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Declaration:

I hereby declare that the project titled "**Strategic Valuation of R&D Investments: A Critical Review of Real Options Thinking"** is my original work and has not been submitted, in part or full, for any other degree or diploma.

All work presented in this report has been carried out by me, except where explicitly stated otherwise. All academic sources, models, and references used have been appropriately acknowledged. This report complies with the academic and ethical standards of UCD Michael Smurfit Graduate Business School.

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Strategic Valuation of R&D Investments: A Critical Review of Real Options Thinking

Executive Summary:

With an emphasis on the biotech and pharmaceutical industries, this research offers a critical evaluation of six scholarly works that investigate the use of real options analysis (ROA) in valuing R&D investments. The review includes applied models, such as compound real options in pharmaceuticals (Cassimon et al.,2011), theoretical contributions (Lambrecht,2017; Trigeorgis and Smit., 2011), and strategic case studies (Bowman and Moskowitz,2001). The discrepancy between theory and managerial practice is further demonstrated by industrial insights from Villiger and Bogdan (2005) and empirical viewpoints from Hartmann and Hassan (2006). The results imply that although ROA provides a versatile and progressive paradigm for valuation, model complexity and estimate issues continue to restrict its usefulness. However, industry decision-making frameworks frequently implicitly incorporate real alternatives thinking.

1. Introduction:

In the modern knowledge-based economy, investment in research and development (R&D) has been a fundamental aspect of strategic growth in sectors such as pharmaceuticals, biotechnology, and technology. Yet R&D projects embody inherent uncertainty, lengthy lead times, and often irreversible outcomes — characteristics that render conventional valuation techniques, such as Net Present Value (NPV), inappropriate. These techniques are incapable of effectively capturing the value that can be derived from managerial flexibility in decision-making throughout an innovation project.

Real Option Analysis (ROA) presents itself as a strong contender, providing a formal framework to estimate the embedded flexibility in investment choices. By analyzing R&D phases as a sequence of options, managers are able to manage uncertainty more effectively and adjust their investment trajectories as new information becomes available. This method is especially applicable in pharmaceutical R&D, where clinical trial phase decisions are sequential and high stakes.

This paper strictly examines the application of real options theory to the valuation of research and development investments with a specific focus on the pharmaceutical and biotechnology sectors. It combines insights from six academic articles- four from the course literature and two from outside sources (UCD Library) – to consider both the theoretical foundations and the practical limitations of implementing real options in strategic financial applications.

1.1 The aim of this paper is to:

i) Describe the theoretical foundations of real options theory
ii) Discuss how real options are used to value pharmaceutical R&D investments.
iii) Compare empirical research with theoretical assertions
iv) Discuss the strategic implications and boundaries concerning the pragmatic use of real options.

The paper follows the following structure: Section 2 sets the theoretical background of real options and its application in R&D. Section 3 is the critical review of six research papers. Section 4 synthesizes significant findings, and implications for practice are discussed. Section 5 summarizes with conclusion and recommendations for future research.

2. Theoretical Background:

The real options theory represents a major milestone in strategic investment appraisal, especially in industries driven by innovation, where major problems include uncertainty, irreversibility, and flexibility. Unlike traditional capital budgeting methods, such as the Net Present Value (NPV), based upon a deterministic investment strategy with restructured decision – making structures, real option analysis (ROA) underscores the value of managerial discretion in altering decision in response to changing uncertainty patterns in the future (Trigeorgis, 1996; Myers, 1977).

The origin of the real options theory is closely tied to the fundamental principles introduced in the financial options theory. Financial operations, as defined by Black and Scholes (1973) and Merton (1973), refer to agreements that give the buyer the option, but not the obligation, to purchase or sell a good at a future date. Recognizing the value of managerial discretion in investment, Myers (1977) encouraged the extension of this logic into tangible investment opportunities, thus resulting in the real options school of thought.

Building upon these underlying principles, Trigeorgis (1996) suggested the use of real options as a strategic tool for allocating resources. His study demonstrated how the decision–making process by managers in conditions of uncertainty could best be captured through option–based approaches, allowing firms not just to estimate the value expected but also intrinsic flexibility within investment plans.

Such flexibility is particularly important in research and development–intensive sectors such as pharmaceutical and biotechnology, where projects are:

i. Irreversible: These funds, once spent, are largely non-recoverable.
ii. Uncertain outcomes depend on scientific progress, regulatory approval, and market reception;
iii. Projects advance through a sequence of developmental phases, involving clinical trials;
iv. Data-intensive-every state generates more data that can potentially impact the next decision.

Traditional DCF models do not account for this adaptive decision-making process and, therefore tend to undervalue projects with strategic flexibility. In contrast, ROA incorporates uncertainty and managerial discretion directly into the valuation, making it more appropriate for high-risk innovation portfolios (Trigegorgis & Smit,2004).

- Types of Real Options Relevant to R&D:

Option Type	**Application in R&D**
1. Defer	Wait for more information before committing to investment.
2. Expand	Scale up investment following positive signals.
3. Abandon	Exit a project if performance is poor.
4. Switch/Contract	Adjust product features, scale, or market scope.
5. Compound	Make multiple sequential investment decisions over time.

Table1: Type of real options relevant to R&D

At the pharma development level, these alternatives adhere to the investment framework – companies will make minimal initial commitments (e.g. preclinical trials) while maintaining the option to increase their commitment for abandon in subsequent stages (cassimon et al, 2011). As an illustration, moving from Phase I to Phase II clinical trials is a compound option within the entire project.

Real Options Analysis (ROA) methods typically employ financial models, such as the Black-Scholes formula, binomial trees, or Monte Carlo simulations; however, applying these tools to actual projects can be extremely challenging.

At the pharmaceutical development level, these alternatives adhere to the investment framework, where companies make minimal initial commitments (e.g., Preclinical trials) while maintaining the option to increase their commitment or abandon in subsequent stages (Cassimon et al., 2011). As an illustration, moving from Phase I to Phase II clinical trials is a compound option within the entire project.

Real option Analysis (ROA) methods usually utilize financial models like the Black – Scholes formula, binomial trees, or Monte Carlo simulations; however, applying these tools to actual projects is extremely difficult. Lambrecht (2017) highlights that volatility estimation, option duration, and future cash flows are even more complex to forecast in the instance of corporate investments compared to traded financial assets. Furthermore, Bowman and Moskowitz (2001) argue that main assumptions of standard models – i.e., lognormal return distribution and stable volatility – do not necessarily apply in strategic projects like R&D.

This type of misalignment can generate biased valuations or poor decisions if models are applied without the appropriate modifications. For instance, in analyzing Merck's project Gamma, Bowman and Moskowitz observed that although the Black-Scholes model had given a measurable value, it had not accounted for elements such as patent life and competitive activities' time sensitivity, which played a critical role in altering the strategic value of the investment.

Empirical research brings to light a disparity between theoretical concepts and actual practice in management. Hartmann and Hassan (2006) surveyed pharmaceutical and financial companies and discovered that though the rationale of Real Options Analysis (ROA) is widely comprehended, its formal application remains limited. Managers use heuristics or internally developed scoring models because of perceived complexity in real options models and the absence of organizational experience in their application.

In conclusion, a more dynamic and practical method of evaluating R&D investments is provided by real options theory. It displays the ability of managers to adjust in the face of uncertainty, which is a crucial component of innovation projects. However, through model calibration and knowledge of when and how its assumptions fit the strategic context are necessary for its actual deployment.

3. Critical Literature Review:

Theoretical advancements, practical models, and empirical evaluations of corporate use are all included in the scholarly literature on real options in R&D. Six chosen papers – four from the course materials and two from outside academic sources- are critically reviewed in this section and categorized into three subject areas:

i. Conceptual foundations
ii. Applied modelling in pharmaceutical R&D
iii. Strategic and empirical insights.

3.1 Conceptual Foundations: Theory vs Practice:

Lambrecht (2017) provides a broad critique of the real options literature for the disparity between academic modelling sophistication and the comparatively low degree of practical adoption. He argues that from a theoretical perspective, real options models are an improvement over NPV through the inclusion of flexibility, but most models construct idealized scenarios- e.g., perfectly known volatility or market- consistent inputs- that have no basis in reality in strategic investments. The lack of balance between analytical depth and managerial applicability forms the foundation of a more general criticism given in the literature.

Along a similar line, Bowman and Moskowitz (2001) challenge the unquestioning application of financial option models to strategic contexts. Their example of Merck's "Project Gamma" illustrates how the application of the Black-Scholes formula, neglecting project–specific conditions such as patent expirations and time-limited market entry, can distort decision-making.

They emphasize the necessity to tailor real options models to strategic planning and that their usefulness arises not simply from quantitative results but also in modifying how companies formulate and assess investment routes. Jointly, these two articles present a critical basis for evaluating the applied literature- emphasizing that the theoretical prowess of ROA is constrained by practical considerations, and effective implementation depends on alignment between model assumptions and strategic context.

3.2 Applied Modelling: Real Options in Pharmaceutical R&D

Cassimon et al. (2011) provide a comprehensive application of compound real options models to the valuation of pharmaceutical licensing opportunities. They build a multi-stage structure that captures technical risk throughout all phases of drug development and show how this method effectively captures the value of deferral, abandonment, and sequential commitment. The strength of the paper is in its clear structural framework and risk-adjusted quantification of decision points, providing a concrete framework for strategic investment in risky environments.

Adding to this, Trigeorgis and Smit (2004) talk about how real options can be used in broader strategic resource allocation. They argue that firms should view investment decisions not as isolated financial computations but rather as strategic games in which flexibility, timing, and contestability drive outcomes. This perspective introduces the interplay of finance and strategy, and that real options thinking can also be applied to drive competitive action and long-term strategy for innovation.

While both papers present convincing frameworks, their limitations are considerable. The framework presented by Cassimon et al. relies on complex probabilistic inputs that might be difficult to determine in real-world settings, while the strategic dimension presented by Trigeorgis and Smit is mostly theoretical in nature, calling for further empirical testing.

3.3 Strategic Use and Empirical Realities:

Hartmann and Hassan (2006) give survey data on the use of ROA in pharmaceutical and financial industries. Their findings show that while managers instinctively comprehend real-options thinking, the formal application of valuation models is uncommon. Most companies employ simplified internal scoring techniques or rely on experience-based decision-making, citing difficulty in calculating volatility and opt-in parameters as major obstacles. This work is critical for grounding the literature since it emphasizes the theory practice divide and advocates for models that are more user-friendly and customized to organizational capabilities.

Villiger and Bogdan (2005) investigate the strategic attitude underlying real options in biotech enterprises. They claim that even in the absence of formal models, managers use real-world reasoning when establishing license structures, milestone payments, and stage-gate funding. Their findings imply that real options logic may be imbedded in strategic decisions, even if not explicitly quantified approach that links the academic and practical perspectives.

In conclusion, these six publications, taken together, highlight the multidimensional character of real options thinking. While the theoretical literature provides mathematically rigorous methodologies, their successful application is dependent on managerial judgement, contextual flexibility, and the capacity to simulate uncertainty realistically. The true value of ROA, as represented in the literature, is not just in more exact assessment but also in how it allows for strategic flexibility and informed experimentation in uncertain circumstances.

4. Key Insights and Strategic Implications

The critical examination of academic literature demonstrates that, while theoretically powerful, real option analysis (ROA) plays a complicated and frequently limited role in practice, particularly when it comes to R&D investment decisions. Throughout the six studies studied, various themes and strategic implications emerge.

4.1 Real options unlock strategic Flexibility

One of the most noteworthy findings is that ROA provides a conceptual framework for valuing flexibility in the face of uncertainty- a key feature of R&D spending. When dealing with long and uncertain development cycles, the capacity to delay, extend, reduce, or terminate projects are crucial. Cassimon et al. (2011) demonstrated that modeling these possibilities over consecutive drug development phases delivers a more accurate representation of value than static models, such as net present value (NPV).

This has significant consequences for pharmaceutical strategy: Corporations may better allocate resources by seeing each phase as a decision point, hence increasing capital efficiency and risk management. Furthermore, Trigeorgis and Smit (2004) emphasize that this flexibility is both financial and strategic, enabling businesses to adapt quickly to changes in competitors, regulators, and the market.

4.2 ROA Challenges Traditional Capital Budgeting:

Real options thinking questions the assumptions that underpin standard valuation techniques. As Bowman and Moskowitz (2001) demonstrate, applying DCF to innovation programs frequently underestimates their potential by overlooking the need for adaptation. ROA changes the way investments are evaluated, shifting away from binary yes/no judgements and toward deliberate staging and learning- based development.

However, the Bowman and Moskowitz case study demonstrates that applying financial models such as Black-Scholes to strategic choices can result in misalignment if assumptions are not changed. For example, real investments lack tradable underlying assets, and volatility is rarely understood. As a result, real options should not be viewed as a plug-and-play paradigm but rather as a prism through which to reimagine how value is generated and maintained over time.

4.3 Practical Usage Remains Limited but Evolving:

Despite their conceptual attractiveness, real choice models are rarely used in a formal, quantitative setting in most organizations. According to the Hartmann and Hassan (2006) survey, enterprises prefer simpler internal frameworks over mathematical models, which is typically owing to a lack of training, data, or model transparency. Even in biotech and pharmaceutical businesses, which have a high R&D intensity, managers choose qualitative assessments, milestone-based evaluations, or scenario planning.

However. Villiger and Bogdan (2005) contend that real options logic is implicitly contained in transaction forms such as license agreements with stage-gated payments or termination provisions. This means that, while complete model-based ROA is uncommon, strategic concepts are increasingly being implemented under various labels- particularly where uncertainty is high and flexibility is required.

4.4 Implications for Financial Strategy and Future Application:

The evidence argues that for ROA to be more broadly accepted:

i. Firms want simple, modular models that represent industry-specific reality;
ii. ROA should be positioned as a supplement to DCF and not a substitute.
iii. Training in strategic finance should incorporate practical case-based modelling, rather than only theoretical ideas;
iv. Real options thinking ay help organizations create initiatives rather than merely assess them.

Finally, ROA is more than a valuation tool; it is a philosophy that promotes experimentation, incremental commitments, and proactive uncertainty management. For finance managers, this requires a shift from conventional static budget forecasting to dynamic strategic decision-making, particularly in highly innovative environments such as pharmaceuticals.

5. Limitations of the Literature:

While the literature on real options offers a comprehensive theoretical foundation, some limitations remain. First, many models, like those by Cassimon et al. (2011) and Trigeorgis and Smit (2004), rely on assumptions that may not be valid in practice, such as perfectly calculated volatility, rational decision-making, or precisely described option structures. This limits their usefulness in messy, real-world contexts.

The second most empirical research (e.g., Hartmann and Hassan,2006) uses survey-based views, which may not adequately reflect real decision processes. There is a dearth of large-scale, longitudinal evidence on how ROA influences business performance, innovation results, or capital efficiency over time.

Finally, the literature shows a bias toward pharmaceutical and biotech applications. While these industries are good for displaying genuine alternatives due to their stage-based structure, their concentration limits the applicability of results to other innovation settings, such as software development or renewable energy.

5.1 Recommendations for Practice:

To increase the adoption of real option in strategic finance, the following ideas emerge:

i. Create simpler and modular ROA tools, which should be adapted to industry standards and integrated into current capital budgeting systems.
ii. Utilize ROA in conjunction with conventional tools: Firms should utilize real options to supplement, not replace, DCF in situations where uncertainty and flexibility are substantial.
iii. Invest in internal capability development: Financial managers, project leaders, and strategies should be trained on the principles and applications of ROA.
iv. Encourage early-stage project design while considering options: Including checkpoints, gates, or staged commitments in investment structures can help to improve strategic control by introducing optionality early on.

5.2 Suggestions for Future Research:

Future research should strive for:

i. Test the predictive validity of real options models in real-world investment results, utilizing case-based or longitudinal methodologies.
ii. Expand the scope to underserved industries (e.g., clean tech, AI, logistics) where unpredictability and innovation play a role.

iii. Bridge behavioral finance and ROA, examining how cognitive biases impact management flexibility under uncertainty.

iv. Investigate the use of AI and analytics in automating option valuation inputs (such as volatility estimates) to facilitate practical implementation.

6. Conclusion:

This study has broadly investigated the use of real options analysis (ROA) for the valuation of research and development investments, particularly in the pharmaceutical and biotechnology industries. Based on a review of six research papers – representing theoretical, practical, and empirical viewpoints – it is clear that real options present an essential advancement compared to conventional valuation methods by explicitly accounting for managerial flexibility during uncertainty.

The theoretical basis, building upon the contributions of Black and Scholes (1973), Myers (1977), and Trigeorgis (1996), offers an integrated perspective for the comprehension of the strategic management of staged investments. The concept of real options is well adapted to the innate features of research and development- that is, irreversibility, uncertainty, and the requirement for sequential decision-making. However, the practical utilization of real options analysis is thwarted by model complexities, difficulties in input estimation, and organizational capability deficiencies (Lambrecht, 2017; Hartmann and Hassan, 2006).

In spite of these restrictions, it is found that Real Option Analysis (ROA) is becoming more involved in strategic decision-making even in the absence of any formalized procedure. Milestone-based contracts, staged licensing agreements, and in-house stage-gate procedures are some instances of the application of real options theory (Villiger and Bogdan,2005).

Ultimately, the value of ROA lies not only in more accurate valuation but also in its ability to transform how companies approach innovation strategy, risk management, and capital budgeting. For financial practitioners and strategic decision-makers, adopting a real options mindset- whether through models or heuristics- is a critical step toward more agile and robust investment decisions under uncertainty.

Appendices:

Appendix A: Literature Matrix – Summary of Reviewed Papers.

Paper	Focus Area	Methodology	Key Findings	Limitations
Lambrecht (2017)	Theory vs practice of real options.	Theoretical Literature Review.	Highlights disconnect between advanced models and real-world application; ROA often too complex for managers.	Too conceptual; lacks empirical data.
Cassimon et al (2011)	Technical risk in pharma R&D	Compound real options model using pharma licensing case.	Models stage-wise technical and commercial risk; captures value of deferral and abandonment.	Case-specific; requires precise input estimates.
Trigeorgis & Smit (2004)	Strategic integration of ROA	Conceptual framework linking finance and strategy.	Emphasizes ROA as a tool for strategic timing and competitive positioning.	Strategic concepts are not empirically validated.
Villiger & Bogdan (2005)	Practical application of ROA in biotech.	Industry-based insights and qualitative examples.	Shows ROA logic used implicitly in licensing, milestone design.	No formal model validation or empirical testing.
Hartmann & Hassan (2006)	Empirical usage of ROA in pharma firms	Survey-based study	Finds ROA rarely used formally, though understood conceptually; barriers include	Small sample size; self-reported behavior.

			data and complexity.	
Bowman & Moskowitz (2001)	Critical reflection on ROA in strategy	Case study (Merck's Project Gamma).	Warns of model misuse; strategic context may not align with Black-Scholes assumptions.	Highlights flaws but doesn't offer alternatives.

Appendix B: Key Real Options Valuation Equations

1. **Black- Scholes Formula for a Call Option:**

$$C = S_0 N(d_1) - Xe^{-rt} N(d_2)$$

Where:

- C = Call Option Value (project value)
- S_0 = Present value of expected future cash flows from the project
- X = Exercise price (cost of investment)
- r = Risk-free interest rate
- t = Time to expiration (option life)
- $N(d)$ = Cumulative standard normal distribution
- $d_1 = \dfrac{\ln(S_0 / X) + (r + \sigma^2/2)\, t}{\sigma\sqrt{t}}$
- $d_2 = d_1 - \sigma\sqrt{t}$
- σ = Volatility of the project's value.

2. Compound Option Logic (Pharmaceutical R&D)

Used when each stage (e.g., Phase I, II, III) is treated as a separate option.

Example:

- Phase I: Option to invest in Phase II (small investment)
- Phase II: Option to invest in Phase III
- Phase III: Option to launch commercially

Each stage has:

- Cost = Exercise price
- Probability of success = Adjusted using binomial or Monte Carlo methods
- Time horizon = Duration of that phase.

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