Marlena Jankowska

Financial Decision Modeling for Intellectual Property Portfolio Optimization: Real-World Evidence for Building Strategies[1]

Keywords: *IP portfolio, IP management, Modern Portfolio Theory, Sensitivity Analysis, Monte Carlo simulation, Linear Programming (LP), Integer Linear Programming (ILP)*

Managing an intellectual property portfolio is, in many ways, akin to managing a financial investment portfolio. Both require balancing potential reward against risk, operating under resource constraints, and adapting to changing conditions. This article demonstrates that by adapting concepts from Modern Portfolio Theory and decision modeling to the IP domain, legal professionals can bring a new level of rigor and strategic clarity to IP management.

We draw parallels between financial assets and IP assets, establishing an analogous vocabulary of expected returns (IP value), risk (uncertainty of legal/commercial success), and correlation (interdependence of patent values). Using the toolkit of financial analytics, we construct a framework for optimizing IP portfolios: identifying which patents or projects to invest in, how to allocate budgets among them, and when to cut losses on underperforming assets. Real-world case studies of IBM, Nokia, Qualcomm, Dow, and others provide concrete evidence that these principles are not merely academic.

1. Introduction

Intellectual property (IP) assets – patents in particular – constitute an important class of assets for technology-intensive companies. In today's knowledge economy, companies such as IBM, Nokia and Qualcomm typically sit on tens of thousands of patents that provide competitive advantage and licensing revenue. But for legal and business decision-makers, handling an extensive IP portfolio raises challenging strategic issues. On which patents

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should a company spend money to file or keep? How to allocate a constrained budget to various R&D projects in order to maximize the innovation impact? When is it reasonable to trim back low-value patents to control costs? These questions have impressive parallels with the process of making decisions in financial portfolio management, that is, when investors decide to spread capital on assets to balance risk against return.[2]

This paper explores how concepts and tools from Modern Portfolio Theory (MPT) and decision modeling can be adapted to the domain of IP management. MPT was developed in the 1950s by Harry Markowitz and subsequently published in his article 'Portfolio Selection' in the Journal of Finance.[3] Financial analysts commonly employ models, such as Linear Programming (LP), Integer Linear Programming (ILP), Sharpe ratios, correlation matrices, sensitivity analysis, and Monte Carlo simulation, in a bid to build optimal stock portfolios and analyse risk-adjusted performance. However, if we consider patents and other collections of IP as being similar to financial portfolios, we can use models such as these to optimise portfolios of IP in a strategic, data-driven manner. The aim is to assist legal and policy decision-makers in optimising the allocation of resources among the different IPR activities (including patenting, renewal, expiry and enforcement) in the most efficient and cost-effective way according to the business targets and risk tendency.

The rest of the paper is organized as follows. The literature review provides an overview of fundamental concepts of financial portfolio theory (efficient frontier, risk–return tradeoff, etc.) and relevant IP management literature, such as problems in IP valuation and previous attempts to model patent holdings as portfolios. In the next section, I will show how individual finance modelling tools – MPT, LP/ILP optimization, Sharpe ratio, correlation analysis, Monte Carlo simulation, and sensitivity analysis – may be generalized to IP portfolio decisions in a way acceptable for lawyers. In the discussion, we relate the findings to actual practices of IP management at companies like IBM, Nokia, Qualcomm, etc., and examine how using optimization modelling can assist strategic decisions to file, prune, enforce, and license patents. Last, the conclusion section discusses the implications for legal and policy listeners (i.e., IP managers).

2. Research review. Financial portfolio theory and decision analytics

Markowitz developed the Modern Portfolio Theory in 1952.[4] It has revolutionized the management of investment by specifying the perceived trade-off between expected return and risk (variance of returns) for a portfolio of assets. The point is that an investor should look at assets together rather than individually. If the uncorrelated assets are combined, the risk of the portfolio is unlikely to remain the same for the same return.[5]

[2] H.M. Markowitz, *Portfolio Selection*, 7(1) The Journal of Finance" 77–91 (1952); H.M. Markowitz, *The Utility of Wealth*, LX(2) The Journal of Political Economy" 151–158 (1952).

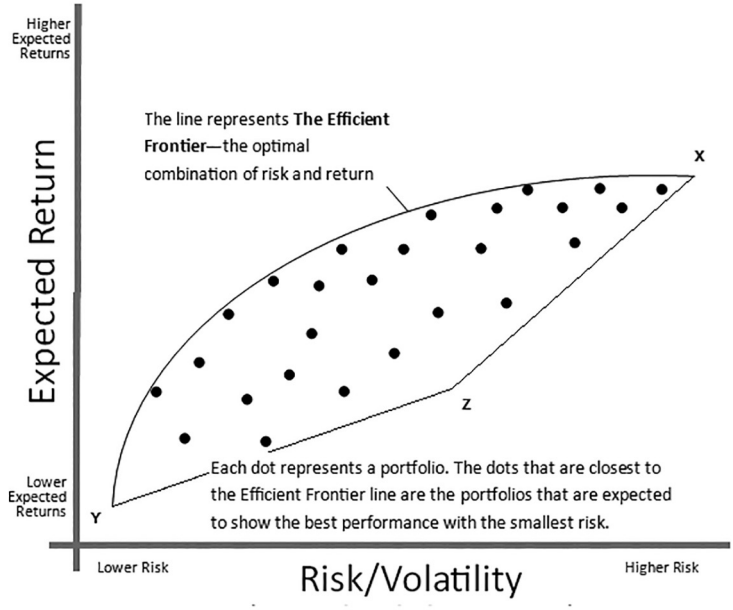
[3] Markowitz, *Portfolio…, supra* n. 2.

[4] Markowitz, *Portfolio…, supra* n. 2.

[5] R.P. Rustagi, *Financial Management* (Taxmann Publications (P.) Ltd. 2010); B. Scherer, *Portfolio Resampling: Review and Critique*, 58(6) Financial Analysts Journal 98–109 (2002); J. Barreiro-Gomez & H. Tembine, *Blockchain Token Economics: A Mean-Field-Type Game Perspective*, 7 IEEE Access 64603–64613 (2019);

This can be achieved by diversification: in Markowitz's mean–variance model, the optimal portfolio that investors should hold is to invest in a portfolio on the efficient frontier (i.e., this portfolio gives the highest return for the level of risk one is prepared to accept), or in other words, it minimizes the level of risk for a given return.[6] All portfolios on this efficient frontier strictly dominate all other portfolios (there is no other portfolio that offers a better risk–return balance).

Fig. 1
Markowitz's efficient frontier (after A. Francis, *Modern Portfolio Theory*).



This theoretical framework, codified in rigorous mathematics, conveyed a precept that most investors had long taken for granted: 'do not put all your eggs in one basket'. For instance, having approximately 20–30 good carefully-chosen stocks should eliminate the vast majority of firm-specific (idiosyncratic) risk through the benefits of diversification.[7] Once an investor gets beyond such number of stocks, more stock adds less and less

K. Henide, *Sherman Ratio Optimization: Constructing Alternative Ultrashort Sovereign Bond Portfolios*, 11 Journal of Investment Strategies (2023); R. Benichou, Y. Lemperiere, E. Serie, J. Kockelkoren, P. Seager, J.-P. Bouchaud & M. Potters, *Agnostic Risk Parity: Taming Known and Unknown-Unknowns*, 6 Journal of Investment Strategies (2017); S. Valeyre, *Optimal trend-following portfolios*, 12 Journal of Investment Strategies (2024).

[6] A. Francis, *Modern Portfolio Theory – Markowitz Portfolio Selection Model*, MBA Knowledge Base, https://www.mbaknol.com/investment-management/modern-portfolio-theory-markowitz-portfolio-selection-model/ (access: 27 Jul. 2025).

[7] M. Kelley, *The Importance of Diversification: Strategies to Manage Risk*, ESL Investment Services, https://www.esl.org/wealth/investment-services/resources-tools/articles/the-importance-of--diversification#:~:text=Research1%20has%20shown%20that%2020,to%20be%20diversified%20across (access: 27 Jul. 2025).

to the degree of risk reduction (yields diminishing risk reduction), which one might want to treat as a rule of thumb and use it to inform one's thinking about how many stocks would be required. Some may compare it to a rule-of-thumb assertion in the patents management literature that a similar order of magnitude of patents can attain a diversity benefit.[8]

Under further advances in financial theory, the measures to assess relative risk-adjusted performance also were provided. A widely used measure is the Sharpe Ratio, formulated by William F. Sharpe (1966), which is the ratio of a portfolio's average excess return (over a risk-free rate) to its standard deviation of returns (a measure of risk).[9] The Sharpe ratio measures how much additional return the investor earns per unit of pain suffered. A higher Sharpe ratio indicates a more efficient portfolio in risk-return space; for example, a portfolio that has a moderate return, but very low volatility will have a higher Sharpe ratio than a portfolio that has slightly higher return but a disproportionately higher volatility. This reward-to-variability concept is widely used in financial analysis to study whether fund performance is due to skill or merely because the manager took on high risk. It creates a single measure that ranks portfolios in terms of desirability (assuming that returns are approximately normally distributed and that investors are risk-averse).

Optimization models are frequently used by financial analysts to build optimal portfolios (particularly in the presence of practical constrains). Note that the standard Markowitz optimization is a hist quadratic optimization (portfolio variance is a histogram quadratic function of asset weights). Many real-world portfolio decisions can be reduced to being linear or integer programs by linearizing risk measures or scenarios.[10]

Linear Programming (LP) is a systematic procedure to determine the best possible outcome in a given mathematical model for a linear equation (in other words, mathematical method to maximize or minimize a linear objective function subject to linear constraints). For example, an investor may use LP to optimize flow of expected return subject to restrictions such as a budget constraint and an upper limit on portfolio risk (approximated by linear quantities or piecewise linear thresholds). Because of this, risk is frequently approximated in a linear fashion (e.g., using absolute deviation rather than

[8] A. Pham, *Strategic Portfolio-Based Patent Investment and Management*, Intellectual Asset Management (January/February 2011).

[9] W. F. Sharpe, *Mutual Fund Performance*, 39(1) Journal of Business 119–138 (1966); A.W. Lo, *The Statistics of Sharpe Ratios*, 58(4) Financial Analysts Journal 36–52 (2002), DOI: https://doi.org/10.2469/faj.v58.n4.2453; C. Bacon, *Practical Portfolio Performance Measurement and Attribution* (Wiley 2nd ed. 2008); B.J. Feibel, *Investment Performance Measurement* (Wiley 2003); S.E. Pav, *The Sharpe Ratio: Statistics and Applications* (CRC Press 2022); W. Goetzmann, J. Ingersoll, M. Spiegel & I. Welch, *Sharpening Sharpe Ratios*, National Bureau of Economic Research 2002, https://www.nber.org/papers/w9116 (access: 27 Jul. 2025).

[10] S.C. Albright & W.L. Winston, *Business Analytics: Data Analysis and Decision Making* (Cengage Learning, Inc. 2020); M.P. Basilio, J.G. de Freitas, M.G.F. Kämpffe & R. Bordeaux Rego, *Investment Portfolio Formation via Multicriteria Decision Aid: A Brazilian Stock Market Study*, 13(2) Journal of Modelling in Management 394–417 (2018); W. Chau Li, Y. Wu & U. Ojiako, *Using Portfolio Optimisation Models to Enhance Decision Making and Prediction*, 9(1) Journal of Modelling in Management 36–57 (2014); E.J. Elton, M.J. Gruber, S.J. Brown & W.N. Goetzmann, *Modern Portfolio Theory and Investment Analysis* (John Wiley & Sons 2009); M.P. Johnson, *Community-Based Operations Research: Introduction, Theory, and Applications,* in *Community-Based Operations Research: Decision Modeling for Local Impact and Diverse Populations* 3–36 (Springer 2011); W.L. Winston & S.C. Albright, *Practical Management Science* (Cengage Learning, Inc. 2019).

variance), fitting portfolio optimization into an LP framework for easier (computationally tractable) solving.[11]

Additionally, if there are indivisibilities or combinatorial constraints, such as choosing a fixed number of assets, or, to guarantee at least one asset from each category, the Integer Linear Programming (ILP) or mixed-integer programming is utilized. ILP permits the inclusion of binary decision variables (0/1), which can be interpreted as 1 or 0 to represent having or not having an asset, and it provides the ability to impose constraints such as 'choose at most 5 assets' or 'if asset A is chosen, then asset B must also be chosen'. Such formulations arise often when one designs index funds or venture capital portfolios, for instance, since one cannot have fractions of a position in some assets. They are NP-hard (Nondeterministic Polynomial-time hard) problems in general, but current solvers handle moderate size problems easily. To conclude, LP and ILP make it possible to translate investment policy and practical constraints into a solvable model for finding the optimal allocation of resources.

The second pillar of decision modeling is the application of Monte Carlo simulation and sensitivity analysis. Monte Carlo simulation is a method for simulating scenarios for uncertain (risk) variables (e.g., asset returns) and estimating the distribution of outcomes of a portfolio.[12] This method allows investors to gain insight into the likelihood of multiple returns, losses of a particular magnitude (value-at-risk) and other risk-related measures (metrics) not observable in the single value. It is a valuable method for risk evaluation and valuation under uncertainty.[13] By way of an example, a Monte Carlo simulation might determine the probability that a portfolio will generate at least a certain return over a year by drawing from historical return distributions or assumed probabilistic models.[14] On the other hand, sensitivity analysis systematically changes inputs (e.g., expected returns of assets or constraint bounds) to observe how the optimal solution or important outputs change. This identifies the assumptions that the portfolio analysis is most sensitive to, that is, where estimation errors could potentially result in different decisions. In finance, one would test how the optimal asset allocation changes when expected returns change by ±1%, or when the client's risk tolerance is more/fewer ticks closer. This is important

[11] E.J. Elton & M.J. Gruber, *Modern Portfolio Theory, 1950 to Date*, 21(11-12) Journal of Banking & Finance 1743–1759 (1997).

[12] Jason, *Power of Monte Carlo Simulations in Finance*, PyQuant News, Interactive Brokers (16 April 2025), https://www.interactivebrokers.com/campus/ibkr-quant-news/power-of-monte-carlo-simulations-in-finance/#:~:text=Power%20of%20Monte%20Carlo%20Simulations,and%20randomness%20of%20financial (access: 27 Jul. 2025); K. Polasko, P. Ponce, A. Molina, *An Income Model Using Historical Data, Power-Law Distributions and Monte Carlo Method for University Technology Transfer Offices*, 13(5) Future Internet 122 (2021), https://doi.org/10.3390/fi13050122; K. Polasko, *Income Modeling of IP Portfolio*, preprint, February 2021, DOI: 10.13140/RG.2.2.19928.83204, https://www.researchgate.net/publication/349043879_Income_Modeling_of_IP_Portfolio (access: 27 Jul. 2025).

[13] N. Beaton & J. Sawyer, *Use of Monte Carlo Simulations in Valuation*, Alvarez & Marsal (31 July 2019), https://www.alvarezandmarsal.com/insights/use-monte-carlo-simulations-valuation#:~:text=Use%20of%20Monte%20Carlo%20Simulations,tools%20for%20the%20valuation%20analyst (access: 27 Jul. 2025).

[14] S. Weingust, *Using the Monte Carlo Method to Value Early Stage, Technology-Based Intellectual Property Assets*, Stout (1 March 2013), https://www.stout.com/en/insights/article/using-monte-carlo-method-value-early-stage-technology-based-intellectual-property-assets#:~:text=Using%20the%20Monte%20Carlo%20Method,to%20effectively%20value%20IP%20assets (access: 27 Jul. 2025).

because all models are based on estimates – estimates that are of necessity uncertain, and decision-makers should be aware of how robust the model's recommendations are.

3. Intellectual property portfolio management

When it comes to management of IP, the practice of managing a patent portfolio as a strategic asset portfolio has evolved over the last couple of decades[15]. Companies are increasingly understanding patents to be something other than just legal certificates or technical disclosures, but as economic assets that translate into dollars and cents (whether as licensing royalties, for competitive advantage, or as a cost savings).[16] Similarly as in the case of financial assets, it is necessary to assess both the contribution of individual patents to the firm´s (or system´s) goals, and the interconnectedness between patents. But they are goods – rather different from stocks or bonds – that have proven notoriously hard to value and their 'risk' hard to quantify.

As noted by Russ Krajec, '[p]atents that are not infringed have no "real" value – yet. Patents are bets that the market will adopt your idea and want to copy it. Until someone copies the patented technology, the patent has only 'speculative' value'.[17] Patents are an intangible asset, whose worth must be understood in relation to other factors: (a) the business potential of the technology a patent protects; (b) the legal 'horsepower' of the patent;(c) the competitive landscape. There are basically three conventional approaches to value patents (parallel to valuation of companies): cost approach, income approach, market approach.[18]

3.1. Sensitivity analysis

In addition, patent investment risk is also attached to multiple dimensions: technological obsolescence, market shifts, regulatory (patent law) changes and litigation risk (a patent could be invalidated or not infringed) among others. Because of their inherent

[15] H. Orelma, *Large Patent Portfolio Optimization* (2007); M. Resta, *Portfolio Optimization: New Challenges and Perspectives*, 5(1) Recent Patents on Computer Science 59–65 (2012); M. Rasoulzadeh & M. Fallah, *An Overview of Portfolio Optimization Using Fuzzy Data Envelopment Analysis Models*, 1(3) Journal of Fuzzy Extension and Applications 180–188 (2020); M. Verma, V. Sharma & V. Singh, *A Hybrid AI Framework for Strategic Patent Portfolio Pruning: Integrating Learning-to-Rank and Market Need Analysis for Technology Transfer Optimization*, arXiv preprint arXiv:2509.00958 (2025); M. Grimaldi, L. Cricelli & F. Rogo, *Valuating and Analyzing the Patent Portfolio: The Patent Portfolio Value Index*, 21(2) European Journal of Innovation Management 174–205 (2018); Y.F. Lee & W.T. Wang, *The Model on Patent Investment Strategy of Technology Portfolio and Industrial Research*, 15th International Multi-Conference on Complexity, Informatics and Cybernetics, IMCIC 2024 159–163 (2024); K.M. Pineda Martinez, *Strategic Patent Portfolio Management: An Expert-Based Framework for IP Value Assessment* (2025); X.P. Yue, *Behavior of Inter-Enterprises Patent Portfolio for Different Market Structure*, 120 Technological Forecasting and Social Change 24–31 (2017).

[16] T. Stevens, *Cashing In On Knowledge*, IndustryWeek (21 December 2004), https://www.industryweek.com/innovation/product-development/article/21955047/cashing-in-on-knowledge (access: 27 Jul. .2025).

[17] R. Krajec, *How to Find a Realistic Patent Value*, Blue Iron IP (27 December 2021, updated 22 July 2023), https://blueironip.com/how-to-find-a-realistic-patent-value/#:~:text=Patent%20valuation%20is%20extremely%20difficult,of%20all%20the%20variables (access: 27 Jul. 2025).

[18] M. Jankowska, M. Pawełczyk, S. Augustyn, M. Panfil (eds.), *Znaczenie wyceny własności intelektualnej. Proving the worth. Putting a value on intellectual property* (Ius Publicum, WSB 2019).

illiquidity, patents do not have liquid markets that offer unambiguous price information in real time; their risk is not reflectable through volatility and beta. Instead, we mean modeling risk by probabilities of the success/failure of certain events (i.e., the probability a patent wins in court, the probability a technology is successful in the market, etc.). Here expert elicitation and analytics are required to quantify inputs to decision models. Some IP valuation professionals use decision tree analysis or Monte Carlo simulations to account for such probabilities (e.g., analyzing the distribution of possible licensing income from a portfolio).[19] In fact, valuation experts have identified Monte Carlo methods as a powerful tool for IP valuation under uncertainty,[20] allowing one to model numerous possible technology adoption or legal scenarios to yield a valuation range that is probabilistic.

4. IP efficient frontier

Researchers have tried to borrow concepts from portfolio theory to the field of IP. For instance, Lin, Chen & Wu (2006) studied the diversity of the patent portfolio and its effect on the firm's performance.[21] They came to a nuanced conclusion: non-R&D-intensive firms tend to benefit more from a focused (i.e., focused on the core technology area) patent strategy, while very large technology stocks benefit from a more diversified (broad) patent portfolio.[22] In short, for small players attention begets depth in their core competence, which yields better performance, but very large players both can afford to, and profit from, diversifying across multiple technology domains – to a point. This is consistent with a competence-based perspective: in the absence of substantial capability, diversification can overstretch the resources of a firm, while an industry front-runner can enter related fields and benefit from cross-technology synergies. Relatedly, Lubatkin & Chatterjee (1994) wondered if modern portfolio theory applies to corporate diversification; they were circumspect with respect to business units, noting differences in managing firms versus stocks.[23]

Patent portfolios are not the same as portfolios of stocks: patents can generate synergistic value (a group of patents that cover a standard or a product line might jointly be more valuable than the sum of the individual patents) and strategic value (some patents are useful for nothing other than blocking competitors or simply for defensive haggling, even though they may produce no revenues from licensing). These considerations carry implications for the naive 'additive return' hypothesis of the MPT. However, some startups and innovative companies talk about an 'IP efficient frontier' – that is, the right amount of patent protection to provide the best coverage without being too redundant.

[19] S. Weingust, *Using the Monte Carlo Method to Value Early Stage, Technology-Based Intellectual Property Assets*, Stout (1 March 2013), https://www.stout.com/en/insights/article/using-monte-carlo-method-value--early-stage-technology-based-intellectual-property-assets (access: 27 Jul. 2025).

[20] Beaton & Sawyer, *supra* n. 13.

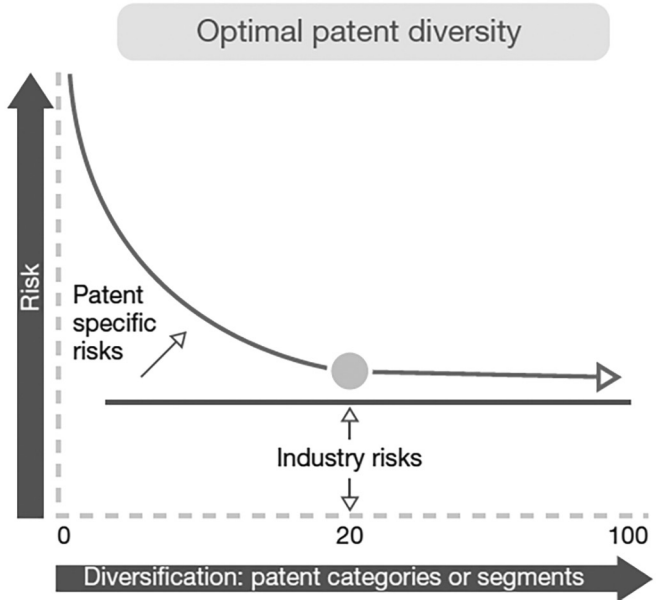
[21] B.-W. Lin, C.-J. Chen & H.-L. Wu, *Patent Portfolio Diversity, Technology Strategy, and Firm Value*, 53(1) IEEE Transactions on Engineering Management 17–26 (2006), DOI: 10.1109/TEM.2005.861813.

[22] Lin, Chen & Wu, *supra* n. 20.

[23] M. Lubatkin & S. Chatterjee, *Extending Modern Portfolio Theory into the Domain of Corporate Diversification: Does It Apply?*, 37(1) The Academy of Management Journal 109–136 (1994), DOI: https://doi.org/10.2307/256772, (access: 27 Jul. 2025).

The modern stock portfolio theory says that a portfolio of 20 stocks gives a maximum diversity, which means that beyond a certain number of patents in a technology area, returns diminish rapidly.[24] Despite being a rough analogy, it would convey the wisdom of maximum portfolio size and composition in patents as well.

Fig. 2.
Optimal patent diversity (after A. Pham, *Strategic Portfolio-Based Patent Investment…*).



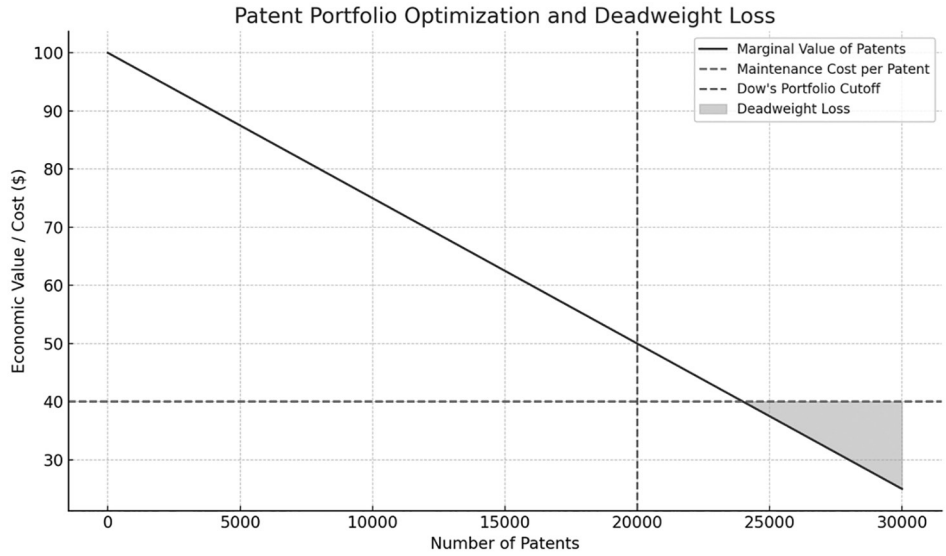
Based on this figure, patent portfolio optimization follows a classic risk-diversification relationship. The curve demonstrates that concentrating patents in just a few categories or segments creates high patent-specific risks, but diversifying across approximately 20 different patent categories or technology segments can dramatically reduce overall portfolio risk. The optimal diversity point (marked by the yellow dot) represents the sweet spot where additional diversification efforts yield diminishing returns. Beyond this point, the portfolio is primarily exposed to broader industry risks that affect all patents regardless of category. This suggests that companies should strategically spread their IP investments across multiple technology areas rather than concentrating everything in their core expertise areas, but they do not need to diversify into every possible patent category to achieve optimal risk management. The model indicates that thoughtful diversification can be a powerful tool for reducing patent portfolio volatility while maintaining focus on the most impactful technology areas.

The savviest companies have followed the principles of portfolio optimization as it pertains to IP management. The Berkeley study noted some tech giants, including IBM – which has long been America's top recipient of patents – recently pursued a "uality over

[24] Pham, *supra* n. 8.

quantity strategy', essentially meaning they were culling their patent collection strategically. In 20202, IBM said they would no longer seek to be the queen of the numbers (numeric patent leadership) when it came to patents, and they saw their total in the U.S. drop from over 8,500 in 2021 to under 5,000 in 2022.[25] IBM's reasoning for it was to concentrate on core areas (like hybrid cloud, AI, quantum, security, etc.) and make the highest impact patents applicable to those, rather than simply accumulate patents for patents' sake.[26] This mirrors the idea of shedding low-value assets and concentrating investment where marginal returns (in terms of innovation and business alignment) are highest. IBM's Chief Patent Counsel has spoken about systematically pruning patent portfolios, managing maintenance fees and aligning patents with the current business strategy.[27] Another example comes from Dow Chemical: in the 1990s, Dow reviewed its portfolio of approx. 20,000 patents by delegating them to business units and having cross-functional teams assess their business value. Some 25% of the patents were determined to have zero business value; Dow downsized its estate by about 10,000 patents, saving $40 million over five years in maintenance fees.[28] Those patents were either donated (to yield tax benefits) or abandoned.

Fig. 3
Patent Portfolio Optimization and Deadweight Loss (own work).



[25] M. Vallone, *IBM's Chief Patent Counsel for Americas Mark Vallone on Changing Patent Portfolio Strategy*, Voice of IP (Clause 8 Podcast) (28 March 2024), https://www.voiceofip.com/p/ibms-new-patent-chief-for-americas (access: 27 Jul. 2025)

[26] D. Gil, *How Do You Measure Innovation?*, IBM Research Blog (9 January 2023), https://research.ibm.com/blog/Ibm-innovation-2022 (access: 27 Jul. 2025).

[27] Vallone, *supra* n. 24.

[28] K. Christopher, *Reclaiming Our Technological Posterity at the Intersection of Intellectual Property and Taxation: Uncovering How Patent Pools Are Key to Recovering the Benefits of Charitable IP Contributions*, 2(3) American University Intellectual Property Brief (October 2012), https://digitalcommons.wcl.american.edu/cgi/viewcontent.cgi?article=1060&context=ipbrief (access: 27 Jul. 2025).

This is textbook portfolio optimization: jettisoning the 'dead weight' with minimal cost and refocusing investment on productive IP assets. It also serves as an example of how analytics can inform maintenance fee budgeting: think of those annual fees on each patent as the cost of an investment and ask yourself whether the expected return is worth it.

Companies such as Nokia and Qualcomm take yet another approach: treating their patent portfolios as profit centres through licensing. Nokia's portfolio (around 20,000 patent families, based on €150 billion in R&D expenses) provides approximately €1.3 billion of licensing income annually.[29] Their most famous customer is of course Apple, from which Qualcomm famously derive much of their profit from patent royalties – in the first fiscal quarter of 2023, Qualcomm's licensing division (QTL) earned $5.3 billion revenue for a profit of $3.6 billion (68% margin) which made up around 49% of the company's total net income.[30]

These companies are actively managing risk and return in their IP operations: Nokia, for example, renegotiates cross-licenses at regular intervals (and litigates where necessary to enforce royalty payments), to create a reliable income stream, resembling one from a high-yield bond portfolio.[31] Qualcomm has hundreds of licensees (virtually all major handset manufacturers worldwide), such that Qualcomm's licensing income is spread around and thus risk can be spread, much the same way holding 50 not one dividend paying stocks to reduce dependence on any one payer.[32] At the same time, Qualcomm's heavy investment (nearly 20% of revenue) into R&D each year continually 'rebalances' its patent portfolio into new technology generations (3G, 4G, 5G, now 6G), analogous to reinvesting in growth assets[33].

5. Constraints on applying financial models to IP management

To summarize, literature and practical experience indicate that strategic IP portfolio management can benefit from quantitative analysis and a balancing of investments. Nevertheless, when one attempts to apply such financial approaches to IP, one has to allow for opaque valuation, no liquid markets – hence lack of instantaneous prices, legal limitations, and value that can be very context-specific, interconnected, fuzzy and synergistic. Given these challenges, any modeling approach can only be a decision support tool, rather than a decision-making tool in its own right – the human judgement of patent attorneys and managers being an essential part of the process. Motivated by this, the next subsection describes a modelling framework that generalizes financial portfolio optimization methods to the IP setting, while trying to stay rigorous and take into account the specific characteristics of IP assets.

[29] S. Dux, *Nokia Declares Patent Peace on Licence Renewals*, Mobile Europe (9 February 2024), https://www.mobileeurope.co.uk/nokia-declares-patent-peace-on-licence-renewals/#:~:text=Nokia%20said%20its%20Q1%20net,families%20declared%20essential%20to%205G (access: 27 Jul. 2025).

[30] E. Zimmerman, *The Secret Behind Qualcomm's Margins? Patents*, Nonobvious blog (7 December 2023), https://blog.withedge.com/p/the-secret-behind-qualcomms-margins (access: 27. Jul. 2025).

[31] Dux, *supra* n. 28.

[32] E. Zimmerman E., *IRS Described Itself as Qualcomm's "Silent Partner" in Imposing Patent Tax on Mobile Device Industry*, FOSS Patents (6 April 2019), http://www.fosspatents.com/2019/04/irs-described-itself-as-qualcomms.html#:~:text=,their%20patent%20licensing%20revenue%20stream (access: 27 Jul. 2025).

[33] Zimmerman, *supra* n. 31.

6. Practical takeaways for legal professionals

There are challenges associated with deploying prediction tools for those in the legal and IP professions – one must marry statistical analysis to legal insight when using decision modeling tools.

6.1. Data and metrics

The first challenge is to get good data – projected licensing income, litigation success probabilities, technology forecasts, maintenance costs, etc. – which generally require coordinating activities across departments (finance, R&D, marketing). IP analytics tools (such as PatentSight, IPlytics, Derwent Innovations Index^{SM}) can assist by providing patent quality scores, citation indices, and competitive landscape data, which serve as proxies for value and risk. For example, one could use PatentSight's 'Patent Asset Index' which quantifies technical relevance and market coverage of patents; and this could be plugged into a model as part of r_i (higher score, higher expected value).[34] Citation counts can indicate technological importance (thus potential licensing demand), and can be factored in.

6.2. User-friendly modelling

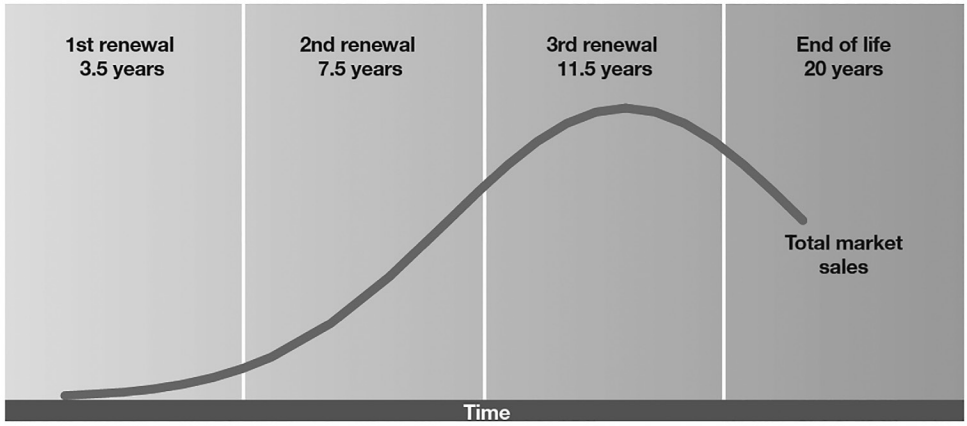
Lawyers are not required to become experts in programming Solver or coding, but rather need to be able to deploy easy-to-use tools, such as a simple Excel model where patent parameters can be input in order to produce a ranked list or optimal set. Many IP departments already use scoring spreadsheets, so it is a good idea to develop these into optimization models. From time to time, visual results (such as pie charts or frontier diagrams) might be helpful to explain strategy to the executives, as our Fig. 1 did in illustrating diversification effects.

6.3. Regular portfolio reviews

Just as a firm does financial portfolio optimization on a quarterly or annual basis, IP portfolios should be periodically re-optimized. Patents move through their lifecycle, business strategy evolves, and external conditions change (e.g., new court precedents, competitor patents). A model can be rerun with updated assumptions each time to guide decisions on renewals and new filings. For example, at each maintenance fee juncture (4, 8, 12 years in many jurisdictions), a model can evaluate if the remaining expected value justifies the fee. Many companies use heuristics here (like 'if no citations and no products using it by year 8, drop it'). A model might express that with value computations.

[34] B. Tran, *Patent Financing Can Help You Navigate Market Uncertainties*, PatentPC (2 July 2025), https://patentpc.com/blog/patent-financing-can-help-you-navigate-market-uncertainties#:~:text=%2A%20Data,increased%20demand%20in%20the%20future (access: 27 Jul. 2025).

Fig. 4
US patent maintenance coupled with product lifecycle (after A. Pham, Strategic Portfolio-Based Patent Investment…).



This figure reveals a critical insight for patent portfolio optimization: the timing of patent maintenance decisions should align with product lifecycle economics. The curve shows that total market sales typically peak around the third renewal period (11.5 years), making this a crucial decision point for patent holders. The early renewal periods (3.5 and 7.5 years) occur during the market growth phase, when maintaining patent protection is generally worthwhile as sales are still ascending. However, the third renewal decision at 11.5 years is particularly strategic, as it coincides with peak market value but also represents the beginning of market decline.

This alignment suggests that patent holders should carefully evaluate maintenance fees against projected market trajectories. For technologies with shorter lifecycles, the value may not justify maintenance through all renewal periods, while breakthrough innovations with extended market relevance may warrant protection through the full 20-year term. The model demonstrates that optimal patent maintenance decisions require integrating both patent costs and market timing to maximize return on IP investment.

6.4. Integration with legal judgement

An important point is that models are a supplement and not a replacement for expert judgement. And then there are other factors that are difficult to quantify—e.g., a patent might have some defensive value in terms of deterring suits (how to quantify 'deterrence'?), or a patent may be a chess piece in cross-licensing (not yielding money directly but in the sense of avoiding payments on it to some other entity). Lawyers need to identify those and either include them qualitatively (perhaps by assigning a notional dollar figure to defensive value, for example) or see that the decisions on those variables are sent out of the model for review. The model might score Patent A extremely low, but the legal team knows Patent A blocks a key competitor's product, so its strategic value far exceeds the direct revenue it appears to generate. In these instances, one can work around the model, or preferably code in that business significance at the model level either with a large weight or as a constraint ('have to carry Patent A in order to provide competitive coverage').

6.5. Addressing uncertainty and subjectivity

The subjectivity of the estimates has to be confessed to. To instill confidence in the modeling process, display sensitivity analysis: for example, 'If we're off by 50% on Patent B in our estimate, we'd still not use it—so we're likely good to drop it' or 'Patent C's fate in court is a coin flip; we accounted for that. If we remove it, our worst-case revenue drops by 30%, which we deemed acceptable given the cost savings of not litigating it'. This style of reasoning is more persuasive to management than vague statements. It shows contingency planning.

6.6. Policy implications

For policy audiences (e.g., advising government bodies), proving portfolio optimization's benefit can inform policies on R&D incentives or IP management best practices. Governments may encourage companies (especially SMEs who tend to under-utilize IP) to view their patents as a portfolio and actively manage them, possibly using tax incentives for IP commercialization (so that patents do not just sit unused). Additionally, as intangible assets now form a large share of corporate value, training legal professionals in basic analytics (or having IP analytics specialists in law firms) is increasingly important. We might see the rise of the 'IP portfolio analyst' role, akin to a financial analyst, within tech companies and law firms.

7. Conclusions. The role of analytics in IP strategy

In recent years, the law has started to see the impact of analytics – predicting litigation outcomes and doing patent landscaping. Another obvious direction is optimization of IP portfolios. There is also growing interest on the part of both law firms and in-house departments to tie IP spending to business justification. That value and savings should be better understood and appreciated in the C Suite when, for example, the General Counsel (GC) or Chief IP Officer (CIPO) comes in with a new and improved plan created by using their spending and value propensity data:

> (by trimming) 20% of low value patents, (we) save $X in fees and only lose $Y in potential licensing (thereby improving our IP ROI by Z%). We will use some of those savings to file within a new emerging technology in which we anticipate a higher return.

Messaging that speaks the language of the CFO, and increasingly the CEO, closing the divide between legal and finance. This resonates with CFOs and CEOs, bridging the gap between legal and finance.[35]

Beyond that, there's a policy dimension: making IP portfolios work more effectively does encourage innovation. Patents that genuinely have value to them do get preserved and are used, the ones that do not are either abandoned (again clearing out the thicket and cleaning up the patent space) or sold to companies where they can be used. It can be good

[35] T. Stevens, *Cashing In On Knowledge*…

for overall innovation, This fluidity can spur overall innovation – it mitigates the 'too many unused patents' problem that some economists point to as a drag (patent thickets that deter innovation).

And by fostering an optimization mindset, companies might be less inclined to hoard patents they do not need (since there is a clear cost to holding them and limited gain under the model) and instead end up licensing them out or allowing them to lapse so that others can use the knowledge. From an economic perspective, it makes IP work more like it should – in a way that incentivizes innovation and sharing of knowledge – rather than being about the numbers, or a legal arms race. Finally, not all value is quantifiable and over-indexing on modeling can be dangerous. Models should inform, not dictate. The qualitative judgments of seasoned patent attorneys – such as how an inventor's vision or how the strategic placement of a patent might open up possibilities for future technology – are priceless and cannot be captured in numbers.

Thus, the optimal approach is blending the two: use models to crunch the data and identify patterns or recommendations and then apply human judgement to refine and implement those recommendations. This synergy can result in much better results than either strategy individually, just like combining quantitative and fundamental analysis often leads to the best investing returns.

Marlena Jankowska
Dr. Hab., Assoc. Prof., Director of the Centre for Design, Fashion and Advertisement at the University of Silesia in Katowice in Poland. She holds an MBA from Deakin University, Australia, where unit Decision Modelling for Business Analytics has become the groundwork for the analysis developed in this article.

Abstract

Financial Decision Modeling for Intellectual Property Portfolio Optimization: Real-World Evidence for Building Strategies

Managing an intellectual property portfolio is, in many ways, akin to managing a financial investment portfolio. Both require balancing potential reward against risk, operating under resource constraints, and adapting to changing conditions. This article demonstrates that by adapting concepts from Modern Portfolio Theory and decision modeling to the IP domain, legal professionals can bring a new level of rigor and strategic clarity to IP management.
We draw parallels between financial assets and IP assets, establishing an analogous vocabulary of expected returns (IP value), risk (uncertainty of legal/commercial success), and correlation (interdependence of patent values). Using the toolkit of financial analytics, we construct a framework for optimizing IP portfolios: identifying which patents or projects to invest in, how to allocate budgets among them, and when to cut losses on underperforming assets. Real-world case studies of IBM, Nokia, Qualcomm, Dow, and others provide concrete evidence that these principles are not merely academic.

Keywords: *IP portfolio, IP management, Modern Portfolio Theory, Sensitivity Analysis, Monte Carlo simulation, Linear Programming (LP), Integer Linear Programming (ILP)*

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