

THE INTEGRATED APPLICATION  
OF EFFECTIVE APPROACHES IN  
SUPPLY CHAIN NETWORKS

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# THE INTEGRATED APPLICATION OF EFFECTIVE APPROACHES IN SUPPLY CHAIN NETWORKS

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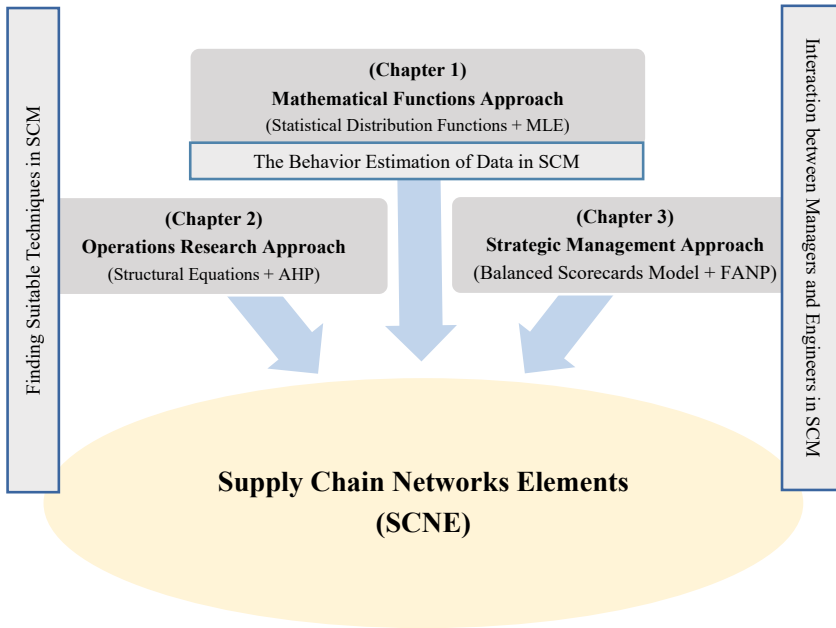
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# PREFACE

In today's competitive world, the necessity of gathering information about supply chain networks and analyzing it from different aspects is not hidden from anybody. International managers, organizational experts, and many decision-makers need this information. This book is one of the rarest books on the integrated application of effective approaches in supply chain networks. While many books with a similar theme explain different techniques in supply chain networks separately, this book links extremely effective approaches belonging to different branches of science to supply chain elements in an integrated format. These topics are categorized as follows in this book:

- (1) In the first chapter, the use of the mathematical functions approach (statistical distribution functions and maximum likelihood estimation) is discussed to explain the behavior of supply chain network data.
- (2) In the second chapter, the use of operations research (multiobjective linear programming by structural equations and analysis hierarchy process) aims to find suitable quality techniques in supply chain elements.
- (3) In the third chapter, the use of a strategic management approach (balanced scorecard model and fuzzy analysis network process) describes the interaction between supply chain managers and quality engineers.

Professor Thurasamy Ramayah with more than 30 years of experience in teaching at the School of Management at Universiti Sains Malaysia and other top universities has shared his expertise in information technology and statistical techniques in the book. Ramin Rostamkhani as a Senior Researcher with more than 20 years of experience in industry has also shared his expertise in supply chain management (SCM) and quality engineering techniques in the book. Both authors have written a book about the application of quality engineering techniques in SCM in 2022. That book was related to the application of statistical and non-statistical tools in SCM. This book is a strong

supplemental source after that book. In fact, this book can assist professional readers to more deeply understand the role of integration of different techniques in an intelligent approach based on conceptual academic issues in supply chain networks.

It should be noted that in the final part of this book, there is a supplemental chapter. This chapter has a brief history of the formation of the subject. In fact, this chapter is for readers interested in the historical review of the subject.

The integrated application of effective approaches in supply chain networks and related data analysis is the main topic of this book. This book, in addition to expanding the application of different techniques belonging to different branches of science aims to create purposeful coordination and integration for the analysis of supply network data. This achievement, with the distinguished academic and industrial experiences of the authors, can provide the book with an attractive destination, especially for professional readers. The knowledge that reading this book will provide to professional readers, including experts, managers, and graduate students in the field of network data analysis, will enhance creativity more than any other effect.

*The integrated combination of applied mathematics (statistical distribution functions) and operations research (multiobjective linear programming) in addition to the analytics hierarchy process along with the basics of strategic management (the balanced scorecard model) and fuzzy analysis network process can be attractive and significant in any branch of science or engineering.*

Ramin Rostamkhani – Thurasamy Ramayah

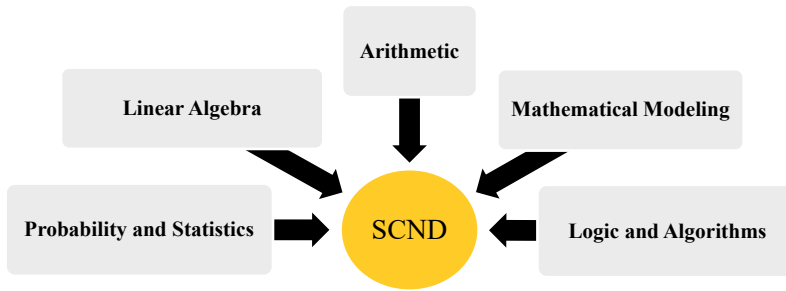
# INTRODUCTION: A BRIEF HISTORY OF THE COMBINATION OF DIFFERENT BRANCHES OF SCIENCE IN SUPPLY CHAIN NETWORKS

Before reviewing the combination of different branches of science on the subject of supply chain, we must emphasize that in some scientific texts, a small distinction is considered between supply chain management and supply chain network data (SCND), but in this book, due to the direct connection between the two scientific subjects, similar elements have been selected in both categories. This means that supply chain data comes from the same elements that are needed for supply chain management. This brief history reviews the application of mathematics basics, operations research, and management concepts to SCND in the first two decades of the 21st century:

- The brief history of the application of mathematics on supply chain networks.
- The brief history of the application of operations research on supply chain networks.
- The brief history of the application of management concepts on supply chain networks.

## THE BRIEF HISTORY OF THE APPLICATION OF MATHEMATICS IN SUPPLY CHAIN NETWORKS

There are different aspects of mathematics that have been applied to SCND. [Fig. 1](#) shows it.



**Fig. 1. Different Aspects of Mathematics in SCND.**

### Probability and Statistics

In today's economy, SCND are critical to developing and maintaining the modern economy. One of the most important aspects of mathematics that can be essential for making informed decisions and analyzing business data is probability and statistics. These concepts can use data analytics to manage, improve, and support supply chain operations. The application of these concepts is fully explained in the first chapter in the constituent elements of supply network data. Of course, the central core of this approach in the first chapter was the use of famous statistical distribution functions. Probability deals with predicting the likelihood of future events, while statistics involves the analysis of the frequency of past events. Both can be applied in modern supply chain networks that will focus on automation, sustainability, digitization, collaboration, innovation, flexibility, and agility to stay ahead of changing customer demands and market disruptions. [Table 1](#) shows the best applications of probability and statistics on SCND.

**Table 1. The Best Applications of Probability and Statistics in SCND.**

Author(s)	Title	Year
Mohsen Hosseini and Dmitry Ivanov	Bayesian networks for supply chain risk, resilience, and ripple effect analysis: A literature review	2020
Hua Wang, Tao Gu, Maozhu Jin, Rong Zhao, and Guanxiang Wang	The complexity measurement and evolution analysis of supply chain network under disruption risks	2018
Viplove Arora and Mario Ventresca	Modeling topologically resilient supply chain networks	2018
Chen-Yang Cheng, Tzu-Li Chen, and Yin-Yann Chen	An analysis of the structural complexity of supply chain networks	2014

## Linear Algebra

The data related to supply chain networks, in many cases, are variables that tend to be processed in ways that do not depend on the square, the cube, or any other power. In general, linear algebra deals with straight lines involving linear equations. In SCND, a formal tensorial framework including two categories, countable and uncountable spaces that can have an important role in analyzing data in supply chain networks. A generalization of linear algebra forms is usually represented by matrices. [Table 2](#) shows the best applications of linear algebra on SCND.

**Table 2. The Best Applications of Linear Algebra in SCND.**

Author (s)	Title	Year
Roberto De Virgilio and Franco Milicchio	A linear algebra approach for supply chain management (RFID data analysis using tensor calculus for supply chain management)	2011
Leslie Gardner and Allison Medley	Supply chain management instructional modules for mathematics with assessments	2009

## Arithmetic

Arithmetic is the fundamental of mathematics that includes the operations of numbers. These operations are addition, subtraction, multiplication, and division. Arithmetic is one of the important branches of mathematics. This is one of the oldest aspects related to mathematics that has been applied in the different calculations of SCND. In all the books and articles published about supply chain management, the effect of common mathematical operations can be seen in the framework of four main operations addition, subtraction, multiplication, and division. These operations can always be useful for each element of supply chain management. The scope of the four main operations in SCND is very large, and as a result, almost all related articles and books can be considered as precedents.

## Mathematical Modeling

The attention toward the use of mathematical models to optimize supply chains has been increasing, mainly because of their lower cost and greater capability. In supply chain management the use of mathematical modeling is not specific to any particular level; it can be used at any level (strategic, tactical, or operational), considering factors like transportation routing, distribution

networks, or warehouse operations. Mathematical modeling approaches that are usually considered in supply chain problems include linear programming, mixed-integer/integer linear programming, non-linear programming, multiobjective programming, fuzzy mathematical programming, stochastic programming, heuristics algorithms, and metaheuristics and hybrid models (Lee et al., 2016). The best examples of this applied model can be seen in Table 3.

**Table 3. The Best Examples of Mathematical Modeling in SCND.**

Author (s)	Title	Year
Oluwadare Badejo and Marianthi Ilerapetritou	A mathematical modeling approach for supply chain management under disruption and operational uncertainty	2023
Young Hae Lee, Paulina Golinska-Dawson, and Jei-Zheng Wu	Mathematical models for supply chain management	2016
D. J. Easters	Mathematical supply-chain modelling: Product analysis of cost and time	2014
N. Anbazhagan	Mathematical modeling of supply chain management systems	2010

### Logic and Algorithms

SCND involves the use of various algorithms to solve complex optimization and decision-making problems. All logic and algorithms in the previous studies have considered the following aspects:

1. Operations
2. Purchasing
3. Distribution
4. Integration

One of the best examples of this conceptualization is a doctoral thesis (Özdemir, 2017) as follows (Table 4):

**Table 4. The Best Example of Logic and Algorithms in SCND.**

Information	Title	Year
<i>Supervisors:</i> John, Robert Ozcan, Ender	An integrated model of supplier selection and inventory planning using fuzzy logic and multiobjective evolutionary algorithms Ph.D. thesis (University of Nottingham)	2017

## Conclusion

As supply chain networks grow, increasing complexity will drive companies to look for ways to manage large-scale decision-making. They cannot go back to how supply chains were 100 years ago – or even two years before the pandemic. Instead, new technologies will help streamline and manage the many moving parts. Logistics, optimization technologies, and organizational skills used in the supply chain all require mathematics. Workers will not necessarily need high-level mathematics skills for all job positions. But folks looking to work in the supply chain should expect to encounter math when solving industry challenges. Also, all relevant students do not need a mathematics degree to work in the supply chain, but it helps to understand the mathematical foundations for supply chain models.

### THE BRIEF HISTORY OF THE APPLICATION OF OPERATIONS RESEARCH IN SUPPLY CHAIN NETWORKS

The advent of the information technology revolution, economic globalization, and high customer expectations has caused various changes in companies' SCND, highlighting the importance of competition among supply chains rather than companies. Artificial intelligence methods based on operations research are the most appropriate methods to cope with this big data-related challenge. Machine learning techniques based on operations research can be considered as the popular sub-disciplines in artificial intelligence that identify and extract automatically the patterns among variables using large datasets (Tirkolaee et al., 2021). Machine learning algorithms related to operations research are mainly divided into four categories: supervised learning, unsupervised learning, semi-supervised learning, and reinforcement learning (Sarker, 2021). One of the newest applications of artificial intelligence, in conjunction with operations research in SCND can be seen in valuable research by Singh et al. (2023). The other aspect of computer programming connected to operations research that is very popular to use in SCND is simulation software. This software is based on computational algorithms in operations research. Moreover, one of the most important applications of operations research in supply networks is the use of linear and non-linear multiobjective planning models, which have received much attention from supply network planners in recent years. In this book, in the second chapter, we discussed its applications related to the use of operations research through linear multiobjectives in supply chain network elements.

THE BRIEF HISTORY OF THE APPLICATION OF MANAGEMENT  
CONCEPTS IN SUPPLY CHAIN NETWORKS

In 1982, Keith Oliver first coined the “supply chain management” term and used it in a public interview conducted by *Financial Times*. However, the concept of a supply chain in management was of great importance long before, in the early 20th century, especially with the creation of the assembly line. Supply chain management is the handling of the entire production flow of a good or service to maximize quality, delivery, customer experience, and profitability. In other words, supply chain management is the application of management concepts in SCND. The 100-year history of supply chain management began with improvements in basic, labor-intensive processes and progressed to current-day engineering and complex international networks. [Table 5](#) shows the used management concepts in supply chain networks from the past to now. It should be noted that in this book, in the third chapter, we discussed its applications related to the use of strategic management concepts in SCND thoroughly.

**Table 5. The Used Management Concepts in Supply Chain Networks from the Past to Now.**

Title of the Used Management Concepts in Supply Chain Networks	Time
The scientific management in supply chain networks	1910
The transportation management in supply chain networks	1950
The inventory optimization management in supply networks	1960
The physical distribution management in supply chain networks	1965
The use of logistics management in SCND	2005
The use of strategic management techniques such as balanced scorecard models	From
The predictive/prescriptive management in SCND at all levels	2015
The use of digitalization or digital platforms management and blockchain management	to
The use of digital platforms management and blockchain management which are data-driven and connect trading partners in a collaborative supply chain ecosystem to drive real value and growth for the relevant customers worldwide is an innovative revolution in the supply chain world. Digital platform management and blockchain management have been at the forefront of supply chain innovation in the last decade. Moreover, advanced quality engineering techniques that have been used in the evaluation of SCND are more applied compared to the past.	2022

## REFERENCES

- Anbazzhagan, N. (2010). *Mathematical modeling of supply chain management systems, enterprise information systems and implementing*. IGI Global Publishing Group. <https://doi.org/10.4018/978-1-61520-625-4.ch022>
- Arora, V., & Ventresca, M. (2018). Modeling topologically resilient supply chain networks. *Applied Networks Science*, 3, 19. <https://doi.org/10.1007/s41109-018-0070-7>
- Badejo, O., & Ierapetritou, M. (2023). A mathematical modeling approach for supply chain management under disruption and operational uncertainty. *AIChE Journal*, 69(4), e18037. <https://doi.org/10.1002/aic.18037>. <https://udspace.udel.edu/handle/19716/32589>
- Cheng, C. Y., Chen, T. L., & Chen, Y. Y. (2014). An analysis of the structural complexity of supply chain networks. *Applied Mathematical Modelling*, 38(9–10), 2328–2344. <https://doi.org/10.1016/j.apm.2013.10.016>
- Easters, D. J. (2014, September 1–5). *Mathematical supply-chain modelling: Product analysis of cost and time* [Conference presentation]. 2nd international conference on mathematical modeling in physical sciences, Prague, Czech Republic (Vol. 490, 012041). <https://doi.org/10.1088/1742-6596/490/1/012041>
- Gardner, L., & Medley, A. (2009). *Supply chain management instructional modules for mathematics with assessments* (Textbook for Teaching). University of Indianapolis.
- Hosseini, M., & Ivanov, D. (2020). Bayesian networks for supply chain risk, resilience and ripple effect analysis: A literature review. *Expert System Application*, 161(15), 113649. <https://doi.org/10.1016/j.eswa.2020.113649>
- Lee, Y. H., Dawson, P. G., & Wu, J. Z. (2016). Mathematical problems in engineering. *Mathematical Models for Supply Chain Management*, 2016, Article 6167290. <https://doi.org/10.1155/2016/6167290>
- Özdemir, S. (2017). *An integrated model of supplier selection and inventory planning using fuzzy logic and multi-objective evolutionary algorithms* [Ph.D. thesis, University of Nottingham]. <https://eprints.nottingham.ac.uk/id/eprint/44504>
- Sarker, I. H. (2021). Machine learning: Algorithms, real-world applications and research directions. *SN Computer Science*, 2, Article 160. <https://doi.org/10.1007/s42979-021-00592-x>

- Singh, R. K., Modgil, S., & Shore, A. (2023). Building artificial intelligence enabled resilient supply chain: A multi-method approach. *Journal of Enterprise Information Management*. <https://doi.org/10.1108/JEIM-09-2022-0326>
- Tirkolaei, E. B., Sadeghi, S., Mooseloo, F. M., Vandchali, H. R., & Aeini, S. (2021). Application of machine learning in supply chain management: A comprehensive overview of the main areas. *Mathematical Problems in Engineering*, 2021, Article1476043. <https://doi.org/10.1155/2021/1476043>
- Virgilio, R., & Milicchio, F. (2011, October 24). *RFID data analysis using tensor calculus for supply chain management* [Conference presentation]. CIKM '11: Proceedings of the 20th ACM international conference on information and knowledge management, New York, USA (pp. 1743–1748). <https://doi.org/10.1145/2063576.2063828>
- Wang, H., Gu, T., Jin, M., Zhao, J., & Wang, G. (2018). The complexity measurement and evolution analysis of supply chain network under disruption risks. *Chaos, Solitons & Fractals*, 116, 72–78. <https://doi.org/10.1016/j.chaos.2018.09.018>