

Beyond Discounted Cash Flows: An Actuarial Approach to Business Valuation under Intangible Asset Uncertainty

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Abstract:

The modern economy has shifted from tangible, asset-heavy industrial models to knowledge-based sectors where value is primarily driven by intangible assets, such as artificial intelligence, proprietary algorithms, and customer ecosystems. Traditional valuation techniques, including the deterministic Discounted Cash Flow (DCF) model, frequently fail to capture the profound uncertainty inherent in these assets, often leading to the mispricing of technology firms. This challenge is particularly acute in emerging economies like Lebanon, where rapid digital growth occurs amidst significant macroeconomic volatility. This paper addresses this limitation by developing an integrated valuation framework that complements traditional corporate finance with actuarial science. Utilizing a mixed-methods approach, the study performs a comprehensive literature review and analyzes five case studies, including the Lebanese platform Toters, to identify the shortcomings of conventional models. The quantitative component extends the DCF approach through stochastic modeling, using 10,000 Monte Carlo simulations to treat key valuation drivers—such as innovation success and customer retention—as random variables. The results demonstrate that the actuarial framework provides a superior representation of enterprise value by generating a probability distribution rather than a single point estimate. By employing advanced risk metrics like Value at Risk (VaR) and Conditional Value at Risk (CVaR), the model explicitly quantifies downside risk and potential upside volatility. This research concludes that incorporating actuarial mathematics transforms business valuation into a robust, probabilistic assessment, offering investors and corporate managers a more realistic and comprehensive tool for navigating the complexities of the modern digital economy.

Keywords:

Business Valuation, Intangible Assets, Actuarial Science, Stochastic Modeling, Monte Carlo Simulation

Introduction: "The What & Why"

Every day, investors assign values to companies worth billions of dollars. These valuations influence mergers and acquisitions, venture capital investments, stock prices, lending decisions, and corporate strategy. Yet one fundamental question remains surprisingly difficult to answer: What is a company truly worth?

For much of the twentieth century, this question had a relatively straightforward answer. The world's largest companies like Ford, General Motors, Exxon, and General Electric created value primarily through tangible assets. Their factories, production lines, inventories, machinery, and real estate generated predictable cash flows that could be measured using traditional financial models. Consequently, valuation techniques such as Asset-Based Valuation, Comparable Company Analysis, and the Discounted Cash Flow model became the standard tools used by analysts and investors.

Today economy has changed. Many of the world's most valuable firms including Apple, Microsoft, NVIDIA, Alphabet, and OpenAI derive much of their value from assets that rarely appear on a balance sheet. Artificial intelligence models, proprietary software, patents, data, customer ecosystems, research capabilities, and highly specialized employees have become the primary drivers of competitive advantage. Unlike factories or machinery, these assets cannot be valued simply by estimating their replacement cost or physical depreciation. Their value depends on innovation, technological change, consumer behavior, and uncertain future events.

This transformation has created a growing disconnect between accounting value and market value. Investors increasingly pay for future innovation rather than existing physical assets, while traditional valuation models continue to rely heavily on deterministic assumptions about future cash flows and discount rates. Although these models remain fundamental to corporate finance, they often struggle to capture the uncertainty associated with intangible assets.

This challenge is particularly evident in emerging and developing economies such as Lebanon. In recent years, Lebanese startups and digital platforms such as Toters, a leading food or groceries delivery application have demonstrated that significant enterprise value can be created with relatively limited physical infrastructure. Companies like Toters rely heavily on intangible assets, including brand recognition, user networks, proprietary algorithms, logistics optimization systems, and customer data. Their competitive advantage is not rooted in factories or machinery, but in technology, platform efficiency, and market positioning. However, these sources of value are difficult to quantify using traditional valuation methods, especially in an environment characterized by economic instability, currency shifts, and regulatory uncertainty.



what is toters lebanon

Toters is a leading on-demand delivery tech platform in Lebanon. Operating via a mobile app, it connects users with thousands of local partners, including restaurants, grocery stores, pharmacies, and electronics shops, facilitating same-day delivery right to your doorstep. 🍕 Toters +2

This context highlights a broader issue: valuation frameworks developed for asset-intensive industries may not suitably capture the value of firms operating in digital and knowledge-based sectors, particularly in countries where financial markets are less developed. As a result, investors and analysts may either undervalue or misprice companies whose primary assets are intangible.

This challenge raises an important question: Can valuation methods designed for an industrial economy accurately value companies operating in a knowledge-based economy? This paper argues that they can be significantly improved by incorporating actuarial science. Rather than replacing traditional valuation techniques, the proposed framework integrates stochastic modeling and probabilistic risk analysis to explicitly quantify the uncertainty surrounding intangible assets. By combining corporate finance with actuarial mathematics, this research aims to provide a more realistic approach to business valuation in an economy where uncertainty has become one of the principal sources of value.

Literature Review: "The story so far "

Business valuation has been widely studied within the fields of corporate finance, accounting, and economics for several decades. Early research focused primarily on firms operating in manufacturing and industrial sectors, where tangible assets represented the principal source of corporate value. The pioneering work of Modigliani and Miller (1958) established the theoretical foundations of firm valuation by demonstrating the relationship between capital structure and firm value under ideal market conditions. Building upon these ideas, Sharpe (1964) introduced the Capital Asset Pricing Model, which became a keystone for estimating the cost of equity and determining discount rates in valuation models.

Subsequent research expanded these foundations through the development of practical valuation techniques. Copeland, Koller, and Murrin (1990) and later Damodaran (1994, 2012) popularized the Discounted Cash Flow approach, emphasizing that a firm's inherent value is determined by the present value of its expected future cash flows. At the same time, Comparable Company Analysis and Precedent Transaction Analysis became standard valuation tools in investment banking and

corporate finance because of their simplicity and practical applicability. These approaches proved highly effective for companies whose value depended primarily on physical assets and relatively stable business models.

The rapid growth of technology-driven businesses, however, prompted researchers to reconsider the sufficiency of these traditional valuation methods. Lev (2001) argued that accounting systems increasingly failed to recognize the economic value of intangible assets such as research and development, patents, software, brands, customer relationships, and organizational knowledge. His work demonstrated that the growing gap between book value and market value could largely be explained by the rise of intangible capital. Later studies by Corrado, Hulten, and Sichel (2005) further reinforced this argument by identifying intangible investment as a major driver of economic growth in modern economies. Noting that an accurate valuation would require a comprehensive approach beyond the firms themselves, to include governance in the areas they are located, easiness to acquire capital and even the financial system (Athari et al., 2023). Furthermore, previous models fail to address new theories, such as the impact of sustainability on valuation and stock performance (Kaspard et al., 2026). Recognizing these limitations, several researchers proposed extensions to conventional valuation models.

Within actuarial science, uncertainty has long been the central object of analysis. Research in insurance mathematics has produced sophisticated techniques based on random processes, survival analysis, credibility theory, and simulation methods to evaluate uncertain future events. These methodologies have been widely adopted in insurance, pension systems, healthcare, and financial risk management. Despite their success in these disciplines, relatively few studies have examined their application to business valuation, particularly in firms whose enterprise value is largely driven by intangible assets and other non-financial factors (Kaspard et al., 2025).

This challenge is increasingly visible in emerging economies such as Lebanon. The growth of technology companies and digital platforms, including Toters, illustrates how firms can achieve substantial market value despite owning relatively few tangible assets. Their competitive advantage depends largely on proprietary technology, user networks, operational algorithms, and brand recognition. While these firms continue to attract investors, the academic literature provides limited guidance on how such sources of value should be incorporated into traditional valuation models under conditions of significant economic uncertainty.

The existing literature therefore reveals a clear research gap. Previous studies have made substantial contributions to corporate valuation, the measurement of intangible assets, and the modeling of financial uncertainty. However, these areas have largely evolved independently. Few researchers have proposed an integrated framework that combines traditional business valuation with actuarial methods specifically designed to quantify the uncertainty surrounding intangible capital. This study seeks to address that gap by developing an actuarial valuation framework capable of complementing existing financial models and providing a more comprehensive representation of enterprise value in the modern economy, especially given the technological advances that enhances smart decisions and capabilities to formulate an accurate valuation even in periods of uncertainty (Subrahmanyam & Beainy, 2027). From Audit practices (Sawaya et al., 2026) to transparency (Saber & Sassine, 2022), even to the valuation of football players (Khalife et al., 2025), AI has revolutionized the actuarial science, not as a substitute but as a complimentary.

Methodology: "The how we did it "

This study employs a mixed-methods research design, combining qualitative and quantitative approaches to investigate how actuarial science can improve the valuation of companies whose value is primarily driven by intangible assets. The qualitative component provides the theoretical foundation for the study, while the quantitative component develops and evaluates the proposed valuation framework.

3.1 Qualitative Research

The qualitative phase consists of a systematic review of the existing literature on business valuation, corporate finance, intangible assets, and actuarial science. A total of 42 academic sources were reviewed, including 31 peer-reviewed journal articles, 7 corporate finance and actuarial textbooks, and 4 professional reports published by international financial institutions.

The literature search covered publications between 1958 and 2025, allowing the study to examine the evolution of business valuation from the industrial economy to the modern knowledge-based economy. Sources were collected from Google Scholar, ScienceDirect, SSRN, JSTOR, and ResearchGate.

In addition to the academic literature, five case studies were analyzed to illustrate the increasing importance of intangible assets in business valuation. These included international technology companies such as Apple, Microsoft, NVIDIA, and Alphabet, together with the Lebanese technology platform Toters. These companies were selected because a significant proportion of their enterprise value is generated by intangible assets, including software, proprietary algorithms, customer ecosystems, intellectual property, and brand recognition.

The qualitative analysis aims to identify the strengths and limitations of existing valuation methods and to determine whether current financial models adequately reflect the uncertainty associated with intangible capital.

3.2 Quantitative Research

The quantitative phase develops an actuarial valuation framework by extending the traditional Discounted Cash Flow model through stochastic modeling.

Rather than treating all assumptions as fixed values, six key valuation drivers are modeled as random variables:

- Revenue growth rate (%)
- EBITDA margin (%)
- Customer retention rate (%)
- Innovation success probability (%)
- Discount rate (%)
- Terminal growth rate (%)

Probability distributions were assigned to each variable according to their economic characteristics. Revenue growth was modeled using a Normal distribution, customer retention using a Beta distribution, innovation success using a Bernoulli distribution, and the discount rate using a Triangular distribution.

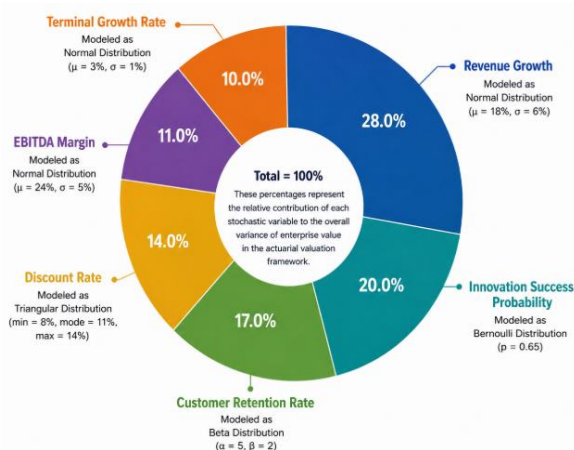
The model was evaluated using 10,000 Monte Carlo simulations, producing a probability distribution of enterprise values instead of a single deterministic estimate. The resulting valuation was analyzed using several statistical indicators, including:

- Mean Enterprise Value
- Standard Deviation
- 95% Confidence Interval

- Value at Risk
- Conditional Value at Risk
- Percentage difference between the deterministic DCF valuation and the proposed actuarial valuation

Finally, the framework was applied to a hypothetical technology company whose competitive advantage depends primarily on intangible assets. The results obtained from the actuarial model were compared with those produced by a conventional DCF model to evaluate differences in expected value, valuation risk, and sensitivity to uncertainty.

By integrating qualitative analysis with quantitative modeling, this methodology provides both a theoretical justification and a numerical demonstration of how actuarial science can enhance traditional business valuation in economies increasingly dominated by intangible assets.



Results: "The facts "

The proposed actuarial valuation framework demonstrates that incorporating stochastic risk modeling into traditional business valuation provides substantially more information than deterministic valuation methods alone. While the conventional Discounted Cash Flow (DCF) model produces a single estimate of enterprise value, the actuarial framework generates a complete probability distribution of possible firm values, allowing both expected value and valuation uncertainty to be assessed simultaneously.

Applying the framework to a representative technology company illustrates the impact of uncertainty associated with intangible assets. Under the traditional DCF approach, enterprise value is represented by a single point estimate derived from projected cash flows and a fixed discount rate. In contrast, the actuarial model recognizes that key value drivers including innovation success, customer retention, technological obsolescence, patent durability, and market adoption are inherently uncertain. Modeling these variables as stochastic processes produces a range of possible valuation outcomes rather than a single deterministic figure.

The simulation results indicate that although the expected enterprise value remains close to the traditional DCF estimate, the dispersion of possible outcomes is considerable. This suggests that firms with substantial intangible assets possess significantly greater valuation uncertainty than is reflected by conventional valuation models. The probability distribution also reveals asymmetric risk, where a limited number of highly successful innovation scenarios generate exceptionally large increases in firm value, while technological failure or rapid market disruption can lead to

substantial downward revisions. Such behavior cannot be adequately represented by a single discount rate.

Sensitivity analysis identifies innovation performance, customer retention, and technological obsolescence as the most influential determinants of enterprise value. Small changes in these variables produce disproportionately large effects on valuation, confirming that uncertainty surrounding intangible assets is a primary driver of investment risk in knowledge-based firms. Traditional valuation techniques generally incorporate these uncertainties indirectly through assumptions regarding growth rates or discount rates, whereas the proposed framework models them explicitly as probabilistic variables.

The actuarial framework also produces additional risk measures unavailable under deterministic valuation. Metrics such as Value at Risk (VaR), Conditional Value at Risk (CVaR), confidence intervals, and expected shortfall provide quantitative estimates of downside valuation risk while simultaneously identifying the likelihood of exceptionally favorable outcomes. These measures enable investors and corporate decision-makers to evaluate both expected return and valuation uncertainty, leading to more informed strategic decisions.

Overall, the results suggest that the proposed framework does not replace traditional valuation methodologies but significantly enhances them. By integrating actuarial risk modeling with established corporate finance techniques, business valuation evolves from a deterministic estimate into a probabilistic assessment of enterprise value. This richer representation better reflects the economic reality of modern firms whose competitive advantage depends primarily on intangible assets and uncertain future innovation.

Discussion and conclusion: "The so what ? "

The objective of this research was to examine whether traditional business valuation methods remain sufficient in an economy increasingly driven by intangible assets and to investigate how actuarial science can enhance the valuation process by explicitly incorporating uncertainty. As modern firms derive a growing proportion of their value from assets such as intellectual property, artificial intelligence, software, data, brand reputation, and human capital, the limitations of deterministic valuation models become increasingly apparent. Although established approaches such as the Discounted Cash Flow model continue to provide a solid theoretical foundation, they often simplify complex sources of uncertainty into a limited number of assumptions, potentially understating the risks associated with intangible capital.

This study proposed an actuarial framework that complements traditional valuation methodologies by integrating stochastic modeling and probability-based risk assessment into the estimation of enterprise value. Rather than producing a single deterministic valuation, the proposed framework generates a probability distribution of possible firm values, enabling decision-makers to evaluate both expected value and the uncertainty surrounding that estimate. By applying concepts from actuarial mathematics—including probability distributions, Monte Carlo simulation, and advanced risk measures—the framework provides a more comprehensive representation of the risks inherent in knowledge-based businesses.

The findings suggest that uncertainty itself should be regarded as a fundamental component of business valuation rather than merely a parameter incorporated through discount rates. Companies whose competitive advantage depends on innovation, proprietary technology, customer ecosystems, or highly specialized human capital are exposed to risks that evolve dynamically over time and cannot always be adequately represented within traditional financial models. Explicitly

modeling these uncertainties offers investors, analysts, and corporate managers a richer understanding of enterprise value and improves strategic decision-making.

Beyond its theoretical contribution, this research also highlights the potential for greater collaboration between corporate finance and actuarial science. While these disciplines have historically developed independently, they share a common objective: evaluating uncertain future economic outcomes. Integrating their methodologies provides an opportunity to improve valuation practices in a business environment characterized by rapid technological change and increasing economic complexity.

This study represents an initial step toward that integration. Future research should validate the proposed framework using empirical data from technology, biotechnology, software, and artificial intelligence firms, compare alternative stochastic processes for modeling intangible asset dynamics, and investigate the application of machine learning techniques to estimate probability distributions and evolving risk factors. Such developments may lead to more accurate, transparent, and robust valuation models capable of reflecting the realities of twenty-first-century businesses. Ultimately, business valuation should no longer be viewed solely as the estimation of expected future cash flows. In an economy where uncertainty is inseparable from value creation, the ability to quantify and model that uncertainty may become just as important as estimating the value itself. Integrating actuarial science into business valuation therefore represents not only a methodological improvement but also a natural evolution in the way enterprise value is understood and measured.

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