

Needs Analysis and Requirements Delivery: Guiding the Development Approach with an Intuitive Framework

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Abstract

The needs assessment and requirements engineering domains involve tasks that help us fully understand a project's motivation. The functions of this domain include exploring the problem or opportunity and recommending a possible solution and development approach to the problem. From a project perspective, this is a critical stage as we can understand the value a viable solution brings to the customer and identify an appropriate development approach. A business investing resources to develop a solution must be pragmatic about the product development approach. Our research paper presents a framework to aid decision-making within this context. It involves considering attributes such as delivery cadence, risk, degree of innovation, and requirements certainty. Knowledge of the impact of these attributes on project outcomes will help educate engineers to become successful entrepreneurs and product managers.

Keywords—*entrepreneurship, requirements, needs analysis, development approach.*

I. INTRODUCTION

The product life cycle begins with the simple ABCs. The first phase, "A" is concerned with "aspire," where innovation and creativity emerge in the context of a solution to a problem or opportunity. The product idea needs to align with the mission statement and vision of the organization. The "B" phase deals with the "business case." The entrepreneur conducts a comprehensive business analysis. Financial benefits and ROI assurance are needed before the product gets gated to the "C" charter phase. A project manager and product owner are identified, and this is where the requirements engineering process begins in all earnest.

Needs analysis includes the processes used to analyze a business problem or opportunity and consider current and future states to determine an optimal solution that will provide value and address the business need; the results from this preliminary analysis will provide decision-makers with relevant information to determine whether an investment in the proposed solution is viable. [1]. When organizations do not conduct a comprehensive needs analysis and subsequently embrace good requirements management practices, it will impact their ability to perform project work effectively and successfully deliver products [1]. According to PMIs report, *Requirements Management: A core competency for Project and Program Success*, "47% of unsuccessful projects failed to

meet original goals due to poor requirements management". Many factors may account for the failure of new product launches. However, patterns are emerging [2]:

- Products do not match customer needs.
- Undeveloped fuzzy front end.
- Breakdown in communication and collaboration.
- Poor governance and execution.

Driving innovation requires teams and a well-organized development approach. Many of the modern world's most impactful creations were invented by passionate innovators working in teams [3]. Teams rely on qualified science and tools and effective delivery techniques to ignite dramatic improvement in life cycle management practices which are core to a successful outcome [4].

The global standard for project management [5] defines the development approach as "a method used to create and evolve the product, service, or result during the project lifecycle, such as a predictive, iterative, incremental, agile, or hybrid method." Selecting a suitable development approach and project methodology is essential, and this topic is discussed early in the product life cycle. A lot has been written in literature about this topic [6].

There are two classical extremes, adaptive and predictive. We must review these two distinct approaches before considering a hybrid development approach. The predictive approach is commonly known as the waterfall approach or traditional approach. Here the product development progresses systematically through stages such as feasibility, design, construction, and testing. We put considerable effort into up-front planning, and the various life cycle phases are typically not revisited when complete. For example, if product design is completed and product construction begins, it is not desirable to review the design phase again. At the other extreme is the adaptive development approach. It is formally defined as "a development approach in which the requirements are subject to a high level of uncertainty and volatility and are likely to change throughout the project [5]." Note that this term is commonly known as agile; we prefer an adaptive approach for many reasons, including the fact that the global standard [5] formally embraces it. The term adaptive approach also addresses alternate paradigms like iterative

delivery models such as the spiral model, which is not typically associated with the agile approach.

II. ENGINEERING EDUCATION AND ENTREPRENEURSHIP

Let us broadly address the topic of engineering education and entrepreneurship within this paper's context. How do engineering schools nurture entrepreneurial skills when educating students? Analysis of several curricula learning outcomes and assessment literature emphasizes developing competencies in teaching students to *generate ideas* for creating a technological application and having students practically *build* it. This approach is also known as project-based learning (PBL) in engineering education [7, 8]. PBL is an instructional method in which students learn by actively engaging in investigating and solving real-world problems, often focusing on creating a technological product or application.

PBL can develop entrepreneurship competencies by providing hands-on experience implementing a project idea. Students start with solving a problem or addressing an opportunity. They develop skills in identifying market needs, developing and testing new ideas, and creating a viable business plan. Throughout the project, students are encouraged to think creatively and take risks. At the same time, they are learning to work collaboratively and manage their time effectively. Also, the industry has been demanding an education model that targets real market practices accurately, for instance, completing projects subject to numerous restrictions of time, budget, and other resources required for its development [9].

From an education perspective, it is helpful to consider categories of PBL competencies to assess them. One can consider many categories for assessment, such as knowledge and skills, attitudes and values, professional and personal development, technical competencies, teamwork competencies, and problem-solving competencies. To illustrate, let us consider one such approach adopted by a university in Denmark [10]. At this university, across all engineering disciplines, students are systematically introduced to and assessed on their PBL competencies throughout their education using three categories of competencies: problem-oriented, interpersonal, and structural used to evaluate students. See Table 1 – Project Based Learning (PBL) Competencies where selected attributes are listed. We specifically note the emphasis on *structural competencies* where skills acquisition in project management, agile management, and project delivery approaches are assessed. Our research addresses this aspect.

TABLE I. PROJECT BASED LEARNING (PBL) COMPETENCIES [10]

Problem-Oriented Competences	Interpersonal Competences	Structural Competences
Problem identification Problem types	Team building Team culture Team roles	Project Management (Product Management)

Methods for problem analysis.		
Creativity	Digital collaboration, and communication strategies	Delegation of work and team roles
Understanding, cultural contexts	Managing diversity Conflict prevention and management Creating a constructive dialogue	Setting objectives Defining and structuring activities
Sustainability; UN Global goals; Ethics	Decision making processes	Agile management
Problem formulation, and criteria for problem-solving	Collaboration within teams and groups, and with stakeholders supervisors and external partners	Time and activity management (delivery)

III. RESEARCH QUESTIONS AND OBJECTIVES

Our goal is to address the following key questions:

- a) What are the defining characteristics of predictive, adaptive, and hybrid approaches?
- b) Can we implement a simple decision-making framework tool to recommend a development approach?

These are important questions as they pertain to needs analysis and requirements delivery. These questions address universal concerns about product scope and requirements engineering. The features and functions that characterize the product scope solution are not always well-defined, and the following are common concerns acknowledged in the literature [7]:

- The initially defined requirements may be flawed, irrational, or unrealistic.
- The initial assessment fails to consider unknown risks and changing economic and environmental conditions.
- Analysts base the product scope and project statement of work on a stationary rather than a moving target for the final business value.

While an *adaptive* development approach can solve many such universal concerns, it is essential to note that the traditional *predictive* development approach can effectively address the above concerns equally. These development approaches can be broadly seen as two extremes in their goals and implementation.

A *predictive approach* is considered when the project and product requirements can be defined, collected, and analyzed at the start of the project. A project life cycle that is structured to execute sequentially along a linear path is preferred for the predictive approach.

An *adaptive approach* is considered when the project and product requirements are not easily defined at the start of the project. A flexible project life cycle that executes iteratively is preferred for the adaptive approach.

The defining characteristics of predictive and adaptive stand in stark contrast as follows [11]:

Predictive: Low-risk tolerance, supports economies of scale, less need for innovation, integrates well with the hierarchical culture

Adaptive: Higher risk tolerance, need for innovation, suitable in culture teams can self-organize and self-manage

Note that between the two extremes, a continuum *hybrid approach* exists. Hybrid approaches are increasingly being considered in organizations today. As we can assume, the term hybrid falls in a large spectrum in the middle. The global standard formally defines this term as “a combination of two or more agile and non-agile elements, having a non-agile end result [5].” This can include a development approach that uses predictive at the front end and agile at the back-end, or vice-versa. It can also include features of both tightly intertwined. For instance, we integrate team practices such as daily standups and retrospectives into traditional predictive development approaches. Unofficial terms such as *Wagile*, which refers to Waterfall blended with Agile practice, are used by some practitioners to communicate that it is possible to conduct a predictive planning phase and follow up with adaptive product delivery. Alternatively, organizations can run adaptive projects within the scope of a larger predictive project—for example, an e-commerce app inside an ERP.

Project management books today address both predictive and agile approaches. Sometimes they are presented as integrated topics, such as [12], or with distinct, separate parts, such as [13]. The new standards address the role of predictive, adaptive, and hybrid approaches [5]. The success of adaptive frameworks is tied to the reality that a product's scope and backlog can change anytime. Customers are encouraged to communicate new priorities and even describe alternate specifications. Stable requirements do not necessarily imply that risks are low. The success of the adaptive approach is tied to the reality that a product scope and its backlog can change anytime. Customers are encouraged to communicate new priorities and even describe alternate specifications.

A quick note on the *agile approach*. The agile approach refers to a development approach where minimum viable increments are released in increments. A unique characteristic of the agile approach is that work is refined iteratively as needed. When stakeholders are satisfied with a working increment, it is released to the customers. Scrum is the undoubted leading framework for agile approaches. Iterative refinement and incremental delivery occur in the Scrum framework. Scrum founders have written engaging and convincing books that conclude that any project, small or large, can and should be implemented using this framework [14, 15].

Today, agile and adaptive methods are successfully emerging from their shells in the software sector into other disciplines and industry domains—Gustavsson [16] documents in a literature review where and how this is occurring. However, the subject of which project should be delivered using a predictive approach and which using the agile approach continues to be an absorbing topic even to the converts. Consider what Canty [17] writes, "Many projects have achieved successful outcomes with agile implementations. On the other hand, some organizations are very cautious about forging ahead with agile. This guarded approach is based upon the acknowledgment that the agile framework is not appropriate for every project. How does an organization know when to select agile rather than the waterfall model for software development? The answer is not always simple."

The interest in agile continues to be associated with entrepreneurial activity and innovation in general. Books on this topic, such as Agile Innovation – The Revolutionary Approach to Accelerate Success, Inspire Engagement, and Ignite Creativity, provide good insight into how this happens [18]. It is, therefore, valuable for us to research a decision-making framework that can guide the engineer involved in entrepreneurial activity.

IV. A DECISION-MAKING FRAMEWORK TO GUIDE THE DEVELOPMENT APPROACH

We introduce two distinct groups of attributes as a starting point for researching a suitable decision-making framework--Product environment and Project & Organization environment. These attributes are well-researched and documented in the latest global standards [5]. The proposed decision-making framework intuitively groups them to propose an innovative tool to guide any product or project development approach.

Product Environment

Attributes such as degree of innovation, requirements certainty, scope stability, and ease of change represent constitute the product environment in the framework.

Selected product environment criteria are summarized below and classified into three columns adaptive, hybrid, and predictive introduced earlier. They provide an appreciation of their differences.

TABLE II. CHARACTERISTICS OF THE PRODUCT ENVIRONMENT

Attributes	Adaptive	Hybrid	Predictive
Degree of Innovation	Highly innovative deliverables are less understood and are developed over time.	Highly innovative – incremental or iterative delivery needed.	Incremental innovation or known project scope.
Requirements Certainty	The full set of requirements is unknown at the	Some of the requirements are known in	Requirements are known in the initiation phase.

	initiation phase.	the initiation phase.	
Scope Stability	There is a high likelihood that scope will change during the project implementation.	The scope is partially known. It might be stable but the risk can be high.	Scope is relatively well known and major changes are unlikely.
Ease of change	Deliverables can easily be adapted.	Some deliverables cannot be changed. Some can be adapted.	Nature of deliverables makes it difficult to incorporate change.
Product delivery	Adaptive approaches can have multiple deliverables.	Multiple deliverables.	Single delivery at the end.

		for deliverables.	governmental contracts.
Project: Compliance	Less desirable approach unless a business analyst is dedicated full-time to ensure compliance.	Components that involve regulation & compliance planning can be conducted upfront using a predictive approach.	Detailed upfront planning is possible to comply with assorted rules and regulations..
Organization: Structure	The structure is not very hierarchical. The project sponsoring departments and teams are empowered.	Some parts of the organization have a flexible structure.	Rigid organizational structure.
Organization: Culture	Teams are encouraged to self-manage and self-organize,	Teams involved with incremental value delivery are empowered and self-manage and self-organize.	Believes in planning work in detail and is set up to manage and direct employees.
Organization: Capability	Has an agile-mindset and believes in reorganizing to deliver adaptive projects.	Organization might be in transition.	Organizational policies and way of working is targeted to delivering projects with predictive outcomes.

Project & Organization Environment

This section describes two cognate areas that influence the development approach. We review project criteria and organization criteria that can impact the recommended product delivery approach.

The project-based criteria are a good starting point for researching a decision-making framework involving a student of the project environmental factors [5]. Project variables influencing the development approach involve stakeholders, schedule constraints, and funding availability. The organization criteria represent variables such as structure, culture, and capability and are a good starting point for researching a decision-making framework involving organizational factors [5].

These attributes are self-explanatory and are not defined further. The project and organization environment criteria are summarized below and classified into three columns.

TABLE III. CHARACTERISTICS OF THE PROJECT AND ORGANIZATION ENVIRONMENT

Attributes	Adaptive	Hybrid	Predictive
Project: Stakeholders	Stakeholders take an active role, like product owner etc., in the project execution.	Stakeholders are needed whenever – incremental or iterative delivery occurs.	Stakeholders are not directly involved in the project execution.
Project: Schedule Constraints	Short-term, partial iterative deliveries are requested.	Schedule is based on fixed milestones. Certain deliverables have schedule flexibility.	Schedule is based on fixed milestones that do not allow for flexibility.
Project: Funding Availability	A flexible funding model is needed.	Funding is largely fixed but some flexibility	Funding is based on fixed budgeting, like

V. FRAMEWORK & USE CASE

Analysis of the variables presented in Tables II and III led us to model a framework we call the PPO Framework, representing the acronyms Product, Project, and Organization for convenience. See Figure 1: PPO Framework for guiding development approach.

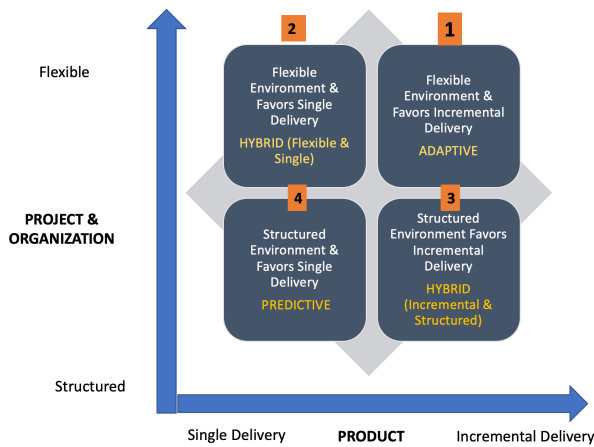


Figure 1: Product, Project & Organization (PPO) Environment Framework for Guiding Development Approach

On the *x-axis* of the PPO framework, we describe the product and focus on the range from *single* or *incremental* delivery.

TABLE IV. CHARACTERISTICS OF THE PRODUCT ENVIRONMENT CLASSIFIED BY DELIVERY

Degree of Innovation	<ul style="list-style-type: none"> Incremental delivery due to the refinement of a new or existing product implies that several iterations will occur. Feedback obtained from the customer for incremental work completed. On the other end, some products especially hardware cannot be released incrementally. The product has to be well planned and launched when fully done, such as a new smartphone delivered with the targeted features. This is considered as a <i>single delivery</i>.
Requirements Certainty	<ul style="list-style-type: none"> If the requirements are well understood it favors <i>single delivery</i>. Otherwise ongoing requirements engineering will reveal opportunities for <i>multiple deliveries</i>.
Scope Stability	<ul style="list-style-type: none"> If the project's objectives, requirements, and deliverables remain unchanged throughout the project's lifecycle it favors <i>single delivery</i>. Otherwise, <i>incremental delivery</i> is favored. The scope of each delivery is established at the beginning of each iteration and can be adjusted as necessary based on the feedback received from the previous iteration.
Ease of change	<ul style="list-style-type: none"> If a project team can modify the project's objectives, requirements, or deliverables during the project's lifecycle can result in several <i>incremental deliveries</i>. Otherwise, the outcome is likely going to be <i>single delivery</i>.

On the *y-axis* of the PPO framework, we describe the Project & the Organization environment classified by Structure ranging from *structured* to *flexible*.

TABLE V. CHARACTERISTICS OF THE PROJECT AND ORGANIZATION ENVIRONMENT CLASSIFIED BY STRUCTURE

Stakeholders	<ul style="list-style-type: none"> In an adaptive environment, stakeholders are classified as <i>flexible</i>; they are often more actively involved in the project's development and decision-making process. The focus is on collaboration, communication, and rapid feedback. In a predictive environment, the stakeholders may be more passive and less directly involved in the project's development. The focus is on planning and supporting the project according to a pre-defined <i>structured</i> plan.
Schedule Constraints	<ul style="list-style-type: none"> In an adaptive environment, schedule constraints are often more <i>flexible</i> than in a predictive environment. The focus is on rapid feedback and adapting the project's objectives and deliverables to changing requirements. This allows the project team to work in shorter, iterative cycles. In a predictive environment, there is a need for <i>structure</i> and predictability as it pertains to schedule or cost.
Funding Availability	<ul style="list-style-type: none"> In an adaptive environment, funding is often more flexible. Work that is not important is moved out of scope providing additional <i>flexibility</i> for funding work that is on the critical path. In a predictive environment, funding is typically more <i>structured</i> and tightly controlled.
Compliance	<ul style="list-style-type: none"> In an adaptive environment, compliance and regulation may be more difficult to manage. Due to incremental deliveries, the project's objectives and deliverables are fluid and in flux. There is a need for <i>flexibility</i> if it can be accommodated. In a predictive environment, compliance and regulation can be tightly controlled. Compliance projects need a <i>structured</i> approach.
Organization and culture	<ul style="list-style-type: none"> In an adaptive environment, the organization and culture is more <i>flexible</i> and favorable. This includes breaking down organizational silos and supporting cross-functional teams. The focus is on rapid feedback and serving the project's objectives and deliverables to changing requirements. In a predictive environment organization and culture may be more structured and hierarchical. The focus is on planning and executing the project according to the formally approved requirements plan. This requires a more <i>structured</i> approach.

Below we illustrate a summary of the four quadrants with a tangible example.

Quadrant 1: Adaptive

- Flexible Environment
- Favors Incremental Delivery

Example: Creative software development in the IT sector. This approach is suitable for projects with evolving requirements and a need for continuous improvement, making it suitable for software development where customer feedback and changing technologies can lead to frequent changes in project requirements.

Quadrant 2: Hybrid (Flexible & Single)

- Flexible Environment
 - Favors Single Delivery
- Example: A design-thinking human-centered approach to innovation that involves iterative prototyping and testing. This approach maintains flexibility in the project organization and structure while focusing on a single delivery. It allows for adjustments based on user feedback throughout the development process.

Quadrant 3: Hybrid (Incremental & Structured)

- Structured Environment
 - Favors Incremental Delivery
- Example: Furnish to rent out office space. A new center for artists and musicians is being furnished. There is market uncertainty about demand and whether artists would be willing to rent suites in the new location. The project is broken down into smaller increments. Each suite involves planning, design, construction, and deployment phases, allowing for customization and incremental release of a working suite.

Quadrant 4: Predictive

- Structured Environment
 - Favors Single Delivery
- Example: Building a home, a bridge, or a new smartphone. These projects often have well-defined requirements and follow a traditional project management approach. The environment is structured, and the projects aim for a single delivery, making it suitable for construction or product manufacturing.

		visual visits to art galleries. The project builds on success.	
3	Buddy App	Provide opportunities for students to network within college environment.	Quadrant 1: Adaptive
4	Greendoor	Collect data and create a database. Create an app that rates sustainable organizations for employment purposes.	Quadrant 2: Hybrid
5	Sustainable & Zero Waste Cosmetics App	An e-commerce app that promotes make-up and cosmetics sales of zero-waste products.	Quadrant 4: Predictive
6	Universal Charger Rentals	Chargers for rent or purchase for laptops and mobile devices.	Quadrant 3: Hybrid
7	Swift Home: Don't Buy - Reuse	Swift home app provides graduating students to sell their goods to incoming students.	Quadrant 2: Hybrid
8	Sustainable Food Curriculum App	Literacy about sustainable food practices and minimizing food waste.	Quadrant 3: Hybrid

VI. BENCHMARKING AND FUTURE DIRECTIONS

We identified eight entrepreneurial projects to benchmark against the PPO framework. The group projects were initially planned in the Fall of 2022 with the help of experts consisting of practitioners and faculty. We illustrate the classification of the PPO framework and recommended development approach using actual projects in Table VI.

TABLE VI. BENCHMARKING PROJECT DEVELOPMENT APPROACH USING THE PPO FRAMEWORK

No.	Project	Description	Development Approach
1	Graduation Gown Recycling Project	Work with University to recycle gowns there were discarded by students upon graduation.	Quadrant 4: Predictive
2	Digital Art Gallery	The Pandemic resulted in promoting	Quadrant 1: Adaptive

Note that at the outset to minimize complexity, we did not classify the hybrid projects further into flexible & single or incremental & structured when the projects were initially assigned to students. As such, the student teams were asked to implement their projects using either predictive, hybrid, or adaptive delivery modes based on the characteristics of the PPO attributes. Upon project completion, it is possible to determine if a specific development approach proved to be successful. A questionnaire was designed for such purposes, and a jury of experts was tasked to assess project success.

For further research, the impact of the risk dimension needs to be investigated further in the framework. There is a preference for aligning high risks with an adaptive approach for reasons explained below:

- *Adaptive Approach* – Consider the case of organizational culture. In the adaptive approach, failure is not punished. Failing fast is the key. The success of agile frameworks is tied to the reality that a product scope and its backlog can change anytime. Teams are encouraged to innovate and communicate with the customers about new opportunities as new learning occurs. Customers are encouraged to reprioritize. High risks can be mitigated with modular design and development. For instance, “spiking” high-risk features is possible in a feasibility study to confirm an architectural design. This can reduce project risk.
- *Predictive Approach* – High upfront project risk analysis occurs. This requires significant effort and upfront planning. A product involving high risk is not necessarily out of scope. They are planned in considerable depth before construction begins. However, having well-

planned project needs can be classified as high-risk for the following reason: Unforeseen technical issues or design might be discovered later in the predictive development process leading to project challenges and even failure. For example, the project team might need to investigate factors outside their control, such as supply chain delays.

Also, a web-based tool based on the framework needs to be completed. This would make it convenient for student teams to assess their project and select a development approach. Currently, a tool using a decision tree approach is being developed.

VII. IMPLICATIONS FOR ENGINEERING EDUCATION

The research described above provides valuable insights for engineering education. Successfully managing project and product risk is core to the entrepreneurial approach. Additionally, we must educate students on the product delivery approach - predictive, hybrid, or adaptive, so that they can select an appropriate method when they are involved in a PBL project. Enhancing project management skills: Engineers learn to choose and apply the most suitable project management methods for specific projects, leading to improved execution and increased chances of successful outcomes. The competencies developed when considering the framework introduced in this paper are:

- Encouraging adaptability: Understanding the importance of flexibility and adaptability prepares engineers for the ever-changing landscape of technology and innovation.
- Fostering entrepreneurial critical thinking and problem-solving: Exposure to diverse delivery models enables engineers to develop a problem-solving mindset and make informed decisions
- Developing collaboration and communication skills: Working on Adaptive or Hybrid projects requires close interaction with stakeholders and team members, fostering robust collaboration and communication skills crucial for any engineer.
- Strengthening risk management: Awareness of the risk factors associated with different project environments and delivery models helps engineers better manage and mitigate risks, especially in projects with high uncertainty and complexity.

We want to conclude with an important note. Due to individual preferences or understanding of the project due to uncertainty, the outcomes might vary. For example, an individual might have a different perspective when weighing specific criteria such as *organization, culture, or degree of innovation*.

VIII. CONCLUSION

Selecting an appropriate development approach is a challenge for many innovative products. At the extremes, we have two distinct paradigms adaptive and predictive. Both have advantages and significant limitations. Various criteria were introduced in this paper that laid the groundwork for an intuitive framework to guide the selection of a product development approach.

Finally, while the paper has targeted project managers and product engineering professionals, the concepts are of value to

senior executives as well since they need to lead and manage innovations within their enterprise [19]. Indeed the framework notes that some attributes are grounded in organizational culture and practices. Leadership from senior executives is crucial in reshaping the organizational culture and driving innovation when it comes to successful solution delivery.

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