile projects achieve benefits relative to traditional projects. The study uses real options analysis as a basis and combines two frameworks to define the research model. First, it uses the uncertainty framework from [9] for mapping life cycle characteristics that enable flexibility to the real option types used to manage the uncertainties. Next, it uses the model from [25] to identify and value private risks. Finally, it uses the procedure for real options analysis from [20] as a valuation model to compare plan-driven and agile projects. The study performs the analysis at the project level.

Real options analysis was chosen as it has been proven a suitable tool to value investment under uncertainties in different contexts, including information technology investments and agile projects [9, 17, 31, 25]. The binomial method was chosen over the Black–Scholes equation as it is easier to adjust parameters over the option's life and to explain the valuation results because the framework is transparent [20].

The model from [9] was chosen for mapping the life cycle characteristics to real options for three reasons. First, it provides transparency on the source of the flexibility within the life cycles. This makes the comparison between life cycles traceable and easy to understand, and explaining the source of flexibility is straightforward. Second, it differentiates the location of the option relative to the project. The mechanisms occur "in" the project and the types occur "on" the project. Third, it highlights which aspect of the life cycle triggers or contributes to which real option.

The model from Chen et al. [25] was used to evaluate private risks as it provides a relevant risk framework and a valuation model for private risks. These models were selected as they are consistent with the scope of this study. A similar valuation model has been used in evaluating agile projects using real options by [17].

ISO 21502:2020-12, Project, Programme and Portfolio Management—Guidance on Project Management 1st Edition [32] was used as a guideline for defining project roles and processes. It was chosen for two main reasons. First, it was updated in 2020 to reflect various types of project lifecycles, including agile. Second, it provides a comprehensive view of how projects fit into an organization and guidelines for how a project should be managed. Thus, it was a suitable guide for mapping the project acts and their value drivers.

B. Approach

The aim of the study is to analyze the mechanisms agile projects use to deliver target benefits. To accomplish this goal, the study explores different aspects of project work and maps that understanding to the financial model. Therefore, the proposed approach involves investigating literature, mapping project characteristics to the real options model, and analyzing the results. The proposed procedure was divided into four steps, which are described in the following sections.

1) Define the project framework.
2) Define the real option characteristics.
3) Map the real options characteristics to the project framework.
4) Apply the model to an illustrative comparison case.

C. Validity

This approach to defining the model and its elements relies on secondary sources. It is consistent with similar studies [8, 33, 17, 17, 2]. The results were cross-validated by using an illustrative case study.

IV. Project Frameworks

A. Overview of Project Management Frameworks

The project management bodies of knowledge are used worldwide as the guiding frameworks for standard practices. The guidelines include, for example, *ISO 21502:2020-12, Project, Programme and Portfolio Management—Guidance on Project Management 1st Edition* [32], *APM Body of Knowledge 7th Edition* [11], *A Guide to the Project Management Body of Knowledge (PMBOK guide)—7th Edition* [16], and *Managing Successful Projects with Prince2* [34]. Although criticized by some researchers, the "standards have come to represent an institutionalized collective identity of project managers" [35, p. 37]. In the most recent releases, the guidelines have evolved to suit different delivery approaches: "predictive, incremental, iterative, adaptive or hybrid, including agile approaches" [32, p. 1].

Table II compares the main difference between agile and plan-driven projects.

B. Project Management Processes

The project management standards use various names to describe similar content, processes, and artifacts. Nevertheless, they all cover similar topics on planning, initiating, directing, monitoring, controlling, and closing projects. For the purposes of defining real option mechanisms, we used the subject areas from the ISO standard. The standard provides a holistic and structured way to consider uncertainty and variability in agile and plan-driven projects.

Table III includes an overview of the project roles and processes.

TABLE II
PLAN-DRIVEN AND AGILE COMPARISON

Plan-driven	Agile
One-time delivery of the product as a big release	Frequent releases of the product in increments (usually less than monthly)
Specifications and details exchanged through written documents	Specifications and details exchanged through collaborative communications
Fixed requirements with detailed upfront planning	Initial set of requirements at the start that are subsequently iteratively defined
Detailed plan fixed at the start of the project; formal process to change the plan	High-level plan at the start, adapted through iterative planning
Customer feedback at scheduled sessions (e.g., workshop at the start, follow-up status, validation at end of the project.	Customer and developer feedback almost daily; co-located virtually or physically

TABLE III
PROJECT MANAGEMENT PROCESSES (ISO 21502:2020)

Role	Process	Description
Spr org	Pre-project	Identifying and formalizing the needs and opportunities to realize benefits before authorizing the project.
	Overseeing	Monitoring that the project meets the organizational needs and stakeholder expectations at an acceptable risk level.
	Post-project	Verify the outcomes are sustainable and expected benefits have been realized.
Prj spr	Directing	Engaging directly and through boards to confirm that organizational resources are used as expected or terminating when support is no longer justified.
Pj mgr	Initiating	Plan the project, organization, governance, and management structure and mobilize the project team.
	Controlling	Monitor and measure project performance against agreed plans or authorize changes.
	Closing or terminating	Confirm the completion of the project scope, enable post-project benefits realization, and demobilize resources and facilities.
Work pkg leader	Managing delivery	Define and plan required outputs and outcomes and deliver outcomes to achieve and realize expected benefits.

Legend: Org-Organization, Pkg-Package, Prj-Project, Spr-Sponsor, Mgr-Manager

C. Agile Practices

Each agile framework provides a set of practices and approaches that implement the values and principles defined by the Agile Manifesto. "This results in a high number of agile practices with many variants used in practice and described in literature" [36, p. 1]. For example, the Agile Alliance's glossary lists 75 different practices. In this section, we identified some of the most frequently used agile practices (in italics) and aligned them in project management subjects from the ISO standards [36, 33].

a) Planning: Breaking requirements into small units called epics or *user stories* that can be *prioritized* and estimated; the prioritized list is called a *backlog*. Deferring decisions on which items to develop until the last moment and prioritizing requirements at the start of any iteration in an *iteration planning* session [37, 17].

b) Schedule: Delivering product increments in fixed duration iterations (usually two to four weeks). Typically, the objective is to deliver a fully functional product with each release composed of one or more iterations [38].

c) Costs: Estimations in group sessions by the team that will perform the work using wide-band estimation techniques; the estimation process is called *agile estimation* or planning game.

d) Resources: Self-organizing teams assign tasks amongst themselves, participate in making decisions, and resolve problems and conflicts. Resources such as people, facilities, equipment, materials, infrastructure, and tools are usually locked in for each iteration.

e) Stakeholders & Communications: Incorporating stakeholders in the project in the iteration planning sessions, *review meetings*, and *daily stand-ups*.

f) Quality: Defining a *definition of done*, performing *retrospectives*, and creating *simple designs* that are part of the quality concepts.

g) Procurement: Contracts where the scope is not predetermined allow features to be implemented based on choices made during the project [17].

h) Lessons learned: Retrospectives after each iteration for lessons-learned sessions and improving project performance.

i) Change control: Small releases introduce decision points and opportunities to change course using the *iteration planning* process to prioritize the user stories in the backlog [17].

j) Termination: Small releases allow the customer to continue or terminate the project at the end of each release [17].

V. REAL OPTION CHARACTERISTICS

A. Real Option Mechanisms

For this study, we define the characterization of real options based on [9]. The mechanisms are the source of flexibility because they are the actions, decisions, or entities that enable a real option. This section describes the mechanisms relevant in a project context when building complex products or processes. The mechanisms described can be applied to agile or plan-driven projects.

1) (Re-)investments: The initial *(re-)investment* mechanism is at work when the sponsoring organization decides to invest in the project by exercising an option. "...the firm has the right to access all cash flows when the project passes the last phase at the investment cost (strike price)" [39, p. 389]. The sponsoring organization can decide to continue or terminate the investment at various stages based on budget, scope, or schedule changes.

2) Iterative Contracting: Iterative contracting is organizing contract terms so that resources are allocated one or multiple iterations at a time, and early termination does not result in a contract breach. The contracting presumes that, where possible, resources are allocated incrementally without negatively impacting quality or creating a moral hazard. A moral hazard is defined as the ineffectiveness or the abuse of trust created by opportunistic behavior [40]. Moral hazards can occur when the supplier and client are from differing organizations. It includes behaviors such as creating a high transparency gap by hiding information, engaging specialists with little competence and experience, or intentionally completing tasks poorly, for example. Moral hazards can be created when the supplier introduces a risk of project failure and increases the transaction cost for the client.

3) Early Termination: Project termination describes when a project should end. The factors that cause early termination include significant financial and non-financial losses, high-risk investments, lack of exploitable knowledge created, inability to leverage its exploration and exploitation experience, the collaboration structure, the firm's position in an inter-firm knowledge network, organizational agility, and various project characteristics [41, 42].

An objective criterion for *early termination* is when "the value of benefits (quantifiable or non-quantifiable) does not justify the cost to complete the project, or a more cost-effective alternative is available" [43, p.7].

Early project termination can affect contractual relationships; it implies the contract ends before its expiration date due to force majeure, default by a party, or voluntary buyout [44]. Prerequisites for early termination include termination decision criteria that define the timing and factual basis for the termination [42] and negotiation of contract clauses, dispute resolution processes, or termination compensation.

4) Modularity: Modularity is "building a complex product or process from smaller subsystems that can be designed independently yet function together as a whole" [45, p. 1]. *Modularity in design* and *Modularity in use* are two types of real options mechanisms.

a) Modularity in design: means dividing the design into visible and hidden components. The visible components follow a set of design rules that consider the architecture, interfaces, and standards [46, 47, 48]. The hidden components may be autonomously designed and developed according to the design rules. Realizing modularity requires architects and designers with a deep level of knowledge to predict future trends and strong leadership to integrate (decentralized) independent teams. Architects compete by attracting designers and having prevalent architecture on the market. Module builders master the production based on hidden information.

In addition, architecture, design rules, interfaces, and standards are key components that enable modularity. The architecture specifies the design's components and controls the visual design rules. The interface describes the interaction, fit, and communication between the subcomponents. The standards establish the tests for conformity to the design rules and measures of the subcomponents' performance. A central architecture requirement is that a hierarchical system can be decomposed into independent, interrelated components and that stable intermediate forms allow for the rapid evolution of complex systems [49]. One of the design challenges is to decompose the system into subsystems with minimal interdependence between the subsystems [46].

b) Modularity in use: allows the end user to compose the final product by mixing and matching components. It accelerates the pace of change, heightens competitive pressures and uncertainty, and transforms companies and markets.

5) Concurrent Engineering: Concurrent engineering is the parallel design and development of a product or subsystem. *Point-based* or *setbased concurrent* engineering varies depending on when alternatives converge to the final solution [50]. Waiting longer, developing multiple alternatives, and gathering more information beyond a certain point increases managerial confidence but does not necessarily increase decision-making. Teams waiting longer to eliminate design alternatives gain access to more accurate quality information and make wiser choices on average. Quality does not increase continuously, indicating a transitory period of development work that does not yield additional useful information. Delaying the start of convergence allows the developers to choose any design alternative as new information becomes available [50]. Thus, concurrent engineering can impact development time and product cost and quality.

a) Point-based concurrent engineering: various alternatives are available, and the best option is quickly selected to reduce complexity and constrain development costs.

b) Set-based concurrent engineering: a range of viable alternatives is selected and eliminated gradually based on weakness to converge at a final solution.

6) Incremental, Prioritized Delivery: Incremental, prioritized delivery involves prioritizing feature development based on value and delivering an incremental release for productive use by the sponsoring organization. Erdogmus and Favaro [17] demonstrated in a mathematical study the beneficial effect of the in-project decisions that had the flexibility to prioritize feature development into incremental releases.

B. Real Option Locations

Real option mechanisms in projects can occur "in" the project or "on" projects [9, 30]. Mechanisms "in" projects are the decisions taken by the project team or project manager and occur in the project management processes managed by those roles. These options affect topics such as the system design. Real options "on" projects affect the topic project and its outcome. These options occur in other project management processes, such as those managed by the project sponsor or sponsoring organization.

C. Real Option Types

Real option types are actions or decisions that the owner of the real option can exercise, so they represent flexibility [9]. They can be exercised before the expiration date of an option, after or as uncertainties are clarified. The types are described in Table I.

Fig. 1 demonstrates how an option can be exercised. At the start of the project, point A in the figure, a real option mechanism is implemented. The decision to exercise a real option type associated with that mechanism or not is made at each decision point, points B, C, D, and E in the figure. If the figure represented an agile project, the boxes would be iterations, and if it were a plan-driven project, the boxes would be project phases.

For example, if the real option mechanism at point A was "early termination", the project contract would have a structure that does not penalize the decision for early termination. Then, the real option type "abandon" or "switch" could be exercised at any decision point. For an agile project, a working solution would be expected at the end of each iteration. For a plan-driven project, a working solution would be expected at the last phase.

TABLE IV
REAL OPTIONS MECHANISMS

Mechanism	Description	Location
(Re-) investment	Invest in the project or decide to continue or terminate the investment at various stages based on budget, scope, or time changes.	on
Iterative contracting	Organizing contract terms so that resources are allocated one or multiple iterations at a time, and early termination does not result in a contract breach.	on and in
Early termination	Ending the project when "the value of benefits (quantifiable or non-quantifiable) does not justify the cost to complete the project, or a more cost-effective alternative is available" [43, p.7].	on
Modularity in design	Dividing the design into visible and hidden components	in
Modularity in use	End user to compose the final product by mixing and matching components.	in
Point-based concurrent engineering	A alternative is quickly selected from a range of options to reduce complexity and constrain development costs.	in
Set-based concurrent engineering	A range of viable alternatives is selected and gradually eliminated based on weakness to converge at a final solution.	in
Incremental, prioritized delivery	Prioritizing feature development based on value and delivering an incremental release for productive use by the sponsoring organization.	in

D. Application of Real Options

Table I maps the real options mechanisms, types, and locations. Each row in the table corresponds to a mechanism that can applied to the project life cycle. This conceptualization is taken from [9], describing real options characterized as a tuple of <Mechanism, Type>.

Fig. 1 provides a visual example of the concept. As an illustration, if the *early termination* mechanism is implemented at time t_0, then the real options types for *switching* and *abandoning* are enabled. Thus, the sponsor or sponsoring organization could exercise the option to redeploy the project resources for an alternative purpose or abandon the project altogether. Similarly, if the *modularity* mechanism is enabled, it means there is strong team leadership, architecture, and a design team that allows for modularity in design and use. Thus, the real option to *stage* by partially deploying the system could be exercised to gain early benefits.

E. Private Risks

Projects are affected by uncertainty internal to the project organization and those external produced by market conditions and competitive environments. The internal project-specific risks are private risks [17]. External risks are market and competitive uncertainties independent of the private risks. External risks are usually priced into the financial markets [17]. Private risks can impact the project costs and the market value of product output [22].

The private risks impact project valuations through their unbiased estimates of cash flows. "An unbiased estimate of a cash flow is calculated as a statistical expectation by considering as many scenarios as is feasible and the respective likelihood of these scenarios" [17, p. 8]. Because budget and schedule risks are unique to project situations, they are private.

Historical data, such as risk registers from similar projects, are sources for identifying private risks. A risk register is a structured record, list, or document that details the identified uncertainties and their characteristics [16, 32, 11]. Alternatively, there is a robust body of research on project, information technology, and software development risk factors [51].

Table V is an example of private risks based on a combination of risk factors from [51] and [25].

TABLE V
PRIVATE RISK FACTORS

Risk category	Risk description
Organizational context	Management stability, organizational support for an investment
Project strategy	The adequacy and accuracy of the planning for the project and of the managing and monitoring to ensure that the project reaches its desired goals.
Project structure	The strategic orientation of the application, the number of departments involved, or the business process needs to be changed frequently.
Customers and users	Lack of user involvement during system development, unfavorable attitudes of users towards a new system
Team	Insufficient knowledge or inadequate experience among team members, frequent team member turnover
Technology complexity	Whether the new technology is used, the complexity of the processes being automated, whether many links to existing systems are required
Changing requirements	Frequently changing requirements; incorrect, unclear, inadequate, or ambiguous requirements

F. Applying Real Options Binomial Tree

The next step is to apply the discussed components to a project analysis. The steps include defining the project use case by defining the real option tuple, quantifying private risks, identifying the input parameters, calculating the option parameters, building the binomial tree, calculating the asset

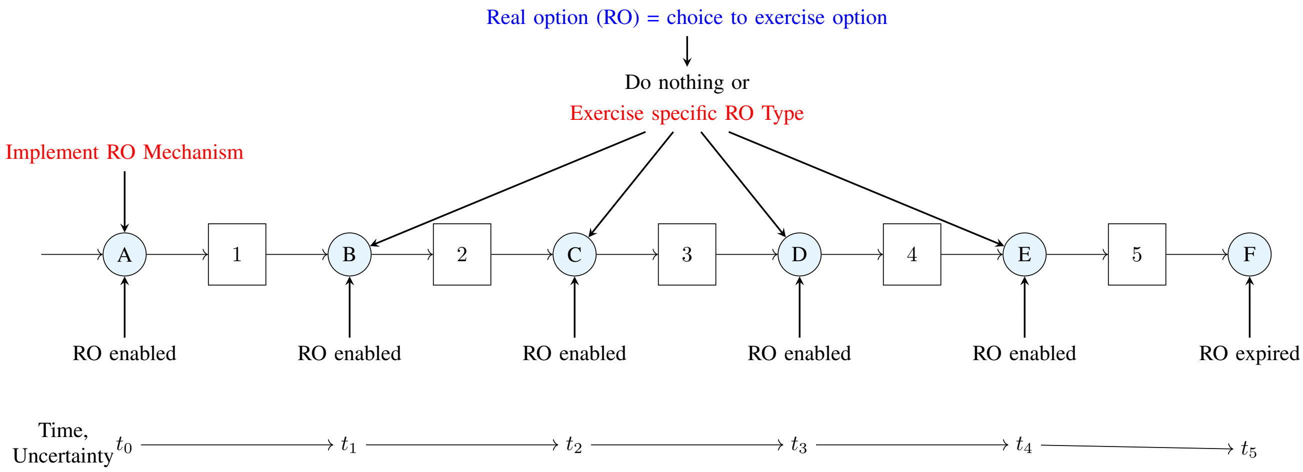

Fig. 1. Real Options Example

values at each tree node, and analyzing the results. The following sections describe the inputs and computations, closely following those given by [20].

1) Define the use case: For a given project use, the mechanism applicable to the project should be determined and then mapped to the real option types to form a tuple of <Mechanism, Type>. The real option types determine the quantitative parameter to compute the real option put values.

2) Quantify the private risks: The private risk factor (F) can be applied as a risk premium or failure rate to the uncertainty model. The risk premium is a quantitative assessment of the financial impacts to address the risk. The value of the risk premium is added to the project investment cost. It measures additional exposure to the risk, and the sensitivity measure is the degree of exposure. "The failure rate describes the extent to which the IS [Information Systems] project will be a failure" [25, p. 779]

Here, we follow the method of using failure rate as described and proposed by [25] because it considers overall project risks. The scores of the probability (P_f) and consequences (C_f) of the risks are from low to major as follows: 0.1-low, 0.2-minor, 0.5-moderate, 0.7-significant, and 0.9-major.

"The scores for each individual dimension of probability (P_f) and consequence (C_f) are added and the sum is divided by the number of factors used to assess them:

$$P_f = \sum P_i/i \qquad C_f = \sum C_i/i \tag{1}$$

The formula for the failure rate is as follows in Equation 2:

$$F = P_f + C_f - (P_f)(C_f) \tag{2}$$

" [25, p. 779].

3) Identify input valuation parameters:

a) Underlying asset value (S_o): The underlying asset value (S_o) is based on the discounted cash flow of the expected free cash flows, and "production phase free cash flows are the net revenues calculated from the expected future revenues and costs associated with project output in its production phase" [20, p. 72]. It is an estimate based on an assumption of the value of the project outcome.

b) Exercise price (X): The exercise price (X) is the investment cost. Investment costs are the development cost and production phase capital costs. They are primarily influenced by how accurately the organization estimates the costs and how efficiently the project is brought to completion; these costs are influenced by private risks and are not influenced by market forces [20]. The investment costs directly impact the option value.

$$X = X * R_p \tag{3}$$

c) Option life (T): The option life parameter (T) is the time to maturity. Unlike financial options that have a known maturity date, in real options, the option life is estimated based on the expected duration of the project's development and production phases. Factors such as loss of market share and competition can reduce option value even as maturity time increases. Thus, the option life should be established sufficiently long to clear uncertainty but not so long as to reduce the value of the project outcome.

d) Volatility of underlying asset (σ) : The volatility factor (σ) is the measure of the variability of the underlying asset over its lifetime. It is given by the standard deviation of the continuous rate of return on the asset value over time. The volatility factor varies in step with the time step.

In a project context, using historical data from similar projects with similar market performance and cash flow profiles is an acceptable method of accounting for market reality [20].

e) Time step (δt): The time step factor (δt) splits the option's life into time increments. "The higher the time increments used in the binominal method, the closer you will get to this value [Black–Scholes equation] ...with only four to six

TABLE VI
REAL OPTIONS MECHANISMS AND TYPE

Real Option Mechanism		Real Options		
“on” the project	“in” the project	Types	Real Option Meaning	Exercise Price (X value) Parameter
Early termination	Incremental, prioritized delivery	Switch	Within the project, you have the option to prioritize deliveries.	Investment costs
(Re-)investment		Change scale: expand	Continue to operation and keep the option open for the future or exercise one of the options.	Expansion factor, cost of expansion
Iterative contracting	Iterative contracting	Change scale: reduce	To maximize continue as planned or reduce planned expenses by the contract factor and save the savings values. At each node, you have an option to continue the operation and keep the option open or to contract by half.	Contract factor, savings of contracting
	Modularity, Incremental, prioritized delivery	Stage	Divide project into multiple investment packages.	Investment costs
Early termination	Modularity	Abandon	At each node, you have the option to either abandon the project for a salvage value or continue until the option expires. Each node represents the value maximization of abandonment versus continuation.	Salvage value
(Re-)investment	Set-based concurrent engineering	Strategic growth	Each node represents the value maximization of continuation versus expansion. At each node, you can either continue the operation and keep the option open for the future or expand it by committing the investment for expansion.	Expansion factor, cost of expansion
	Modularity (in use) Incremental, prioritized delivery, Point-based concurrent engineering	Defer with revenue leakage	The annual leakage rate or revenue lost due to the delayed investment	Investment or annual leakage or revenues lost due to the delayed investment.
	Modularity (in use), Incremental, prioritized delivery	Defer	Option to invest in production development or the option to wait until the next time period before the option expires.	Investment costs

time steps, a relatively good approximation can be obtained” [20, p. 145]. “The higher the number of time steps, the higher the level of granularity and therefore the higher the level of accuracy of option valuation” [20, p. 113].

f) Risk-free interest rate (r): The risk-free interest rate parameter (r) is the current interest rate on the risk-free asset. In a “real options model [it] is usually determined based on the U.S. Treasury spot rate of return, with the maturity equivalent to the option’s time to maturity” [20].

4) Calculate the option parameters: The uncertainty model is defined using the binomial tree. The tree is built by starting with the underlying asset value S_o as the first node on the left and multiplying it by the up factor (u) for the up node and the down factor (d) for the down node for the first step. Then, moving to the right, perform this action for each node in the binomial tree for each time step until the last time step. The results are the expected asset values at each node of the tree. The up and down factors are based on the volatility of the underlying asset S_o and calculated using Equations 4 and 5.

$$u = \exp(\sigma\sqrt{\delta t}) \tag{4}$$

$$d = 1/u \tag{5}$$

The option values are calculated using the risk-neutral probabilities (p) as represented by Equation 6. It represents the riskless asset during the life of the option. The model involves “risk adjusting the cash flows throughout the lattice with risk-neutral probabilities and discounting them at the risk-free rate” [20, p. 115].

$$p = \frac{\exp(r\delta t) - d}{u - d} \tag{6}$$

5) Defining the uncertainty model: Build the binomial tree by using the time step (δt) for the options life (T) to calculate the asset values over the life of the option, starting at the underlying asset value (S_o) and multiplying by the up factor (u) and the down factor (d) at each time step, moving right until the last time step. The value computed is the asset value at each node.

The option values calculated at each node will depend on the real option type chosen. For example, if the option type is to abandon the project, then at each node, the option price will be based on comparing the exercise price (X) to the value of keeping the option open until it expires. Starting with the last node, compare the asset value on the node as computed above with the exercise price (X), and to maximize the value, the biggest value is the option value. As an illustration, if the asset value at the node is 100 USD and the exercise price is 10 USD, then the option value would be 100 USD.

At the intermediate nodes, those steps away from the last node, “the expected asset value for keeping the option open...is the discounted (at the risk-free rate) weighted average of potential future option values using the risk-neutral probability as weights:”

$$[p(S_o u^5) + (1-p)(S_o u^4 d)] * \exp(-r\delta t) \tag{7}$$

[20, p. 159]. The formula is an example of computing the asset value at node $S_o u^4$.

The option valuation binomial tree is computed backward to time zero, and the higher of the exercise price or computed expected asset value is retained.

6) Analyzing the results: After quantifying relative benefits and costs as relative option values at each tree node by backward induction, the retained put option value at time zero is the real option put value. Kodukula and Papudesu [20] notes this real option put value should be a good approximation to that produced using the Black–Scholes equations.

a) Probability of success using the failure rate: The value at each node would consider the impact of the risk failure rate by educing the chances of achieving the value [25].

$$[\max[0, (1 - F)S_o u^4 - I_4]] \tag{8}$$

The formula is an example of calculating the value at node $S_o u^4$ using the project investment (I) in the time period (t) four and the failure rate (F).

b) Probability of success from the binomial lattice: The information in the binomial tree has further uses, such as using the probabilities for investment decisions. For example, summing the number of steps in the binomial lattice, computing paths where the options will not be exercised, and dividing the two gives a probability that the options will not be profitable. This value can be used to compute the probability that the project will succeed. For example, there are 32 paths for all end nodes in a five-step lattice. If the two bottom-end nodes where the option will not be exercised include six paths, then the probability of failure will be 6/32 or 19%. Thus, the probability of success will be 81%. See [20] for more information.

VI. Illustrative Case Comparison

A. Case Background

The project is an illustrative case using the abandon real option type to compare the agile and plan-driven methodologies. The project entails bringing a new product to the market. The total estimated cost to bring the product to market, including development, is $95 million, and it should return $100 million at a market risk-adjusted discount rate. The project is estimated to last five years. The $95 million investment cost is distributed evenly at $19 million per year. If the project can deliver a minimally viable product to the market, it would have a payout of $65 million; we refer to this as salvage value. The annual volatility rate of the future cash flows is 35%, and the annual risk-free interest rate of the period is 5%. The data in this example follow the structure of the simple example from [20].

B. Define the use case

Referring to Table VI, for the abandon option, the tuple of <Mechanism, Type> suggests that the sponsoring organization or project sponsor should have organized the contractual model for early termination. Further, the project team could influence the ability to deliver value prior to abandonment if they have included modularity in the design and use.

TABLE VII
ILLUSTRATIVE CASE RISK SCORES

ID	Risk Category	Plan-driven P_f	Plan-driven C_f	Agile P_f	Agile C_f
R1	Organizational context	0.28	0.52	0.28	0.52
R2	Project strategy	0.00	0.00	0.00	0.00
R3	Project structure	0.2	0.30	0.2	0.20
R4	Customers and users	0.18	0.22	0.1	0.20
R5	Team	0.10	0.18	0.1	0.50
R6	Technology complexity	0.42	0.60	0.42	0.60
R7	Changing requirement	0.3	0.32	0.3	0.10

TABLE VIII
ILLUSTRATIVE CASE FAILURE RATES

Risk failure rate	F (agile) = 0.50
Risk failure rate	F (plan-driven) = 0.52

C. Quantify the Private Risks

The private risk factor (F) varies per methodology type and is based on the risk options mechanisms. For this study, we used the risk scores from Chen et al. [25] for the plan-driven project and adjusted the parameter for the agile project.

First, the modularity mechanisms discuss the need for strong leadership, architecture, and design skills. Thus, the lack of these capabilities would severely impact an agile project. Next, the delivery method for agile projects suggests high customer engagement, so the probability of this risk would be low. The probability of many requirement changes would be similar for both project types. However, the consequences in an agile project would be lower than in a plan-driven one. Therefore, the private risk profile for the two types of projects would differ.

The corresponding risk scores are shown in Table VII, and the risk failure rates are shown in Table VIII.

D. Applying Real Options Binomial Tree

Based on the inputs discussed, the next step is to use the binomial tree to compute the real options based on the uncertainty model. The following sections describe the inputs and computations.

1) Identify valuation parameters: The input parameters for the real options calculation are provided in Table IX and are the same for agile and plan-driven projects, except for the Exercise price, which represents the abandoned- value for the delivery of a minimally viable product after early termination of the project.

TABLE IX
ILLUSTRATIVE CASE INPUT PARAMETERS

Project investment	I = $95 million
Underlying asset value	S_o = $100 million
Exercise Price	X = $65 million
Option Life	T = 5 years
Volatility of underlying asset	σ = 35%
Time Step	δt = 1 year
Risk-free interest rate	r = 5%

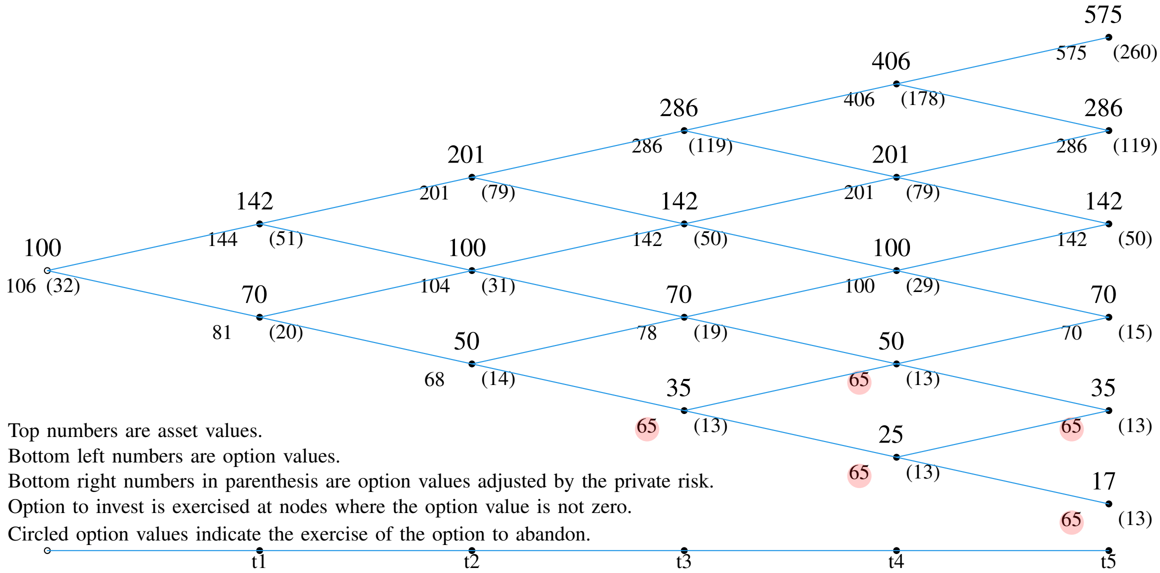

Fig. 2. Binomial Tree for Agile Project with an Option to Abandon

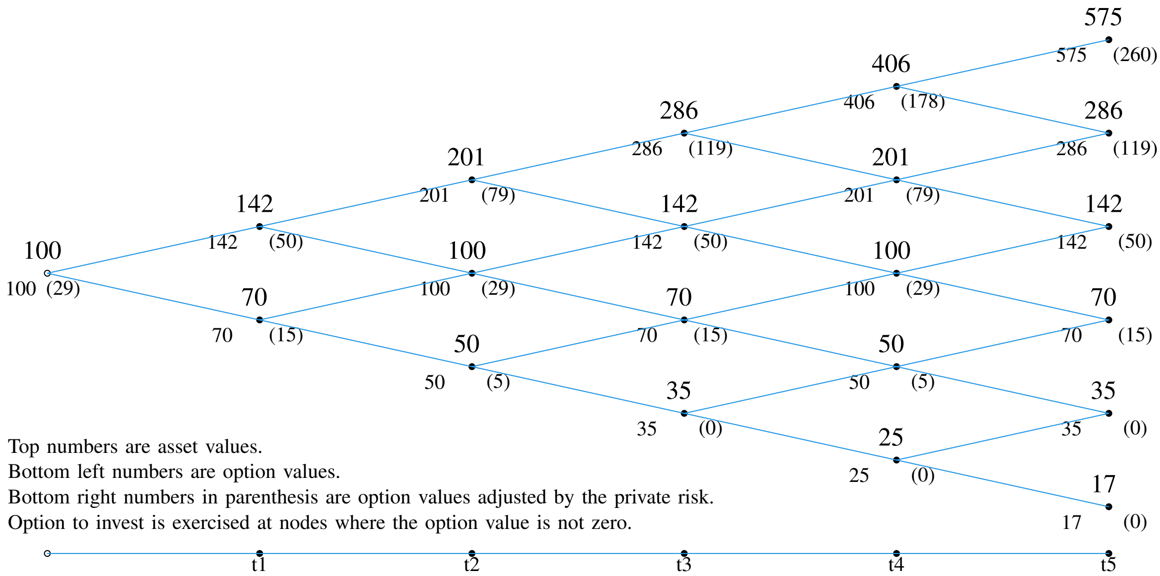

Fig. 3. Binomial Tree for Option for Plan-Driven Project with no Abandon Option

TABLE X
ILLUSTRATIVE CASE OPTION PARAMETERS

Up factor	u = 1.42
Down factor	d = 0.70
Risk-neutral probabilities	p = 0.49

2) Calculate the option parameters: The same formula calculates the option parameters for both methodology types, and the values are shown in Table X.

3) Defining the uncertainty model: The binomial tree is shown in Fig. 2 is for the agile project and Fig. 3 is for the plan-driven project. They show a binomial lattice where the top numbers are asset values, and the bottom left are option values. The bottom right number is the risk-adjusted option values. From the left, it starts at time = 0 with the underlying asset value (S_o) and real option project value just below. The paths proceed to the right with the asset and option values for the five years.

4) Analyzing the results: The binominal tree quantifies the relative benefits and costs at each tree node. First, if the project succeeds as planned for the full five years, the agile project would yield \$106 million, considering the option to recover if abandoned. The plan-driven project does not have the abandon option; thus, it would yield \$100 million. Both the agile and plan-driven projects deliver a respectable return. For agile, it would be \$11 million based on a \$95 million investment and \$5 million for the plan-driven.

Second, for our purpose of comparing agile and plan-driven methods, if the project ends earlier than five years, then the ability to benefit at all would depend on whether the project delivered a minimally viable product in the year before abandonment. Because we used the modularity mechanisms, at a minimum, an agile project would recover the salvage value of \$65 million before we consider the failure rate. If we pursued the plan-driven project and stopped before the final delivery, then the salvage value would also be at risk. Thus, the option values are lower starting at year 3.

Finally, considering the failure rate, the risk failure rate must reduce the option value and subtract the investment costs. For example, at the beginning of year 5, the $S_o u^5$ option value of \$575 million would be \$285 million for an agile project and \$260 million for a plan-driven project using Equation 8. Further, the S_o real option value would be \$32 million for the agile project and \$29 million for the plan-driven project.

VII. CONCLUSIONS

As noted by Kodukula and Papudesu [20, p. 95], "ROA [Real Options Analysis] is most valuable when there is high uncertainty with the underlying asset value and management has significant flexibility to change the course of the project in a favorable direction and is willing to exercise the options." In this study, we identified the mechanisms that provide management flexibility to act and change the course of agile or plan-driven projects.

First, the sponsoring organization and project sponsor can use investment and termination options to deploy corporate resources away from a project. Next, the project manager and the project team can make in-project decisions that enable or prohibit certain investment options. For example, a project that does not have a modular design or prioritizes iterative and incremental delivery inhibits deriving value from an early termination.

Second, the study relates project acts (e.g., mechanism) to the real options types and computation model. The binomial tree provides a visual method for connecting a project timeline to the economic value of the expected benefits. Further, the project failure used in the computation explains the consequences of the risks on the economic value. Thus, the research provides a multi-faceted view for evaluating a project's contribution to organizational benefits. Finally, the analysis structure compares how different project approaches react under similar uncertainty scenarios.

A. Contributions to Knowledge

The results quantify subjective and theoretical speculation on how agile projects contribute to realizing organizational benefits. Using real options, the study connects the project structure to the methods for calculating organizational benefits. The results contribute to the project management literature on agile methodologies and the theory of benefits realization in projects.

B. Implications for Practice

Three management levels are involved in the governance and structuring of project work. The study offers some guidance for people at those levels to understand the mechanisms that make an agile project function and how those mechanisms can be used to contribute to organizational benefits. The sponsoring organizations, sponsors, and project managers should consider ways to structure project teams, contracts, and investments to retain the flexibility to deploy or redeploy corporate resources. The project managers and work package leaders should consider how the internal operations of the project should be organized to allow for changes in corporate direction.

C. Implications for Research

In future studies, researchers investigating agile methodologies should consider methods for investigating and validating the mechanisms that contribute to project performance. Most research simply accepts that agile projects improve project performance. However, there is insufficient empirical evidence on the mechanisms that explain performance. Further, the risk failure rate for agile and plan-driven methodologies differs slightly, for example, by a few points in our illustrative case. However, the time dimension of the project is the strongest indicator of achieving organizational benefits. The longer the project, the more likely it is to fail. This aspect was not considered sufficiently in the modeling of this work, and it offers an interesting and important area for future research.

D. Limitations and Further Research

The results of this study are not generalizable beyond information technology projects due to the type of mechanisms identified in this research. Specifically, software development projects have been the most active in applying agile methodologies. No steps were designed to determine whether the proposed methods would apply to other project types. Further, we lacked financial or factual data to comprehensively measure an actual case study.

REFERENCES

[1] O. Zwikael, Y.-Y. Chih, and J. R. Meredith, “Project benefit management: Setting effective target benefits,” *International Journal of Project Management*, vol. 36, no. 4, pp. 650–658, 2018.

[2] C. Marnewick and A. L. Marnewick, “Benefits realisation in an agile environment,” *International Journal of Project Management*, vol. 40, no. 4, pp. 454–465, 2022.

[3] P. Serrador and J. K. Pinto, “Does agile work? — a quantitative analysis of agile project success,” *International Journal of Project Management*, vol. 33, no. 5, pp. 1040–1051, 2015.

[4] A. Gemino, B. Horner Reich, and P. M. Serrador, “Agile, traditional, and hybrid approaches to project success: Is hybrid a poor second choice?” *Project Management Journal*, vol. 52, no. 2, pp. 161–175, 2021.

[5] R. A. Lundin and A. Söderholm, “A theory of temporary organization,” *Scandinavian Journal of Management*, vol. 11, no. 4, pp. 437–455, 1995.

[6] K. Beck, M. Beedle, A. v. Bennekum, A. Cockburn, W. Cunningham, M. Fowler, J. Grenning, J. Highsmith, A. Hunt, R. Jeffries, J. Kern, B. Marick, R. C. Martin, S. Mellor, K. Schwaber, J. Sutherland, and D. Thomas, “Manifesto for agile software development,” Dec 2001.

[7] J. Binder, L. I. V. Aillaud, and L. Schilli, “The project management cocktail model: An approach for balancing agile and ISO 21500,” *Procedia Social and Behavioral Sciences*, vol. 119, pp. 182–191, 2014.

[8] D. F. Rico, “What is the roi of agile vs. traditional methods? an analysis of xp, tdd, pair programming, and scrum (using real options),” *unpublished*, 2008.

[9] T. Mikaelian, D. J. Nightingale, D. H. Rhodes, and D. E. Hastings, “Real options in enterprise architecture: A holistic mapping of mechanisms and types for uncertainty management,” *IEEE Transactions on Engineering Management*, vol. 58, no. 3, pp. 457–470, 2011.

[10] R. Gunther McGrath and A. Nerkar, “Real options reasoning and a new look at the R&D investment strategies of pharmaceutical firms,” *Strategic Management Journal*, vol. 25, no. 1, pp. 1–21, 2004.

[11] APM, “APM body of knowledge seventh edition,” 2019.

[12] T. Cooke-Davies, “The “real” success factors on projects,” *International Journal of Project Management*, vol. 20, no. 3, pp. 185–190, 2002.

[13] R. J. Turner, “Projects for shareholder value the influence of projects at different financial ratios,” in *29th Annual Project Management Institute 1998 Seminars & Symposium*. Project Management Instiatue, 1998, Conference Proceedings.

[14] P. Serrador and R. Turner, “The relationship between project success and project efficiency,” *Project Management Journal*, vol. 46, no. 1, pp. 30–39, 2015.

[15] R. Joslin and R. Müller, “The impact of project methodologies on project success in different project environments,” *International Journal of Managing Projects in Business*, vol. 9, no. 2, pp. 364–388, 2016.

[16] PMI, *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)—Seventh Edition*. Newtown Square, PA: Project Management Institute, 2021.

[17] H. Erdogmus and J. Favaro, “Keep your options open: Extreme programming and the economics of flexibility,” in *Giancario Succi, James Donovan Wells and Laurie Williams, "Extreme Programming Perspectives", Addison Wesley, 2002*, 2002, Conference Paper.

[18] Y. Shastri, R. Hoda, and R. Amor, “Does the ’project manager’ still exist in agile software development projects?” in *2016 23rd Asia-Pacific Software Engineering Conference (APSEC)*, Hamilton, New Zealand, 2016, Conference Paper, pp. 57–64.

[19] A. Tiwana, M. Keil, and R. G. Fichman, “Information systems project continuation in escalation situations: A real options model,” *Decision Sciences*, vol. 37, no. 3, pp. 357–391, 2006.

[20] P. Kodukula and C. Papudesu, *Project valuation using real options: A practitioner’s guide*. J. Ross Publishing, 2006.

[21] R. G. Fichman, M. Keil, and A. Tiwana, “Beyond valuation:“options thinking” in IT project management,” *California Management Review*, vol. 47, no. 2, pp. 74–96, 2005.

[22] M. Benaroch and J. Goldstein, “An integrative economic optimization approach to systems development risk management,” *IEEE Transactions on Software Engineering*, vol. 35, no. 5, pp. 638–653, 2009.

[23] F. D. Maddaloni, G. Favato, and R. Vecchiato, “Whether and when to invest in transportation projects: Combining scenarios and real options to manage the uncertainty of costs and benefits,” *IEEE Transactions on Engineering Management*, pp. 1–15, 2022.

[24] J. L. Wellman, “Project valuation using real options: A practioner’s guide,” *Project Management Journal*, vol. 37, no. 5, p. 116, 2006.

[25] T. Chen, J. Zhang, and K.-K. Lai, “An integrated real options evaluating model for information technology projects under multiple risks,” *International Journal of Project Management*, vol. 27, no. 8, pp. 776–786, 2009.

[26] I. Krystallis, G. Locatelli, and N. Murtagh, “Talking about futureproofing: Real options reasoning in complex infrastructure projects,” *IEEE Transactions on Engineering Management*, pp. 1–14, 2020.

[27] C.-H. Wang and K. J. Min, “Electric power generation planning for interrelated projects: a real options

approach," *IEEE Transactions on Engineering Management*, vol. 53, no. 2, pp. 312–322, 2006.

[28] A. Jahanshahi Asghar and A. Brem, "Does real options reasoning support or oppose project performance? empirical evidence from electronic commerce projects," *Project Management Journal*, vol. 48, no. 4, pp. 39–54, 2017.

[29] Z. Racheva, M. Daneva, and L. Buglione, "Complementing measurements and real options concepts to support inter-iteration decision-making in agile projects," in *2008 34th Euromicro Conference Software Engineering and Advanced Applications*, 2008, Conference Proceedings, pp. 457–464.

[30] T. Wang and R. de Neufville, "Identification of real options 'in' projects," in *Systems Sciences*, vol. 16, 2005, Conference Proceedings, pp. 1124–1133.

[31] H. Erdogmus, "Valuation of learning options in software development under private and market risk," *The Engineering Economist*, vol. 47, 2002.

[32] ISO, "ISO 21502: 2020-12 project, programme and portfolio management — guidance on project management," 2020.

[33] G. J. Miller, *Framework for Project Management in Agile Projects: A Quantitative Study*, ser. Information Technology for Management: Current Research and Future Directions. Springer International Publishing, 2020.

[34] The Stationery Office, "Managing successful projects with PRINCE2," 2017.

[35] P. Eskerod and M. Huemann, "Sustainable development and project stakeholder management: What standards say," *International Journal of Managing Projects in Business*, vol. 6, no. 1, p. 36–50, 2013.

[36] M. Neumann, "The integrated list of agile practices — a tertiary study," in *Lean and Agile Software Development*, A. Przybyłek, A. Jarzębowicz, I. Luković, and Y. Y. Ng, Eds. Springer International Publishing, 2022, Conference Proceedings, pp. 19–37.

[37] A. Appari and M. Benaroch, "Monetary pricing of software development risks: A method and empirical illustration," *Journal of Systems and Software*, vol. 83, no. 11, pp. 2098–2107, 2010.

[38] H. Alahyari, R. Berntsson Svensson, and T. Gorschek, "A study of value in agile software development organizations," *Journal of Systems and Software*, vol. 125, pp. 271–288, 2017.

[39] M. Montajabiha, K. Alireza Arshadi, and B. Afshar-Nadjafi, "A robust algorithm for project portfolio selection problem using real options valuation," *International Journal of Managing Projects in Business*, vol. 10, no. 2, pp. 386–403, 2017.

[40] B. Wachnik, *Moral Hazard in IT Project Completion. An Analysis of Supplier and Client Behavior in Polish and German Enterprises*, ser. Information Technology for Management. Cham: Springer, 2016, vol. 243, pp. 77–90.

[41] H. Delerue and H. Sicotte, "Resource interdependence and project termination: An analysis in the biopharmaceutical industry," *International Journal of Project Management*, vol. 38, no. 5, pp. 256–266, 2020.

[42] M. Vaculík, A. Lorenz, N. Roijakkers, and W. Vanhaverbeke, "Pulling the plug? investigating firm-level drivers of innovation project termination," *IEEE Transactions on Engineering Management*, vol. 66, no. 2, pp. 180–192, 2019.

[43] J. Schmidt, "IT project failure, termination and the marginal cost trap," *Journal of Modern Project Management*, vol. 10, pp. 255–275, 2022.

[44] W. Xiong and Y. Han, "Incentives of early termination compensation in public–private partnership projects," *IEEE Transactions on Engineering Management*, pp. 1–13, 2021.

[45] C. Y. Baldwin and K. B. Clark, "Managing in an age of modularity," *Harvard Business Review*, vol. 75, no. 5, pp. 84–93, Sep/Oct 1997, copyright - Copyright Harvard Business Review Sep/Oct 1997 Last updated - 2015-11-06.

[46] E. J. de Waard and E.-H. Kramer, "Tailored task forces: Temporary organizations and modularity," *International Journal of Project Management*, vol. 26, no. 5, pp. 537–546, 2008.

[47] R. N. Langlois, "Modularity in technology and organization," *Journal of Economic Behavior & Organization*, vol. 49, no. 1, pp. 19–37, 2002.

[48] G. Lizarralde, M. d. Blois, and I. Latunova, "Structuring of temporary multi-organizations: Contingency theory in the building sector," *Project Management Journal*, vol. 42, no. 4, pp. 19–36, 2011.

[49] H. A. Simon, "The architecture of complexity," *Proceedings of the American philosophical society*, vol. 106, no. 6, pp. 467–482, 1962.

[50] J. K. Liker, D. K. Sobek, A. C. Ward, and J. J. Cristiano, "Involving suppliers in product development in the United States and Japan: evidence for set-based concurrent engineering," *IEEE Transactions on Engineering Management*, vol. 43, no. 2, pp. 165–178, 1996.

[51] E. Ziemba and I. Kolasa, "Risk factors relationships for information systems projects – insight from polish public organizations," in *Information Technology for Management. Lecture Notes in Business Information Processing*, E. Ziemba, Ed., vol. 243. Cham: Springer, 2016, Book Section, pp. 55–76.