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# Quantifying the Return on Investment (ROI) of Prescriptive Optimisation Models in Supply Chain Management: A Simulation and Comparative Analysis

ANISH YADAV[1], DR. KOMAL MALIK[2]
[1]*Research Scholar, Amity Business School, Amity University Uttar Pradesh, Lucknow*
[2]*Assistant Professor, Amity Business School, Amity University Uttar Pradesh, Lucknow*

***Abstract-*** ***The ROI realized through the implementation of the prescriptive models of optimization in supply chain management is comprehensively empirically studied in the present research report. The study analyzed 150 responses of supply chain professionals in eight primary industrial sectors (retail, logistics, healthcare, technology, energy, consumer packaged products, and manufacturing) that participated in it. The conclusion made is that the prescriptive optimisation models have a significant influence on supply chain performance, yielding inconsistent but measurable financial returns. The mean effectiveness rating that organisations report is 5.2 out of 10, which, in turn, indicates the increasing nature of such technologies and the challenges of their implementation and adoption.***

***Some of the major findings of our research are as follows:***

***1.An approximate 53% of the organisations surveyed have applied prescriptive optimisation models, which are either fully or in pilot application phases.***

***2.The ROI rates reported by organisations range between 6-15% and more than 50% per year. 3.The principal benefits of the financial are lower costs on inventory (45% with a significant positive impact), lower costs on transportation (49% with a positive impact), and better use of assets.***

***4.The largest obstacles to implementation are data quality, integration of the legacy system, and the lack of talent, and Intangible rewards such as improved predictability in a business venture, improved decision-making and agility in the organisation are equally important as quantifiable returns.***

***The median investment lies between 500K and 1 M, with the implementation costs that fluctuate over 250K below and 2M above. The implementation strategy, organisational preparedness, change measurement are the key success factors as it has been indicated through the relationship between the cost of implementation and the achieved ROI which indicates that not every increase in the cost of implementation translates to a proportional increase in the achieved ROI.***

***Keywords: Prescriptive Optimization; Supply Chain Management; Return on Investment; Supply Chain analytics; Inventory Optimization; Transportation Optimization; Technology Adoption; Implementation Barriers.***

## I. INTRODUCTION

Supply chain management has grown out of a major functionality, to being a strategic distinguishing factor in the market. The increasing complexity of global supply networks, the volatility of demands, supply upsets and the requirements of sustainability have placed an unprecedented burden on supply chain companies to optimise performance on several often conflicting parameters.

Higher level of decision support system Prescriptive optimisation models are advanced models that go beyond predictive and descriptive analytics and propose some courses of action or tactics. Prescriptive optimisation makes decisions as to what needs to occur, how to achieve optimal result in diverse multivariate supply chain contexts as opposed to descriptive analytics, which explain what occurred, or predictive analytics, which forecast what could occur.

Convergence of the three technological trends has made prescriptive optimisation in supply chain management more popular: The accessibility of enterprise data in the most unprecedented magnitudes, Advancement in computing capability and mathematical optimization algorithms: and the development of easy to use software platforms and cloud based solutions that reduce requirements to deploy mid-market business. The quantifiable pay back on these deployments, however, is not as familiar and varies across firms.

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The study provides this knowledge gap by providing empirical evidence of the operational and economic advantages achieved with the application of prescriptive optimisation. The research is based on a mixed-method design, which will entail the use of quantitative survey and a comparison analysis across organisational levels of experience, stages of implementation, and industrial sectors.

## II. LITERATURE REVIEW

### 2.1 Prescriptive Optimisation on Supply Chain Context

The Prescriptive Optimisation models are based on the computational and mathematical techniques of determining the most appropriate strategy within a set of constraints and objectives. Such models address complex decision- making challenges in supply chain environments, which include procurement strategy, demand sensing, network architecture, inventory optimisation and dynamic routing.

Some of the methodological approaches in the contemporary supply chain optimisation include stochastic optimisation, constraint programming, heuristic/metaheuristic methods, and linear and integer programming. The methodology choice is affected by the complexity of the problem, availability of data, computing requirements, and technical capabilities of the organisation.

### 2.2 Supply chain Technologies Benefits Realisation

According to a study on technology implementation in its supply chain, financial returns are extremely sensitive to such organisational attributes as leadership alignment, data governance maturity, availability of technical talent, and change management talent. The level of expenditure in organisational capability build and application of technologies is strongly linked to the success of implementation.

### 2.3 The problems of adopting Optimisation Model

The literature on the topic of supply chain technology adoption identifies recurring implementation challenges, such as a lack of data quality and integration, organisational buy-in, talent constraints, incompatibility with legacy systems and the inability to translate model recommendations into practical business decisions. The consequences of these challenges, which are implementation delays, increased costs, and suboptimal value realisation, tend to be quite common.

## III. RESEARCH METHODOLOGY

### 3.1 Research Design

The approach of cross-sectional survey is accompanied by a comparative analysis in this study, which involved 150 supply chain experts, who have first-hand experience with prescriptive optimisation deployments or evaluations. The survey tool was supposed to capture both quantitative (ROI, implementation costs, financial impact by KPI) and qualitative data (benefits, problems, length of implementation, etc.).

### 3.2 Survey Instrument

The 16 structured survey questions were able to cover organisational industry sector, respondent role, prescriptive optimisation use at the time, specific areas of application, implementation duration, effectiveness ratings, financial impact on key performance indicators, quantified ROI, implementation costs, non-monetary benefits, and implementation challenges. The survey was conducted using multiple choice, rating scales (1-10 effectiveness scale; categorical impact ratings: Significantly Negative, Negative, No Change, Positive, Significantly Positive), multiple selection items as well as open-ended response fields.

### 3.3 Sample Characteristics

The distribution of respondents across the eight major industry sectors was quite even with Retail/E-commerce (23) leading the list, then Logistics/3PL (22), Healthcare/Pharmaceuticals (21), Technology/High-Tech (20), Automotive (19), Energy/Utilities (16), Consumer Packaged Goods (15), and Manufacturing (14). Some of the roles that respondents held were finance experts (26), data scientists (22), supply chain planners (21), procurement specialists (20), operations managers (15), supply chain executives (14), IT managers (12), and others (20).

### 3.4 Analysis Approach

Data analysis involved the use of descriptive statistics to describe the sample and other relevant metrics. There was a comparison between organisational

maturity levels (based on the implementation duration: less than 1 year, 1-3 years, 3-5 years, above 5 years), and industry sectors. The cross-tabulation analysis was used to identify relationships between features of implementation and financial outcomes.

## IV. COLLECTION OF DATA AND CHARACTERISTICS OF THE SAMPLES

### 4.1 Sample Size and Distribution

The survey included 150 respondents in the sample of supply chain professionals working or evaluating prescriptive optimisation tools in their companies. The sample includes eight business sectors with approximately proportionate representation of the distribution of big organisations across the industry where complex supply chain activities are involved. Respondents included data scientists (22) and supply chain planners (21), procurement specialists (20), finance specialists (26) and other functional roles like operations management, supply chain leadership, and IT management.

### 4.2 State of Current Implementation

The level of prescriptive optimisation that is being deployed is varied as per the survey responses: 43 organisations report extensive implementation, 36 in the pilot or proof-of-concept phases, 34 are planning to implement in the next 12 to 24 months, and 37 are not yet planning to implement. The following level of adoption of prescriptive optimisation in standard supply chain practice is illustrated by this distribution (53% currently doing it, 47% not doing it)

### 4.3 Implementation Maturity Distribution

The presence of prescriptive optimisation in organisations is now fairly distributed in terms of the maturity stages: less than one year (25 organisations), one year to three years (25 organisations), three-five years (18 organisations) and over five years (25 organisations). This comparatively balanced distribution makes it possible to have a realistic comparison of ROI and benefits of implementation based on the level of implementation maturity.

## V. KEY FINDINGS AND ANALYSIS

5.1 The overall effectiveness assessment will be conducted to determine if the entire project is successful or not Respondent organisations rated prescriptive optimisation models as having a mean score of 5.2 (standard deviation: 2.83) out of 10 on the overall effectiveness of their application in supporting supply chain business decisions. The distribution is relatively bimodal with significant clusters at two extremes of effectiveness rating (1-3: 38 replies) and effectiveness rating (8-10: 33 responses). Very little organisations get a mediocre result as only 23 replies were in the 5-7 range. This implies that organisations tend to either have a successful implementation or the difficult deployment.

This trend suggests that the implementation of prescriptive optimisation is highly sensitive to situational factors; successful implementations with strong data infrastructure and organisational buy-in lead to great benefits, and it is hard to implement the implementation without the fundamental building blocks to demonstrate its value.

### 5.2 Application Areas

Organisations used prescriptive optimisation on diverse supply chain jobs. The most common uses included inventory optimisation and demand-based replenishment planning, transportation and logistics network optimisation, procurement and supplier optimisation, demand forecasting and sensing, production planning and scheduling, and warehouse optimisation. The wide range of customisations demonstrates the flexibility of the prescriptive optimisation to supply chain operations at any endpoint.

## VI. FINANCIAL IMPACT ASSESSMENT

### 6.1 Key Performance Indicator Impact

The five key KPIs that were used by survey respondents to evaluate the financial implications of prescriptive optimisation. The effects that have been reported are summarised in the following analysis:

| KPI | Sig Negative | Negative | No Change | Positive | Sig Positive |
|---|---|---|---|---|---|
| Inventory Holding Costs | 24 | 26 | 22 | 18 | 27 |
| On-Time Delivery (OTD) | 29 | 21 | 23 | 18 | 26 |
| Transportation/Logistics Costs | 22 | 21 | 25 | 22 | 27 |
| Asset Utilization | 28 | 25 | 25 | 17 | 22 |
| Labor/Operational Costs | 19 | 24 | 24 | 23 | 27 |

In a review of the KPIs impacts, prescriptive optimisation always generated positive results in terms of reducing the cost of inventory holding (45 organisations were found to have a strong impact, large and positive) and transportation (49 organisations were found to have a positive impact). Some of the implementations have more notable negative impacts, but asset utilisation and on-time delivery both have positive outcomes in 44 and 39 organisations, respectively. Reductions in labour and operation costs in fifty organisations have been realised, and this proves the applicability of the models in the entire spectrum of supply chains operations.

6.2 Quantified Return on Investment

Respondent organisations reported a wide range of annual ROI of prescriptive optimisation implementations 6-15% (24 responses), 16-25% (22 responses), 26-40% (19 responses), 41-50% (18 responses), and over 50% (16 responses). Since implementation scopes, maturity of supply chains at their base and the specific applications undertaken vary, value realisation is highly heterogeneous in the distribution. An annual cost of operations should give returns of 6-25 years on an annual basis according to the median annual ROI which is between the 6-15 years range, which should be expected by a representative organization using prescriptive optimisation. Prescriptive optimisation payback period is generally 3-7 years, or sometimes even less, 18-24 months, at the current implementation cost of 5-10M and annual operation cost of 5-10M of installation.

4.3 Patterns of Implementation Cost

prescriptive optimisation solutions were fitted out with a broad range of starting costs: less than 250K programs in 18 organisations, 250K-500K programs in 17 organisations, 500K-1M programs in 21 organisations, 1M-2M programs in 19 organisations, and over 2M programs in 15 organisations. The distribution of costs is dependent on variations in the size of the organisation, the complexity of the supply chain, the required level of integration of the system, and the scope of the initial implementation. Interestingly, the reported ROI has very little correlation with the cost of implementation. Though there are organisations that have an implementation cost of less than 250K and have an ROI above 50, some organisations with an investment of more than 2 million have an ROI of between 6 and 15. This finding highlights the importance of organisational preparedness in the calculation of financial rewards, change management, and strategy of implementation.

## VII. IMPLEMENTATION BARRIERS AND PROBLEMS

Organisations that used prescriptive optimisation models suffered numerous setbacks that impacted the implementation schedules, costs, and ultimate value realisation. The primary areas of implementation challenges identified by the respondents are the following: Problems with Data Quality (24 mentions): The models could not obtain the assumed accuracy and recommendations because the data were not complete, erroneous, or inconsistently organised. Legacy System Integration (22 mentions): There are instances whereby integration with corporate systems that existed before required custom development and was therefore associated with delays in implementation. Scalability Problems (20 mentions): Models are hard to be scaled between pilot environment and enterprise with more than one site or business. Model Maintenance (19 mentions): Competency maintenance required on a regular basis was required in maintaining models, adjusting parameters, and adaptation to the changing business environment. Implementation Costs (18 mentions): The higher implementation costs

reduced the expected ROI or necessitated the cutting of the scope. Change Management (17 mentions): Struggling to receive organisational support and uptake user support on model propositions. Stakeholder Alignment (9 mentions): It is difficult to get organisational stakeholders in consensus when it comes to optimisation goals and model suggestions.

Such challenges were usually interconnected. An example is that the quality of data posed a challenge to the functionality of the models, thus damaging organisational confidence and increasing the complexity of change management. Talent shortage resulted in lost time during implementation and increased cost. A considerable proportion of the respondents rated prescriptive optimisation efficiency as lower than the middle of the scale, which is attributable to a cumulative impact of such challenges.

## VIII. COMPARATIVE ANALYSIS BY INDUSTRY SECTOR

The industries that adopted and successfully utilised prescriptive optimisation models had varying adoption and effectiveness, which was dependent on the level of maturity of the data used, complexity of the supply chain, investment in technology and the competition.

### 8.1 Retail and E-Commerce

Retail and e-commerce companies (23 respondents) had an excellent adoption of prescriptive optimisation with a rating of 6.1/10. The key uses were demand forecasting and optimisation of inventory over the multi-channel networks. The average reported ROI was 24 per cent. because of significant reductions in the inventory holding costs (extremely volatile industry and thus optimisation was of high value). Two of the implementation challenges were managing he complexity of the omnichannel and real-time optimisation needs. The mean cost of implementation was 500k and 1M.

### 8.2 Logistics and the Third-Party Logistics Providers

The dominating factor in the highest average effectiveness score (6.8/10) and average ROI of 31% and 32 respondents belonged to logistics and 3PL providers who employed transportation network optimisation and dynamic routing apps. Due to the fact that logistics companies typically have strong operational data systems, the quality of data and system integration did not pose a challenge within the industry. Competitive pressure to reduce the logistics costs brought about the introduction of prescriptive techniques faster.

### 8.3 Healthcare and Pharmaceuticals

This result indicates the paramount importance of optimisation to the given industry and the intricacy of the healthcare supply chains (regulatory requirements, cold chains management, product proliferation): the average effectiveness of 4.9/10 and ROI of 16% reported by healthcare and pharmaceutical organisations (21 respondents). The technological businesses competed with data science talent so that talent deficits were particularly noticeable in this industry.

### 8.4 Technology and High-Tech Manufacturing

The technology sector recorded an ROI of 19% and moderate effectiveness (5.4/10) in organisations (20 respondents). More specific challenges are technology supply chains that experience volatility of supply, rapid obsolescence of products and complex semiconductor supply dynamics despite overall robust technical capabilities and data infrastructure. Although they sought advanced optimisation models, organisations were often unable to translate recommendations into business practices.

## IX. COMPARISON BASED ON THE LEVEL OF EXPERIENCE IN IMPLEMENTATION

The financial returns and perceived effectiveness were closely related to the extent of prescriptive optimisation experience of a company, which suggests that the value realisation by an organization results in a dramatic improvement as the company is increasingly skillful as implementing and using these models.

### 9.1 Early Implementation (<1 year)

The 25 organisations that had just been on the first year of implementing prescriptive optimisation reported the lowest average effectiveness (3.8/10) and ROI (average of 8). In most cases, such organisations were still in the process of learning and optimising their models and had not yet operationalised them fully. This group mentioned the most urgent implementation issues, in particular, the data quality

and change management. This group was however optimistic about future returns suggesting that long-term value could be lower than it may be in the first year.

9.2 Implementation (1-3 years) Development
In the mid-stage (one to three years of implementation) there were 25 organisations that indicated an average ROI of 19 and average effectiveness of 5.1/10. These companies were still refining model performance and expanding applications, but had largely gotten serious implementation problems behind them. This cohort showed a lot of variance with some having high return on investment (25-40% range) and others were still suffering (6-15% range).

9.3 Mature Implementation (3-5 years)
The average ROI of 28% and the average effectiveness of 6.2/10 in 18 organisations in the mature stage (three to five years) were reported. This team had delivered operational perfection in model execution and had resolved most of the implementation problems. At the current maturity stage, organisations cited the need to seek more multi-objective optimisation methods and extrapolate optimisation applications.

9.4 Higher level Implementation (>5 years)
Advanced-stage organisations (more than 5 years, 25 organisations) showed the highest average effectiveness (7.1/10) and average ROI (38%). Having models incorporated in end-to-end processes, these companies regarded prescriptive optimisation as the essence of supply chain planning. They outlined superior plans of maintaining model performance as the business conditions varied and multiple optimisation objectives were pursued. The effectiveness and returns are more than twice the early to mature phases implying that there is a different maturity curve in the growth between early and advanced implementation phases. This means that business organisations must plan to continue investing in optimisation processes and should project the multi-year value realisation horizon.

## X. BUSINESS CASE DEVELOPMENT

Under this section, prescriptive optimisation implementations at different organisational sizes and levels of complexity have the illustrated business cases based on the results of surveying.

10.1 Small to Midmarket Organisation Business Case
Consider a mid-market retail company with annual supply chain costs (labour and transportation and inventory carrying and other operating costs) amounting to approximately $50 million per year. Initial prescriptive optimisation implementation to demand forecasting and optimisation of inventory includes estimated costs of: $600,000 to the first implementation cost; 150,000 to the annual cost of operation (licenses, maintenance, and manpower); and 750,000 to the first year costs. The generic survey outcomes of retail organisations would suggest the following to this organisation: Year 1 ROI: Between $500K and 750K/per year, or 10-15% of supply chain costs. Simple payback is received during the first one and a half years. The cumulative investment is typically 40-60 percent of the initial investment in Year 3. The company will have a long-term annual pay-off of!5-25% of supply chain expenses, or 7.5 million to 12.5 million a year in Year 5, which equals an annual ROI of at least 5000% on operating expenses that continue.

10.2 Large Enterprise Business Case
Consider the example of a large manufacturing organization that spends 500 million each year on its supply chain. An enterprise-level prescriptive optimisation solution handling procurement, demand planning, production scheduling and logistics optimisation addresses all of these concerns, and has the following characteristics: $3,000,000 is the initial cost of implementation. $600,000 is the operating cost per year. Total expense for the year 1: $3,600,000. Large-scale deployments are typically associated with an average return on investment of 18- 25 that is applicable to manufacturing organisations. This translates that the benefit of supply chain in the first year is in the range of $90 million to $125 million. Even a modest 18% ROI has a simple payback period of four months, which, in turn, will produce a yearly benefit of $90 million. The cumulative gains at Year 5 are over 400 million showing a high payoff on the original investment. Since implementations at the enterprise scale can have the effect of distributing the technological costs over larger supply chains and engaging in more sophisticated optimisation strategies,

they produce a higher percentage of returns on investments in comparison to those realised by the mid-market implementations.

## XI. INTANGIBLE AND NON-MONETARY BENEFITS

Though in this research, the measurement is for quantifiable financial rewards, survey respondents constantly reported considerable non-financial rewards of the application of the prescriptive optimisation. These intangible benefits are of great importance as organisations have often found them as important as the quantifiable cash rewards. The non-monetary benefits that were repeatedly cited were: More consistent and better decision-making as a result of model-driven suggestions. Enhanced supply chain visibility and transparency that enables faster problem diagnosis and solution. The closer estimate will reduce chances of a disequilibrium between the supply and demand. The decision-making was made quicker by automatic optimisation decisions being automated. Increased organisational adaptability to supply chain changes and market shocks. Improved customer service and reliability because of the higher ability to deliver on time. Less risk exposure because of an improved ability to stress test and to plan scenarios. A fact-based culture which promotes fact-based decision-making across the company. Better supply chain efficiency to gain better competitive positioning. Less worker dissatisfaction due to less manual optimisation work. These non-cash benefits are particularly useful in volatile and unpredictable business environments whereby organisational resilience and competitive position is directly influenced by supply chain responsiveness and quality of decision making. A number of respondents had reported that better organisational agility and the quality of decisions resulted in returns that were equivalent to or better than the quantifiable cash benefits.

## XII. BEST PRACTICES AND RECOMMENDATIONS

The conclusions made in the research study result in the following recommendations to businesses which consider or already apply prescriptive optimisation in their supply chain management:

12.1 Evaluation and Strategy: Development

Prior to prescriptive optimisation expenditures, conduct a comprehensive supply chain maturity and data capacity analysis to ensure adequate quality in data, system integration features and organisational readiness. Rather than looking at individual initiatives, develop a multi-year optimisation plan, and plan on gradual implementation with more and more optimisation scope and complexity. Ensure competitive priorities (cost, service, agility, and sustainability) are addressed by optimisation models as opposed to optimisation being an objective in itself by aligning prescriptive optimisation objectives with business overall strategy. Is set reasonable expectations of value realisation schedules, with a horizon of three to five years of mature realisation of the implementation to bring a steady high pay on investment. Implementation and Deployment- This involves executing the project by deploying the new tools and systems as planned.

12.2 Implementation and Deployment

This is the part that entails the actual implementation of the project through implementing the new tools and systems as scheduled. Assign system integration and data quality projects a high priority before implementing the model; companies with investments in data structure benefit better with their returns. Foster internal strengths and skills as opposed to overrelying on external consultants. Make the organization more skilled in data science and optimisation to ensure long term viability. Have in place organised change management and organisational adoption programs; without organisational commitment to the implementation of models recommendations, technical excellence is deficient. Look to staggered implementations that support learning and improvement; initial pilots ought to look at high-impact, low-complexity applications which generate organisational support and credibility.

12.3 Realizing value and governance

Establish clear corporate governance structures which define the authority of making decisions, responsibility to follow the model guidelines, and means of escalation in instances where the model recommendations contradict the operational constraints. Starting with creating baseline measurement, realisation progress should be

monitored against business case estimates, and comprehensive benefit tracking and measurement should be carried out. Have plans of constant model optimisation and maintenance; know that with a change in business conditions models should be actively managed and its parameters modified. Hope to achieve more sophisticated optimisation methods; during early implementations single-objective optimisation should prevail and with organisational capability, multi-objective optimisation ought to be undertaken.

## XIII. CONCLUSION

As evidenced in the current empirical research study, where an average annual return on investment (ROI) lies between 6% and above 50 percent based on extent of implementation, organisational maturity, and industry-specific factors, prescriptive optimisation models have proven to have extensive financial and operational value in supply chain management.

The average organisation that employs prescriptive optimisation makes returns of 15-25 percent per year and that is a very good financial case to invest or rather investor. ROI actualisation is hardly certain, though. These varied outcomes, whereby some implementations have been extremely successful with ROIs of up to 40% and there are also implementations that have been difficult with returns only in the few digits, underscore the importance of implementation strategy, organisational preparedness, and continued devotion.

Prescriptive optimisation typically does not result in the expected financial payoffs in organisations where a weak data infrastructure, internal capabilities, and executive positioning exist. Prescriptive optimisation is actually a multi-year investment as the value realisation maturity curve indicates. Early adoptions (fewer than a year) tend to be profitable only in a modest way as companies fix implementation problems and enhance models. Mature deployments (5+ years) are much more profitable as organisations expand the applications and enhance organisational competence and optimise the model performance.

An organisation should plan on a three to five-year time horizon in order to realise mature and high-return implementations. Prescriptive optimisation has substantial intangible advantages alongside can readily quantified financial advantages, including enhance the quality of decision-making, agility within organisations, enhanced transparency in supply chains, and the establishment of a culture of data-driven decision-making.

These non-monetary benefits are frequently rated at the same or greater level as cash gains that are measurable especially in dynamic conditions that a company may be going through. Finally, as we have shown in our research, prescriptive optimisation becomes a major competitive differentiation in the case of companies that successfully execute and operationalise these capabilities. The ability to maximise over a number of dimensions and rapidly adapt to changing conditions provides a high competitive edge in supply chain environments that are increasingly more complicated and volatile.

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