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Preface

Supply chain logistics planning is the key issue of supply chain management. Supply chain logistics planning optimization mainly involves a reasonable arrangement of each node enterprise in the supply chain for its raw materials or products purchase quantity, production quantity, inventory quantity, and transport quantity under a myriad of constraints so that the operations of supply chain logistics system is optimized during the planning period. In the practical operation of supply chain, there exist many uncertain factors that influence the supply chain logistics planning. This uncertainty mainly includes parameter randomness, fuzzy randomness, and so on. Therefore, the uncertainty of parameters should be fully considered when a supply chain logistics planning is made. The book, based on the research of customer demand forecasting techniques, will work over the decision-making model of supply chain logistics planning under uncertain environment, including the three-level strategic-alliance supply chain, decentralized control supply chain in which the nodes have been unlimited expansion, and the three-level mixed control supply chain. At the same time, different hybrid intelligent algorithms will be designed for solving these models.

In many cases, customer demand forecasting should be made first in the decision-making of the supply chain logistics planning. On considering the conditions of customer demand, and on the basis of some hypotheses, the dynamic equation model of customer demand was established by using the theory of differential equation to reflect the changing law of customer demand in supply chain logistics system, the method to determine the parameters in the model was presented, and the method of parameter estimation and hypothesis testing of the error of the forecasting model was discussed. Furthermore, in order to improve the forecasting precision of customer demand in the supply chain and obtain satisfactory forecasting results, fuzzy consistent judgment matrix was applied to solve the weights allocation problem of different forecasting methods in the combination forecasting. As regards the three-level strategic-alliance supply chain, the model of supply chain logistics planning was established with stochastic expected value programming theory under the market prices and the market requirements of finished products as random variables, and the hybrid intelligence algorithm of solution this model was

designed. Considering that the decision-makers do not always care the expected revenue maximization, but consider how to achieve the optimal income under the probability meaning, and as for the supply chain logistics planning issue with upstream business's market supply price of raw materials and downstream business's market demand price of finished products as random variables in supply chain cell of decentralized control supply chain in which the nodes have been unlimited expansion, the stochastic programming model under chance-constrained was established with the stochastic chance-constrained programming theory in order to express how to obtain optimal decision-making in a certain confidence level, and the hybrid intelligence algorithm to solve model was designed. Particularly for the three-level mixed control supply chain, supply chain logistics planning model was established by using fuzzy stochastic programming theory under customer demand as fuzzy random variables, and the hybrid intelligent algorithm to solve this model was designed.

In conclusion, the book brings forth some new and challenging topics that are listed as follows. (1) Aiming at the customer demand forecasting problem in the supply chain logistics planning, the dynamic equation model of customer demand forecasting of supply chain logistics system is put forward, the weights allocation method of combination forecast is presented, and the correctness and reliability of the forecasting models and weights allocation methods are testified with numerical examples. (2) The book proposes the stochastic expected value programming model of purchase-production-inventory-transport integrated logistics planning of three-level multi-product strategic-alliance supply chain under the environment of random market price and random demand of finished products, and designs a hybrid intelligent algorithm based on random simulation to solve the model, and the effectiveness of the model and algorithm is illustrated with numerical examples. (3) Aiming at the coordination problem of multi-level and multi-product decentralized control supply chain planning under uncertain environment, the supply chain cell is defined, and the stochastic chance-constrained programming model for multi-level and multi-product decentralized control supply chain logistics planning that includes purchase, production, inventory, and transportation under random supply prices and random demand prices among the node enterprises in the supply chain is put forward, the hybrid intelligence algorithm based on random simulation is designed, and the effectiveness of the model and algorithm is illustrated with numerical examples. (4) Aiming at the coordination problem of three-level multi-product mixed control supply chain planning under uncertain environment, the fuzzy random expected value programming model for the three-level and multi-product mixed control supply chain logistics planning that includes purchase, production, inventory and transportation under fuzzy stochastic customer demand environment is put forward, the hybrid intelligence algorithm based on fuzzy stochastic simulation and neural network and genetic algorithm is designed, and the effectiveness of the model and algorithm is illustrated with numerical examples.

It takes nearly 4 years (2012–2015) to publish the book, from the birth of the general idea to the final printing. During this period, relevant professional groups

have achieved substantial cognition of the true value of logistics both in developed and developing countries. In the standpoint of professional technique to observe this change, we know that this change should be mainly credited to a lot of effective and successful work done by many outstanding scholars and business managers. In this sense, we are standing on the shoulders of our predecessors, but it is a pity that the author has not enough wisdom to see farther. The book gained support from Humanities and Social Sciences Planning Fund of Chinese Ministry of Education under Grant No. 12YJA630097 and China Post-doctoral Science Foundation under Grant No. 20110491567.

It should be noted that although the author has done some work on the optimization of integrated supply chain logistics planning, the work is too shallow and rough. Moreover, this is a rudimentary theory research of supply chain management based on practical data, so there is a considerable gap between the established integrated supply chain logistics planning model, its solution algorithm, and the current enterprises practice; in particular, there is a great difficulty in collecting data of more successful businesses in practice to verify this model. Therefore, the guidance value of this research results upon practice can only be verified through simulation. It is the happiest thing for the author if a word or two in this book can revoke even a little inspiration and resonance in the heart of a thinking reader.

Limited by the author's vision and scholarly attainments, there may be some inaccuracies and omissions in this book; please feel free to give your valuable comments and corrections.

Acknowledgments

First of all, our heartfelt gratitude goes to Professor Xiangyi Xu from School of Management of Shandong University, and Professor Shaohua Dong and Professor Sujian Li from the Logistics Research Institute of Beijing University of Science and Technology because they not only gave us valuable comments and suggestions in the course of study but also generous help for the work in the later stage.

We would also like to thank the authors of references for their research results. The study of this work made us feel that our vision and knowledge are not enough, and the wise results of these authors give us constant inspirations, and the details about their research results are indicated in the part of quotations and in the references.

The authors would like to thank the anonymous reviewers for their helpful suggestions. This research work was supported by Humanities and Social Sciences Planning Fund of Chinese Ministry of Education under Grant No. 12YJA630097 and China Post-doctoral Science Foundation under Grant No. 20110491567, and we would like to express our deep appreciation!

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Finally, this book would definitely not be the same without the generous help and support from Toby Chai, Lydia Wang and Karthik Raj from Springer. Please accept our thanks for working so hard to have this book published.

As the first author and corresponding author of the monograph, I am very grateful to my family, including my aged parents, my wife Lihua Wu and daughter Jingjie Shao. Without their understanding and support, it is hard to imagine that I would have more time to carry out the research. So this book is dedicated to my

family in order to express my deeply love and gratitude for everything they have done for me.

In a word, this work has been finished with the help and support from many people. As we could not list all of their names, please forgive us and accept our greatest respect and deepest thanks!

April 2015 Juping Shao

Contents

Symbols

ξ, η	Stochastic (fuzzy) variables
$\boldsymbol{\xi}$, $\boldsymbol{\eta}$	Stochastic (fuzzy) vectors
$\mathrm{Pr}\{\cdot\}$	Probability measure
$Pos\{\cdot\}$	Possibility measure
$Nec\{\cdot\}$	Necessity measure
$Cr\{\cdot\}$	Credibility measure
E	Expected value operator
$(\Omega, \mathrm{A}, \mathrm{Pr})$	Probability space
$(\Theta, \mathrm{P}(\Theta), Pos)$	Possibility space
ϕ	Empty set
$\Re$	Set of real numbers
$\Re^n$	n-dimensional real vector set
$\wedge$	Mini operator
$\vee$	Max operator

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Chapter 1
Introduction

1.1 Significance of the Research

This is an era of rapid change [1]. With the background of the rise of knowledge economy and the accelerated pace of economic globalization, the internal and external operating and competition environments of companies are fundamentally changed [2]. These changes bring higher uncertainties. Obviously, the traditional management mode appears to be too slow and too inefficient. In fact, it is phased out, and is replaced by IT-based new management concept and mode-the supply chain management, which has obtained widespread concerns and attention of companies and researchers in recent years. The emergence of supply chain management thinking and method has been the most important basic theory in Management Science field since Mr. Peter F. Drucker founded the Management discipline, and it is also the forefront of the development of Management Science in the 21st century.

Currently, thinking and method of supply chain management has been used in many businesses, and a great achievement has been made. However, as the supply chain system is operating in a huge and complex uncertain environment, it is hard to succeed without scientific method of management. The first reason is that the supply chain itself is a complex network system, whose facilities are dispersed in geographical layout; they are even globally dispersed in many cases. Secondly, different nodes in the supply chain usually have different, even mutual-conflicting goals. For example, the supplier apparently hopes the manufacturer can keep a stable bulk purchase, and delivery time is flexible. Unfortunately, although most manufacturers hope to implement stable and long-term production process, they require more flexibility to satisfy the ever-changing demands of customers. Hence, the supplier's goal conflicts directly with the manufacturer's expectation for flexibility. In fact, due to the lack of precise information of customer demand in most production decision, the manufacturer's ability of matching supply and demand depends on the ability of changing the supply when precise demands information of

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customer arrive. Similarly, the manufacturer's goal of large batch production conflicts with the goal of reducing inventory in warehouses and distribution centers. What's worse is that the goal of reducing inventory level means the increase of freight cost. Thirdly, the supply chain is a dynamic system, which will continuously change as time goes. Actually, what changes over time are not only the customer's demands and the supplier's ability, but also the supply chain relationship. For instance, the increase of the customer's ability will oblige the manufacturer and the supplier to produce various kinds of quality products, and produce customized products as the final trend. Fourthly, it is another key factor that system factors affecting supply chain planning change with time passing on. Supply chain planning is an important part of supply chain management control, even though we can acquire precise demands information, the influence of seasonal fluctuation, trend, advertisements and promotions, and competitor's pricing strategies etc., as well as the change of demand and cost parameters with the passage of time should be taken into account in planning process. These parameters which change over time make it quite difficult to minimize the system cost and satisfy customer's demands with effective supply chain decisions [3]. The issue of how to manage and control these uncertain factors to make effective supply chain logistics planning is the focus of discussion and research in the book.

Various uncertainties exist in the supply chain system and the Bullwhip Effect is the most typical phenomenon which is one of the main factors influencing the supply chain planning. The research concerned with this aspect was first studied by Forrester, J.W. working in the Massachusetts Institute of Technology in 1958. He proposed using industry dynamics model to solve optimization problems of material distribution and transport routes. Through a series of case studies, Forrester pointed out that, for the seasonal goods, the changes in demand that manufacturers sensed surpassed that of the customers. He also noted that this effect would be amplified in each link of the supply chain, which was just the phenomenon of distortion and amplification of demand information caused by the demand uncertainty [4]. Similar to Forrester, Buribidge [5] further researched the information distortion resulting from the demand uncertainty in the supply chain. Based on the numerical analysis of real data, Blanchard [6] and West [7] reached a conclusion that, from the perspective of economics, the changes in factory product planning were much greater than those in sales volume. Blinder [8], Krane and Braun [9] indicated, through their research, that the purchasing quantity had a trend of increasement while moving toward the upstream supply chain. In 1989, Sterman [10] developed the "beer distribution game", attracting many researchers and people of the industry to continue the research of the Bullwhip Effect phenomenon. In 1997, Lee et al. in the Stanford University proposed the concept of Bullwhip Effect for the first time during the research on the market demand and the order policy of the "disposable diaper" for P&G in the USA and systematically analysed the production mechanism of the Bullwhip Effect and its counter-measures [11, 12]. They found that the retail volume of the "disposable diaper" was quite stable as the demand of a certain day or a certain month was not higher or lower than the other periods. However, the order quantities of distributors fluctuated more widely than

the retail volume. In addition, the fluctuation margin of the order quantities by P&G from its suppliers was even larger. The same issue was also found in the companies such as HP, IBM, etc. Actually, since 1984, the researches on the effect of these uncertainties in the supply chain on the planning [13–15] have all been based on the work of Forrester J.W., Blanchard O.J. and Burbidge J.L.

Due to the effect of uncertainties, it is very difficult to match demand with supply in the supply chain. Fisher et al. [16] and Fisher [17] researched the matching problem between supply and demand in the uncertain environment, and they also researched and brought up different types of products and their matching supply chains from the perspective products from the sight of products which are produced and sold by the supply chain. Afterwards, the research on the effect of uncertainties on the supply chain has become an entirely new field in the supply chain management.

Although the effect of uncertainties on the supply chain can not be completely eliminated, we still try to seek all kinds of approaches to decrease its effect. The issue of optimizing the supply chain logistics planning under uncertain environment researched in the book is to probe into the relationship (association) between related factors in the supply chain logistics system considering uncertainties of parameters totally, which is a model and algorithmic problem on how to reasonably arrange the purchase quantity, the production lot, the storage rate and the transport volume of companies' raw materials or products for each node of the supply chain in order to optimize the operation of supply chain logistics system within the planning period. Specifically, the following three aspects of issues during the formulation of supply chain logistics planning are discussed and studied in the book.

The first issue is the forecasting technique and method for customer demand in the supply chain logistics system. According to the customer demand characteristics and on the basis of many assumptions, the research holds that the customer demand has a motivation of its own which has regularity to conform to and the regularity is reflected by the customer demand motivation equation; furthermore, in order to enhance the precision of customer demand forecast in the supply chain and obtain relatively ideal forecast results, the research applies the fuzzy consensus judgment matrix in the relationship of fuzzy consensus to solve weight distribution's problem of every forecast method in each combination forecasting. The second issue is the construction problem of optimizing the model of supply chain logistics planning with uncertainty of parameters. Targeting to the supply chains of strategic-alliance type, decentralized control type and hybrid control type and considering the parameters, such as randomness of price, demand and others' fuzzy randomness, the book applies the uncertain programming theory and method to seek the relationship between the factors in the system during the formulation of supply chain logistics planning, and establishes the optimization model. The third issue is the artificial intelligence algorithm. For the solution to the complex optimization decision-making system model, the traditional calculation method is never applicable under most circumstances. Meanwhile, due to the rapid development of computer science, artificial intelligence springs up increasingly, such as genetic algorithm, evolutionary programming, genetic programming, taboo search, simulated annealing, neuroid and others, all of which fall into the category of artificial intelligence algorithm and are

able to solve more complex optimization problems. Particularly, after their organic integration, their special advantages are fully exploited so as to form more effective and powerful hybrid intelligence algorithm. This research combines stochastic simulation, fuzzy simulation, fuzzy random simulation, neuroid and genetic algorithm and designs the hybrid intelligence algorithm to solve the uncertain supply chain logistics planning model.

On the whole, the research on optimization of supply chain logistics planning under uncertain environment has significance both in theory and practice. Its theoretical significance is that the research can complement and perfect the existing results of supply chain planning in terms of quantification. Its practical significance is that the result of this research is able to guide companies to formulate supply chain logistics planning under uncertain environment to some extent.

1.2 Research Ideas and Content Structure

According to the way of supply chain management control, supply chain can be divided into three types: strategic-alliance type, decentralized control type and mixed control type. Based on the research of the forecasting technique for customer demand in the supply chain, the book researches and establishes the stochastic expected value programming model for the strategic-alliance supply chain logistics planning, the stochastic chance-constrained programming model for the decentralized control supply chain logistics planning and the fuzzy stochastic expected value programming model for the mixed control supply chain logistics planning while designing the intelligence algorithm to solve these models. The technical route of this book is shown in Fig. 1.1.

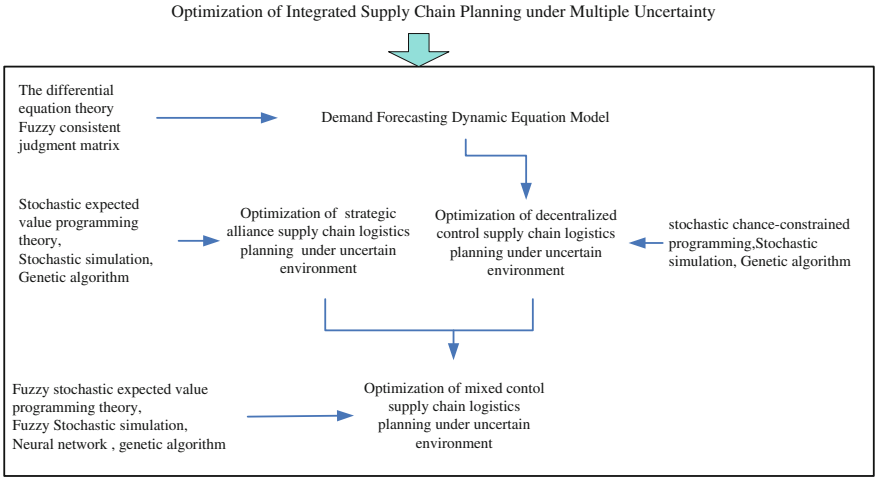

Fig. 1.1 Technical route of the research

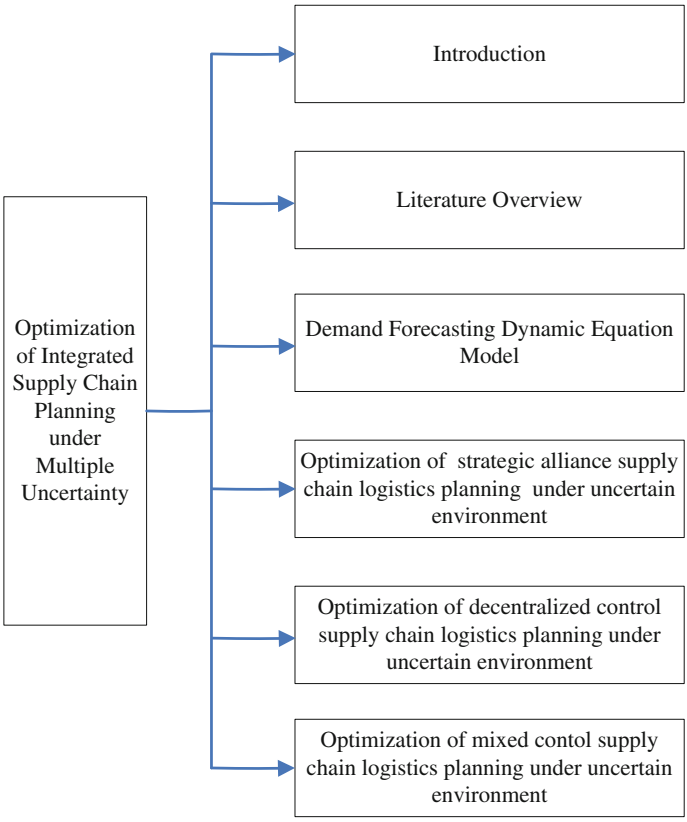

Fig. 1.2 Contents structure of the book

The content structure of this book, shown in Fig. 1.2, is arranged as follows.

Chapter 1 briefly illustrates the scope, purpose, assumptions, methods, the expected result and significance of this research. Meanwhile, it indicates the research ideas and the content structure.

Chapter 2 introduces some key literatures and their comments on fields related to the research and emphasizes some related thoughts and the theories and technical methods that the researches are based on, including supply chain management and its uncertainties, random theory, fuzzy theory, fuzzy random theory, tendency and characteristics of supply chain planning research, neural network algorithm and genetic algorithm.

Chapter 3 offers the customer demand forecast dynamic equation model, provides the model to determine the parameters in the model and discusses the method for parametric estimation and hypothesis testing for forecasting model error aimed at the customer demand forecast issue in the formulation of supply chain logistics planning. Furthermore, in order to enhance the precision of customer demand forecast in the supply chain and obtain relatively ideal forecast results, the research