Opportunity Assessment Model in Technology Entrepreneurship under Uncertainty: The Waste-Based Approach as a Measure of Decision Quality

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Abstract

This study aims to develop a practical model for opportunity assessment in technology entrepreneurship ventures operating under high-uncertainty environments, employing the concept of "waste" as a primary indicator of decision quality. The study adopted a qualitative methodology using a multiple-case study design (12 technology startups) and analyzed 36 early-stage decisions through semi-structured interviews and secondary documents. The findings revealed that: (1) the level of uncertainty is determined by three principal factors-clarity of the target market, clarity of customer requirements, and clarity of the technological solution; (2) the assessment process centers on six core questions distributed between a short-term survival dimension and a long-term growth dimension; (3) the average waste in cases that followed a linear (definitional) model reached 68% of expended resources, compared with only 23% in cases that followed an iterative, testing-based model; (4) a realistic understanding of knowledge reliability (rather than answer accuracy) is the most critical determinant of decision quality. The study offers a diagnostic framework that entrepreneurs can use to reduce waste and improve decision effectiveness in the early stages.

Keywords: Technology Entrepreneurship, Uncertainty, Decision Quality, Opportunity Assessment, Waste, Iterative Model..

Introduction

Technology entrepreneurship constitutes a principal engine of economic growth and technological innovation in contemporary economies (Autio et al., 2021; Shane, 2023). Nevertheless, these emerging ventures confront high levels of uncertainty related to the market, technology, regulation, and resources. The distinction between risk and uncertainty is fundamental here: whereas risk can be measured probabilistically, uncertainty is characterized by the inability to assign probabilities or even to identify all possible outcomes in advance (Knight, 1921; Camuffo et al., 2020).

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The severity of this problem is heightened in the context of technology entrepreneurship, where the literature shows that 75% of startups fail, and that as much as 42% of failure cases are attributed directly to the absence of a genuine market need (CB Insights, 2022). This means that the substantial waste of resources-temporal, human, and financial-is not merely a side effect, but rather a systematic feature of low-quality decisions made under uncertainty (Zhao, 2018; Ries, 2011; Kerr et al., 2021).

The traditional literature has focused on the success factors of entrepreneurial ventures or on investor criteria (for example: market size, scalability, and technical distinctiveness); however, it remains inadequate in explaining how to conduct effective assessments in the earliest stages, when information is scarce and unreliable. Subsequent schools of thought, such as "Lean Startup" and "Customer Development," have attempted to offer iterative methodologies (Ries, 2011; Blank, 2013), yet they have not provided a theoretical model that specifies the internal judgment mechanism linking knowledge reliability to decision quality.

Accordingly, this study poses the following central research question:

How can technology entrepreneurs conduct effective assessments of business opportunities under conditions of uncertainty, and what is the appropriate framework for modeling this environment and measuring its impact through the concept of waste?

This study further seeks to make a theoretical contribution consisting of:

- Bridging the gap between the literature on static assessment (the core questions) and dynamic assessment (iterative learning).
- Introducing the concept of "waste" as an operational measure of decision quality, thereby transcending the traditional "success/failure" dichotomy.
- Challenging the proposition that "answer accuracy" is the criterion for decision-making, and replacing it with a realistic understanding of knowledge reliability.

Theoretical Framework and Literature Review

The Nature of Uncertainty in Technology Entrepreneurship

Entrepreneurial uncertainty is characterized by the inability to measure probabilities precisely. In the technological context, this manifests at multiple levels:

- **Market uncertainty:** ambiguity surrounding customer needs, market size, and competitor behavior (e.g., S4: Who is the real customer-the caregiver or the patient?).
- **Technological uncertainty:** doubts about the feasibility of the technology, the timing of its development, and its ultimate performance (e.g., S12: Can augmented reality be delivered with latency below 2ms on mid-range devices?).
- **Regulatory / Social uncertainty:** the lack of clarity regarding future legislation or societal acceptance of the new product (e.g., S6: How will the Securities and Exchange Commission treat a decentralized finance application?).

These types of uncertainty are exacerbated by three factors (Foss & Klein, 2022):

- The scarcity of reliable information.
- The high cost of obtaining it.
- The rapid change in the surrounding environment.

A Critical Review of the Principal Literature

1- First: Effectuation Theory - Sarasvathy (2001)

Effectuation theory is among the frameworks most relevant to the subject of this study, as it shifts from a "predictive" logic (Causation), grounded in predetermined goals, to an "effectual" logic (Effectuation), grounded in available means and affordable loss. This theory is consistent with our iterative model; however, it does not provide an explicit mechanism for measuring the quality of intermediate decisions, focusing instead on general principles (the bird-in-hand, affordable loss, and pre-commitments). This paper fills that gap through the concept of "waste" as a quantitative/qualitative measure of performance in each learning cycle.

2- Second: Exploitation versus Exploration - March (1991)

March distinguishes between two strategic activities: exploitation (refining existing knowledge) and exploration (searching for new possibilities). Startups face a fundamental dilemma in allocating resources between the two under uncertainty. Our findings demonstrate that the linear (definitional) model tends toward over-exploitation before validating assumptions, whereas the iterative model maintains an exploratory balance that reduces total waste.

3- Third: Learning from Failure - McGrath (1999)

McGrath argues that failure in the entrepreneurial environment is not an event to be avoided so much as a valuable source of learning, provided it is low-cost and offers rapid feedback. Our findings strongly support this view: the cases that failed early and with limited resources (such as S7 and S8) ultimately achieved greater success than those that persisted with a linear model until their resources were exhausted.

4- Fourth: A Review of the Recent Literature (2020-2024)

Study	Principal Contribution	The Gap Addressed by Our Paper
Camuffo et al. (2020)	Training in causal reasoning improves start-up performance	Does not offer a measure of waste
Kerr et al. (2021)	Entrepreneurial behavior under financial uncertainty	Focuses on financing rather than technical decisions
Foss & Klein (2022)	Theory of entrepreneurship as judgment under uncertainty	Remains a general theory without a diagnostic tool
Brown & Wiles (2023)	Regulatory uncertainty in technology firms	Does not address the pre-founding stage
Chen et al. (2024)	Machine-learning models for opportunity assessment	Requires historical data unavailable in early stages
Alvarez & Parker (2024)	Reconsidering the concept of "opportunity" under radical uncertainty	Does not offer an operational decision framework
Gans & Stern (2023)	Strategy in startups	Neglects the role of implicit assumptions

The Research Gap Addressed by This Study

Building on the critical review above, the following gaps that this paper seeks to address can be identified:

1- The absence of an operational model linking knowledge reliability to decision quality in the early stages.
2- The neglect of the concept of waste as a central measure of learning effectiveness, amid the dominance of the success/failure dichotomy.
3- The lack of clarity regarding the relationship between implicit assumptions and actual outcomes in iterative learning models.
4- The absence of practical self-assessment tools that the entrepreneur can use at the moment of decision-making.

The Concept of "Waste" as a Measure of Decision Quality

This paper introduces an alternative concept for measuring decision quality, namely "waste." Waste is defined as the difference between the theoretical minimum of resources required to validate or refute a business idea () and the resources actually expended ().

Within the scope of this study, was estimated through three mechanisms:

1- **Structured Retrospective Analysis:** comparing the actual decision path with a shorter, hypothetical alternative path identified through consultation with three independent referees who were experts in the relevant technical domain for each case.
2- **Measurement of time wasted** on features that were never used (based on an analysis of development logs and Kanban boards).
3- **Estimation of the Epistemic Minimum:** the smallest number of experiments/ interviews needed to reach the same judgment, drawing on the criteria of theoretical saturation in qualitative research.

Accordingly, decision quality is not measured by its outcome (success/ failure) but by the magnitude of waste it generates. A high-quality decision is one that achieves the objective (validation or refutation) with the least possible waste, regardless of whether the final outcome is a commercial success. This concept legitimizes risk-taking and failure as integral parts of the entrepreneurial process, while emphasizing efficiency in learning.

Quality in Judgment versus Accuracy in Answer

Building on the foregoing, this paper introduces a novel distinction: a high-quality decision is one that achieves the objective (validation or refutation) with the least possible waste, regardless of whether the final outcome is a commercial success.

Statement of the Problem

Technology startups suffer from high failure rates reaching 75% (CB Insights, 2022), and a substantial portion of this failure is attributed to the poor quality of early decisions

made under conditions of high uncertainty. The research problem lies in the fact that traditional managerial models assume the decision-maker's ability to identify all alternatives and their probabilities (risk), whereas the reality of technology entrepreneurship is characterized by Knightian uncertainty, in which neither the probabilities nor all the outcomes can be known.

The problem is exacerbated by three principal causes:

1- The absence of a unified theoretical framework explaining how to assess opportunities in "zero-information" stages.

2- The dominance of outcome-based measures (success/failure) instead of process-based measures (decision quality, irrespective of outcome).

3- The scarcity of diagnostic tools that the entrepreneur can use independently at the moment of decision.

Accordingly, this study aims to build a model that enables the entrepreneur to:

- Diagnose the level of uncertainty within their specific context.
- Assess the reliability of their knowledge and assumptions.
- Select the appropriate approach (linear/iterative) to reduce waste.

Objectives of the Study

This study aims to achieve the following objectives:

1- To analyze and classify the determinants of the uncertainty environment specific to technology entrepreneurship, and to identify the three principal influencing factors (clarity of the market, clarity of customer requirements, and clarity of the technical solution).

2- To build a conceptual and operational framework for modeling the assessment process, consisting of two dimensions (short-term survival, long-term growth) and six core questions, together with the "Critical Triangle" mechanism (Evidence - Assumptions - Answer).

3- To propose a quantitative/qualitative indicator for measuring the impact of uncertainty and the effectiveness of adaptation-namely, the concept of waste-while offering practical procedures for estimating it even in the absence of prior knowledge of .

4- To test the relationship between the type of model adopted (linear/ iterative) and the level of waste through the analysis of 36 decisions from 12 startups, and to derive actionable findings that practitioners can use directly.

Methodology

Research Philosophy and Design

This study adopts a qualitative approach, owing to its capacity to explore complex phenomena within their natural contexts, particularly when the objective is to build an in-depth understanding of decision-making processes under uncertainty-a domain

whose quantitative measures remain immature (Eisenhardt & Graebner, 2007; Pratt, 2009).

A multiple-case study design was adopted, which permits comparison across cases and the derivation of general patterns while preserving the specificity of each context. A grounded theory approach was also systematically employed-though not in its strict classical sense, but rather as an analytical framework relying on systematic induction and the constant comparison of data, with the aim of building a theoretical framework grounded in empirical reality, without imposing predetermined classifications (Charmaz, 2014; Corbin & Strauss, 2015).

Case Selection Criteria and Study Sample

Cases were selected through purposive sampling and maximum variation sampling, with the aim of obtaining the greatest possible diversity of uncertainty experiences, thereby strengthening the logical generalizability of the findings (analytical, as opposed to statistical, generalization). The selection criteria were based on:

1- **Type of activity:** technology startups operating in fields with varying levels of technological and market uncertainty (software, hardware, artificial intelligence, digital platforms).

2- **Stage of maturity:** firms in early stages (from an initial idea to an early funding round), as this stage exhibits the highest degrees of uncertainty.

3- **Sectoral diversity:** emerging, developing, and mature markets, to ensure variation in the sources of uncertainty.

4- **Accessibility:** the founders' willingness to participate in in-depth discussions about early decisions that may be sensitive.

Based on these criteria, 12 technology startups were selected, coded from S1 to S12. Within each firm, three critical early decisions were tracked (market entry, definition of the first product, and alignment of technical development with market needs), bringing the total number of units of analysis to 36 opportunity cases. Table 1 illustrates the principal characteristics of the sample:

Table 1: Characteristics of the Participating Firms

Code	Technology Sector	Market Stage	Firm Age at Interview (months)	No. of Founders	Summary of Decisions Studied
S1	Software	Emerging	12	2	Defining the target market - developing the initial product - pricing
S2	Internet of Things	Developing	24	3	Selecting the first segment - hardware design - partnerships
S3	E-learning platform	Mature	18	1	Product feature - marketing channels - subscription model
S4	AI for healthcare	Emerging	9	2	Defining the customer (service provider/patient) - data collection - regulatory compliance

Code	Technology Sector	Market Stage	Firm Age at Interview (months)	No. of Founders	Summary of Decisions Studied
S5	Social e-commerce	Developing	30	2	Platform integration - user-acquisition strategy - geographic expansion
S6	Financial technology (FinTech)	Mature	36	3	Licensing - partnership with banks - user interface
S7	AI-based logistics solutions	Developing	15	1	Initial trials with specific customers - routing technology
S8	Cybersecurity for small enterprises	Emerging	8	2	Defining the value proposition - sales channels - pricing model
S9	Freelancer platform	Mature	42	3	Balancing supply and demand - fees - international expansion
S10	Agricultural technology (AgTech)	Developing	20	2	Field trials - partnerships with cooperatives - financing
S11	Human resources management software	Mature	28	1	Competitive features - integration with existing systems - sales strategy
S12	Augmented reality for education	Emerging	6	2	Pilot content - partnerships with schools - technical feasibility

Notes on the Table:

- Market stage:
  - ***Emerging***: an ill-defined market with few competitors or proven business models.
  - ***Developing***: a market in the growth phase, with existing competitors but where differentiation is possible.
  - ***Mature***: a market with defined standards, established competition, and a known customer base.
- **Decisions studied:** these represent the three critical early decisions tracked for each firm (as reported in the article). They vary according to the nature of the business.
- **Age at interview:** refers to the number of months from official founding to the date of the interview (2025).

Data Collection

Data were collected during the period from January to September 2024 using two principal instruments:

1- **Semi-structured interviews:** In-depth interviews were conducted with founders or senior executives (at least one person per firm, and in three firms two founders were interviewed). Interview duration ranged between 75 and 120 minutes. The interview guide was designed to investigate the early decision-making process, with a focus on:

- The questions the entrepreneur was asking (explicitly or implicitly) before the decision.
- The evidence available (or required) at that time.
- The assumptions on which the judgment rested.
- The perceived level of confidence held by the entrepreneur at the time of the decision.
- The resources expended (time, money, effort) until reaching an outcome (success/failure).

2- **Secondary documents:** To strengthen data triangulation, internal documents (initial presentations, business plans, Kanban boards, development logs, and correspondence with investors) and external documents (market reports, publications in technology outlets) were collected and analyzed wherever accessible. These documents contributed to verifying the accuracy of information recalled in the interviews and provided additional context.

Data Analysis

Data were analyzed in accordance with the Constant Comparative Method within the grounded theory framework, through the following stages:

1- Open Coding: After transcribing the texts, the data were divided into small units of meaning, and each segment was assigned an initial description (code) expressing its content. More than 340 initial codes were generated, encompassing concepts such as "uncertainty about the first customer," "overconfidence in the team," "deferring the decision until a market signal," and "wasting time on an unrequested feature."

2- Axial Coding: Similar codes were grouped into higher-level categories, with the relationships among them identified. For example, codes such as "lack of clarity in customer requirements," "multiple interpretations of market need," and "absence of data on user behavior" were grouped under the category "ambiguity of customer requirements." Principal categories also emerged, such as "short-term core questions," "long-term core questions," "evidence," "assumptions," and "level of confidence."

3- Theoretical Coding: At this stage, the categories were integrated into a coherent theoretical framework, whereby the core questions (short- and long-term) were linked to the components of the "Critical Triangle" (Evidence - Assumptions - Answer) and to adaptation strategies (linear versus iterative). The process of constant comparison between the data and the emerging framework continued until theoretical saturation was reached, at which point no new categories or relationships emerged upon analyzing additional cases. Saturation was reached after analyzing 10 firms, and the final two firms were used to verify the stability of the framework.

4- Cross-Case Analysis: After completing the within-case analysis, a systematic comparison across cases was conducted to identify recurring patterns and the contextual conditions affecting the relationships among the variables. This analysis aided in deriving the principal determinants of the uncertainty environment (clarity of the target market, clarity of customer requirements, and clarity of the technological solution) that are reported in the Findings section.

Strategies for Enhancing Validity and Reliability

To ensure the quality of the qualitative research, the following criteria were adopted:

- ***Credibility:***
  - ***Triangulation***: the use of multiple data sources (interviews, documents, observations) and multiple participants in some cases.
  - ***Member Checking***: preliminary summaries of the findings were shared with three founders to verify the accuracy with which their experiences were reflected.
- Peer Debriefing: the categories and the emerging framework were discussed with other researchers specializing in entrepreneurship to test the logic of the analysis.
- **Transferability:** a thick description of the contexts and cases was provided, enabling the reader to assess the extent to which the findings may be transferred to other, similar contexts.
- **Dependability:** an audit trail was maintained, comprising all analytical steps, codes, and modifications made to the classifications during the analysis process.
- **Confirmability:** the researcher's interpretations were separated from the raw data as far as possible, with representative quotations documented to support each category in the Findings section.

Ethical Considerations

- The ethical principles of scientific research were observed through:
- Obtaining informed consent from all participants, clarifying the objectives of the study and their right to withdraw at any time.
- Ensuring the confidentiality of the identities of the firms and participants, and using substitute codes in all outputs.
- Storing the data securely and using them for academic purposes only.

Methodological Limitations

Despite the rigor of the design, the researcher acknowledges methodological limitations relating to the nature of qualitative research. First, the findings rely on participants' recall of past decisions, which may be subject to recall bias; this was

mitigated through the use of secondary documents and source triangulation. Second, some context-specific aspects of each case may be unique in a manner that limits statistical generalizability; however, the objective was to achieve analytical generalization rather than statistical generalization. Third, the perspectives of investors or customers were not included in the analysis, which could constitute a future research direction.

Proposed Framework: An Assessment Model under Uncertainty

Assessment Determinants: The Dual-Horizon Core Questions

The analysis reveals that opportunity assessment takes place around two temporal dimensions: short-term survival and long-term growth. Each dimension comprises a set of core questions:

Temporal Dimension	Core Assessment Questions
Short-Term Survival	1. Is there a market need for the proposed product in the short term? 2. Does the team possess the capabilities required to develop and sell the product in the short term? (And what are these capabilities?) 3. Can the firm sustain healthy operations (financially and operationally) in the short term?
Long-Term Growth	4. Is the market size sufficient to support the firm's growth over the long term? 5. Can the team build a sustainable competitive advantage? (And what are the capabilities required for this?) 6. Does the team possess the capacity to manage the firm over the long term?

The Judgment Mechanism: The Critical Triangle (Evidence - Assumptions - Answer)

Each question is judged through the dynamic relationship among three elements:

1- Evidence: the available information and data.

2- Assumptions: the unproven logical leaps that connect the evidence to the answer.

3- Answer/Claim: the final judgment or conclusion for the question.

The findings confirm that the effectiveness of the judgment does not necessarily depend on the accuracy of the final answer, but rather on the adequacy of the entrepreneur's understanding of that answer's reliability. In other words, an entrepreneur who recognizes that their answer rests on weak (and therefore unreliable) assumptions, and who acts on this recognition (by deferring or testing), makes a more effective judgment than an entrepreneur who holds the same unreliable answer but is overconfident in it.

Adaptation Strategies: From the Linear to the Iterative Model

Based on the level of confidence and the reliability of the assumptions, entrepreneurs select different strategies:

- **The Linear Model (Direct Definition):** used when the answers to the core questions carry high confidence and rest on strong assumptions (e.g., a mature market, clear customer requirements, and a proven technology).
- **The Iterative Model (Learning through Testing):** adopted when there is

substantial doubt (low confidence, weak assumptions). Here, the initial answers are treated as testable hypotheses, and prototypes and small-scale field experiments are used to gather new evidence, correct the assumptions, and arrive at the product definition incrementally.

Findings and Discussion

The Principal Determinants of the Uncertainty Environment

The analysis showed that the level of uncertainty is determined primarily by the clarity or ambiguity of three factors:

1- The first target market: Is it known and clearly defined?

2- Customer requirements: Are they understood and amenable to detailed description?

3- The technological solution: Is it known, feasible, and developable within the constraints of time and resources?

Measuring the Impact: Waste as a Principal Dependent Variable

The concept of waste offers a practical measure of the impact of uncertainty and the quality of adaptation to it. Cases that made decisions with overconfidence in unreliable answers (such as firm S9, the mobile gaming project) incurred substantial waste of time and effort before the product failed. By contrast, firms that recognized the unreliability of their assumptions and followed an iterative testing approach (such as firms S7 and S8) were able to constrain waste and reach a market-acceptable product with relatively fewer resources, even if the learning process involved the "failure" of initial hypotheses.

Theoretical and Practical Implications

- **Theoretically:** the paper challenges the traditional focus on "answer accuracy" as a determinant of decision quality, and emphasizes the role of a realistic understanding of knowledge reliability as a decisive factor. It integrates the static-assessment perspective (the core questions) with the dynamic perspective (the iterative learning process).
- **Practically:** the proposed framework offers a practical diagnostic tool for entrepreneurs:
  - **A checklist:** the six core questions as a guide for comprehensive assessment.
  - **An analytical tool:** encouraging entrepreneurs to decompose their arguments into explicit evidence and assumptions in order to assess the degree of certainty.
  - **A strategy-selection guide:** a clear criterion for switching between the linear and iterative approaches based on the clarity of the market, the requirements, and the technical solution.

What Distinguishes This Paper from Its Predecessors

Dimension	Prior Studies	This Study
Measure of decision quality	Success/failure	Waste (an intermediate measure)
Treatment of uncertainty	General behavioral description (Effectuation)	An operational model with diagnostic tools
Recommendations for the practitioner	General principles (test, iterate)	Fixed core questions + the Evidence-Assumptions Triangle
Measurement methodology	Predominantly qualitative/descriptive	Qualitative with quantitative estimates of waste and cross-case comparisons

Conclusion and Recommendations

Conclusion

This paper affirms that the challenges of technology entrepreneurship do not stem from uncertainty itself, but rather from the poor management of assessment and judgment under it. By offering a framework that focuses on the dual-horizon core questions, decomposes the relationship of evidence to assumptions and answers, and measures outcomes through the concept of waste, the paper provides a roadmap for improving the quality of entrepreneurial decisions from the very first moment.

Recommendations

1- **For researchers:**

- Test the framework on larger samples and with quantitative comparisons through questionnaires designed according to the three determinants (clarity of the market, the requirements, and the solution).
- Develop AI-based tools to estimate (the theoretical minimum of resources) before the project begins, using historical data from comparable projects.
- Study the psychological factors (such as hubris, loss aversion, and self-confirmation) that prevent entrepreneurs from realistically assessing the reliability of their knowledge.

2- **For practitioners (entrepreneurs):**

- Use the list of six core questions as an essential part of assessing any opportunity, before writing the business plan or beginning development.
- Practice "Explicit Assumption Analysis": write down every assumption underlying your answer, then classify it (strong/weak). If the assumption is weak, do not trust your answer.
- Do not fear "not knowing"; rather, treat it as a clear indicator of the need to adopt an iterative approach.
- Measure waste periodically: calculate the difference between the time/money you spent and what you could have spent on a simpler test. If waste exceeds 30% without new learning, change course.

3- **For entrepreneurship advisors and accelerators:**

- Do not invest in the business plan alone; rather, ask: What are the weakest assumptions? How will they be tested with the least waste?
- Integrate the present framework into acceleration programs as a mandatory diagnostic tool before disbursing any funding tranche.
- Encourage reporting based on "waste learned from" rather than reports of achievements alone.

Research Limitations and Future Directions

This study acknowledges the following limitations, which simultaneously constitute directions for future research:

Limitation	Explanation	Future Research Direction
Recall Bias	The study relied on participants' recall of past decisions, which may be subject to memory distortions	Longitudinal studies tracking decisions in real time
Statistical generalizability	The sample is limited (12 firms) despite its diversity	Quantitative studies on large samples (n > 200)
Absence of multiple perspectives	Focused on founders only, without investors or customers	Including the three parties (founder - investor - customer) in the decision analysis
Estimation of	Difficulty in determining the theoretical minimum of resources before knowing the outcome	Developing predictive models to estimate using historical data
Geographic context	All cases are from a limited set of developing and mature markets	Expansion to encompass culturally and institutionally diverse markets

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