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Quantitative Models for Operational Risk to Implement Tobacco Supply Chain Strategies

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1. Introduction

Environmental issues are rapidly emerging as one of the most important topics for strategic manufacturing decisions. The scarcity of natural resources and the growing concern in the market for "tobacco" issues have forced executives to manage operations within an environmental perspective (Huang & Su, 2009). Growing public awareness and increasing government interest in the environment have induced many Chinese manufacturing enterprises to adopt programs aimed at improving the environmental performance of their operations (Dai & Su, 2009; Wang, Chen, & Xie, 2010). By bringing together existing contributions on strategic environmental management and performance measurement systems, the present paper aims to develop Dynamics Models for Tobacco Supply-Chain Management (DMTSCM) using super matrix, cause and effect diagrams, tree diagrams, and the analytical network process.

To provide quantitative decision tools for the tobacco supply chain, this chapter will introduce some mathematic methods to model the decision process of tobacco supply chain. Since the coordination is the key issue of supply chain management, to be more specific, we will introduce the coordination mechanism under risk-averse agent environment.

The rest of this chapter is divided into five major sections. The second section gives taxonomy of tobacco supply-chain strategies and highlights the critical factors of such strategies for a company's operations policy. The third section specifies quantitative model for a GSCM, while the fourth seeks how to structure critical factors hierarchically to support managers in the implementation of each tobacco supply-chain strategy. The fourth section describes how to quantify the effect of the factors on a GSCM and analyses how the suggested DMTSCM can be implemented in practice. The final section draws some

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conclusions from the suggested approach and indicates future directions for further environment-related research.

2. Literature review

The introduction of a tobacco supply-chain strategy is a very complex issue, since it presents a multi-dimensional impact on performance and often induces a significant modification in management procedures. In the light of these issues, it is important to analyze feasible patterns of strategic environmental behaviour, under which conditions these are a sustainable option and the implications on operations management.

In the light of the above issues, we distinguish between (see Tab. 1):

Strategy	Context	Characteristic
"evangelist" strategy	ethical objective and radical approach to environmental issues	Futurity(Godsell, Birtwistle, & van Hoek, 2010)
Pro-active tobacco strategy	"systemic" initiatives affecting the whole value chain and relationships with suppliers	High bargaining power of the company. Strategic perspective(Liwei, Yuchi, Jijiong, & Yingguang, 2009)
Responsive strategy	bargaining power vs. suppliers/shredders is low the regulators' pressures are low	High/low bargaining power of the company. Technical perspective (Joossens & Raw, 2008)
Re-active strategy	comply with environmental regulations or customers' environmental requirements (Chunming & Yingzi, 2008)	External oriented: High pressures from regulators and Technical perspective Market driven: High pressures of "tobacco" customers and Technical perspective
Unresponsive strategy	limited financial resources, passive pattern of environmental behaviour and delay "tobacco" programmes	High importance of cost based strategy (Juttner, Godsell, & Christopher, 2006)

Table 1. Main characteristics of the tobacco supply-chain strategies

First, we review the most related literature in supply chain coordination under risk-averse and tobacco supply-chain strategy briefly. Theoretical field has yielded plenty of literature on supply chain. Cachon(2003) offered a comprehensive review on supply chain contracts for coordination. Moreover, Taylor (2002), Cachon and Lariviere(2005)also have done this kind of research. In practical business, the agents of supply chain are often sensitive to risk, Seshedri(2000b) and Gan et al.(2004,2005) studied the supply coordination with risk-averse agents. As for the risk-averse, CVaR is shown to be a coherent risk measure and has better computational characteristics. Due to the advantage of CVaR, we will adopt CVaR criteria as the performance measure. Chen et al. (2003, 2009), Tomlin and Wang (2005), Tomlin and Wang (2005) and Gotoh and Takano (2007) adopted CVaR to measure risk.

As for the tobacco supply-chain strategy, (Godsell, Birtwistle, & van Hoek, 2010) have studied the ethical objective and radical approach to environmental issues. (Liwei, Yuchi, Jijiong, & Yingguang, 2009) researched show that "systemic" initiatives affect the whole value chain and relationships with suppliers considering High bargaining power of the company. (Joossens & Raw, 2008) studied bargaining power vs. suppliers/shredders issues from the technical perspective. (Chunming & Yingzi, 2008) investigated the Re-active strategy which includes external oriented: high pressures from regulators and technical perspective and market driven: High pressures of "tobacco" customers and Technical perspective. (Juttner, Godsell, & Christopher, 2006) studied the Unresponsive strategy about limited financial resources, passive pattern of environmental behaviour and delay "tobacco" programmes.

3. System dynamics models for tobacco supply-chain management

This section is a detailed discussion of the system dynamics modelling, which allows for simple representation of complex Cause-and-Effect Relationships. For the discussion that follows it is important to understand that it is the Levels (or state variables) that define the dynamics of a system. For the mathematically inclined we can introduce this in a more formal way. The following equations show the basic mathematical form of the DMTSCM.

$$measures[i]_t = \int_0^T levels[j]_t \, dt ; \text{or } \frac{d}{dt} measures[i]_t = levels[j]_t \quad (1)$$

$$rates_t = levels_t dt = \int_0^T rates_t dt \quad \frac{d}{dt} levels_t \quad (2)$$

$$rates_t = \mathrm{g}(levels_t, aux_t, data_t, const) \quad (3)$$

$$aux_t = \mathrm{f}(levels_t, aux_t, data_t, const) \quad (4)$$

$$levels_0 = \mathrm{h}(levels_0, aux_0, data_0, const) \quad (5)$$

In these equations g, h, and f are arbitrary, nonlinear, potentially time varying, vector-valued functions. Equation (1) represents the evolution of the system over time, equation (3) the computation of the rates determining that evolution, equation (4) the intermediate results necessary to compute the rates, and equation (5) the initialization of the system.

4. Research objectives and methodology

The objective of the research adopted under the heading of Dynamics Models for Tobacco Supply-Chain Management (DMTSCM) was to identify tools and techniques that would facilitate:

- Identification of factors affecting Environmental Performance,
- Identification of the relationship between factors affecting Environmental Performance,
- Quantification of these relationships on one another, and on the overall performance of the supply processes, and

- Establishment of 'What if' analysis on process performance and strategy selection.

The six steps of the approach were developed as a result of the DMTSCM methodology implementation as depicted in Fig. 1. The details of this approach have been explained through a case study in Section 5.

The flow variables represent the flows in the system (i.e. remanufacturing rate), which result from the decision-making process. Below, we define the model variables (stock, smoothed stock and flow) converters and constants and cost parameters, their explanation, where necessary, and their units. We chose to keep a nomenclature consistent with the commercial software package that we employed; thus for the variable names we use terms with underscore since this is the requirement of the software package (it does not accept spaces). The stock variables in order that they appear in the tobacco supplying processes are the following:

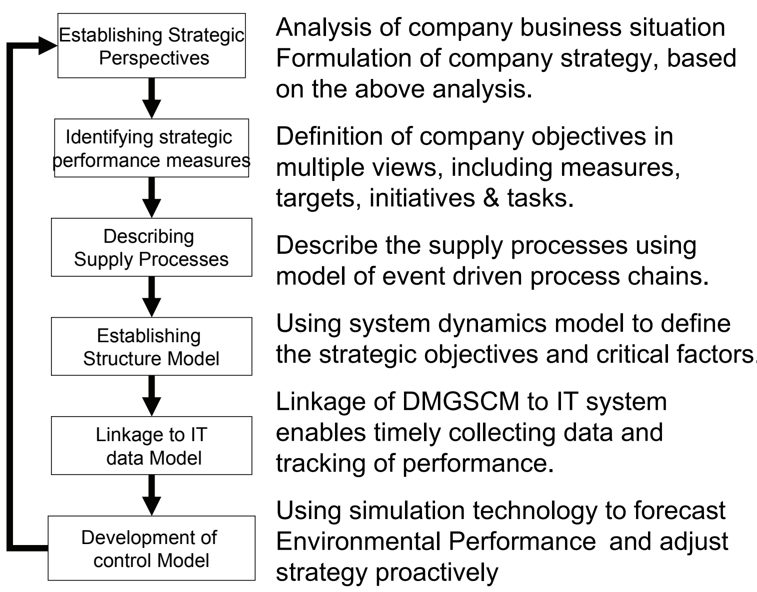

Fig. 1. DMTSCM Methodology Implementation

- Raw_Materials: inventory of raw materials [items].
- Serviceable_Inventory: on-hand inventory of new and remanufactured products [items].
- Distributors_Inventory: on-hand inventory of the distributor [items].
- Collected_Products: the inventory of collected reused products [items].

The smoothed stock variables are:

- Expected_Distributors_Orders: forecast of distributor's orders using exponential smoothing with smoothing factor a_DI [items/day].
- Expected_Demand: demand forecast using exponential smoothing with smoothing factor a_D [items/day].
- Expected_Remanufacturing_Rate: forecast of remanufacturer rate using exponential smoothing with smoothing factor a_RR [items/day].
- Expected_Used_Products: forecast of used products obtained using exponential smoothing with smoothing factor a_UP [items/day].

Constants, converters are:

- CC_Discrepancy: Discrepancy between desired and actual collection capacity [items/day].
- CC_Expansion_Rate: Collection capacity expansion rate [items/day/day].
- DI_Adj_Time: Distributor's inventory adjustment time [days].
- DI_Cover_Time: Distributor's inventory cover time [days].

4.1 Cause-effect diagram

The structure of a system in DMTSCM methodology is captured by cause-effect diagrams. A cause-effect diagram represents the major feedback mechanisms. These mechanisms are either negative feedback (balancing) or positive feedback (reinforcing) loops. A negative feedback loop exhibits goal-seeking behavior: after a disturbance, the system seeks to return to an equilibrium situation. In a positive feedback loop an initial disturbance leads to further change, suggesting the presence of an unstable equilibrium. Cause-effect diagrams play two important roles in DMTSCM methodologies. First, during model development, they serve as preliminary sketches of causal hypotheses and secondly, they can simplify the representation of a model.

The first step of our analysis is to capture the relationships among the system operations in a DMTSCM manner and to construct the appropriate cause-effect diagram. depicts the cause-effect diagram of the system under study which includes both the forward and the reverse supplying processes. To improve appearance and distinction among the variables, we removed underscores from the variable names and changed the letter style according to the variable type. Specifically, stock variables are written in capital letters, the smoothed stock variables are written in small italics and the flow variables are written in small plain letters. These variables may be quantitative, such as levels of inventories and capacities, or qualitative, such as failure mechanisms.

4.2 Mathematical formulation

The next step of DMTSCM methodology includes the development of the mathematical model, also presented as a cause-effect diagram that captures the model structure and the interrelationships among the variables. The cause-effect diagram is easily translated to a system of differential equations, which is then solved via simulation.

The cause-effect diagram is a graphical representation of the mathematical model. The embedded mathematical equations are divided into two main categories: the stock equations, defining the accumulations within the system through the time integrals of the net flow rates, and the rate equations, defining the flows among the stocks as functions of time. In the remaining of this section, we present selected formulations related to important model assumptions.

The equations related to collection tobacco supplying policy are the following:

$$\mathit{Desired\_CC(t)} = \mathrm{DELAYINF}(\mathit{Used\_Products}, \mathit{a\_CC}, 1, \mathit{Used\_Products}) \quad (6)$$

$$\mathit{Collection\_Capacity}(0) = 0 \quad (7)$$

$$Collection\_Capacity(\mathrm{t} + \mathrm{dt}) = Collection\_Capacity(\mathrm{t}) + \mathrm{dt} * CC\_Adding\_Rate, \quad (8)$$

$$CC\_Adding\_Rate = \mathrm{DELAYMTR}(CC\_Expansion\_Rate, 24, 3, 0), \quad (9)$$

$$CC\_Discrepancy = \mathrm{PULSE}(Desired\_CC * Collection\_Capacity, 50, P_c), \quad (10)$$

$$CC\_Expansion\_Rate = \max(K_c * CC\_Discrepancy, 0), \quad (11)$$

Desired_CC is a first order exponential smoothing of Used_Products with smoothing coefficient a_CC. Its initial value is the initial value of Used_Products. Collection_Capacity begins at zero and changes following CC_Adding_Rate, which is a delayed capacity expansion decision (CC_Expansion_Rate) with an average delay time of 24 time units, an order of delay equal to 3 and initial value equal to zero at t = 0. CC_Expansion_Rate is proportional to the CC_Discrepancy between the desired and actual collection capacity, multiplied by Kc. The pulse function determines when the first decision is made (50 time units) and the review period Pc. Similar equations dictate the tobacco supplying policy.

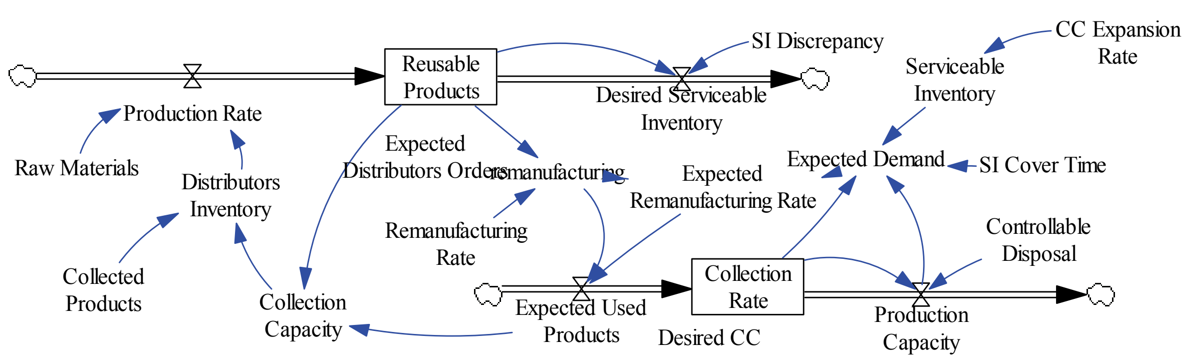

Fig. 2. Cause-effect diagram of the tobacco supplying processes

The total profit per period is given from:

$$Total\_Profit\_per\_Period = Total\_Revenue\_per\_Period - Total\_Cost\_per\_Period, \quad (12)$$

Where

$$Total\_Cost\_per\_Period = Investment\_Cost + Operational\_Cost + Penalty\_Cost, \quad (13)$$

$$Total\_Revenue\_per\_Period = Sales * Price, \quad (14)$$

$$\begin{aligned} Investment\_Cost &= (CC\_Expansion\_rate)^{0.6} * Col\_Cap\_Construction\_Cost \\ &+ (RC\_Expansion\_rate)^{0.6} * Rem\_Cap\_Construction\_Cost, \end{aligned} \quad (15)$$

$$\begin{aligned} Operational\_Cost &= Collection\_Rate * Collection\_Cost + Production\_Rate \\ &* Production\_Cost + Reusable\_Products * Holding\_Cost \\ &+ Sales * DI\_Transportation\_Cost + Distributors\_Inventory \\ &* DI\_Holding\_Cost + Shipments\_to\_Distributor * \\ &SI\_Transportation\_Cost + Serviceable\_Inventory * SI\_Holding\_Cost, \end{aligned} \quad (16)$$

4.3 Supply chain coordination with quantity-flexibility contract under CvaR

In this subsection, considering a supply chain comprises a risk-neutral supplier and a risk-averse retailer where the supplier's product is sold via the retailer to end consumers. We present a Stackelberg game in which the supplier is the leader and the retailer is the follower. Here, the retailer adopts CVaR as its performance measure. The definition of η-CVaR for an inventory policy μ is (see Rockafellar and Uryasev, 2000, 2002; and Pflug, 2006)

$$\eta\text{-CVaR}(g(\mu, D)) = \max_{v \in R} \left\{ v + \frac{1}{\eta} \mathrm{E}[\min(g(\mu, D) - v, 0)] \right\} \tag{17}$$

Where E is the expectation operator, and η∈ (0, 1] denotes the degree of risk-aversion of the decision-maker (the smaller η is, the more risk-averse the decision-maker is).

Market demand for the product is a stochastic variable D, and the cumulative distribution function (cdf) of D is F(·). We let the marginal production cost of the manufacturer be c and the salvage value per unit of unsold product is s. Let w be the wholesale price and r be the retailer's retail price. To avoid trivial, we assume that s<c<r. Before production, the supplier offers a supply contract under which the retailer decides the order quantity Q if he agrees the contract. Only once order is allowed because of long production setup lead time (see e.g., Cachon (2004)).

According to Cachon (2003), LEI YANG (2009), given a quantity-flexibility contract, the supplier charges w per unit purchased and then compensate the retailer for unsold losses. Namely, the retailer receives (w − s)min(I, δQ) from the supplier when selling season is over, where I is the amount of leftover inventory, Q is the order quantity and δ ∈ [0, 1] is a contract parameter indicating that the retailer may return up to δQ units for unsold items for a full refund. With the quantity-flexibility contract the transfer payment the transfer payment can be written as

$$T(Q, w, \delta) = wQ - (w - s)\left[(Q - D)^{+} - \left((1-\delta)Q - D\right)^{+}\right] \tag{18}$$

To be specific, expression (18) can be rewritten as

$$T(Q, w, \delta) = \begin{cases} wQ & \text{if } Q \le D; \\ wQ - (w - s)(Q - D) & \text{if } (1 - \delta)Q \le D < Q; \\ wQ - (w - s)\delta Q & \text{if } (1 - \delta)Q > D. \end{cases} \tag{19}$$

And then the retailer's profit can be expressed as

$$\begin{aligned} \pi_r(Q, w, \delta) &= r\min(Q, D) + s(Q - D)^{+} - T(Q, w, \delta) \\ &= (r - s)[Q - (Q - D)^{+}] \\ &\quad - (w - s)[Q - (Q - D)^{+} + ((1 - \delta)Q - D)^{+}]. \end{aligned} \tag{20}$$

Consider the set of quantity flexibility contracts (w, δ) with η_r -CVaR: the retailer pays wholesale price w(δ) for unit product, where

$$w(\delta) = s + \frac{(r - s)(1 - F(Q^*)/\eta_r)}{1 + [(1-\delta)F((1-\delta)Q^*) - F(Q^*)]/\eta_r} \; with \; \delta \in (\hat{\delta}, 1], \tag{21}$$

Where $\hat{\delta}$ is the unique solution to $E[\pi_r(Q^*, w(\delta), \delta)] = E[\pi_{sc}(Q^*)]$. The quantity flexibility contract can induce the retailer to order a quantity at Q^*; that is to say, these contracts can fully coordinate the supply chain. The quantity-flexibility contract shares a part of demand risk by providing the retailer refund on a portion of the retailer's leftover inventory.

For more detailed proof of (21), see (LEI YANG et al., 2009).

5. Illustrative case

After the State Tobacco reform and several decades of development of the tobacco industry, market competition becoming increasingly fierce, various brands of tobacco companies have become the focus of the competition, the cigarette brand development strategy become the key to survival and development of cigarettes industrial enterprises.

Since 2000, senior management has been committed to a reduction in the environmental impact resulting from production activities, and product usage. In terms of operational policy, such an interest in "tobacco" issues has given rise to two major programmes: (1) The F1 program, specifically aimed at improving the environmental performance of the supply processes; (2) The F2 program, which focuses on the introduction of new environmentally friendly cigarettes.

The implementation of the above initiative results in the modification of design, process efficiency and volume indices (see Table 2). Specifically, the take-back of bumpers leads to a reduction in the purchase of plastic raw materials and energy consumption (30 per cent with respect to traditional plants), since the fluff resulting from the grinding of cigarette bodies is cleaner.

		Planned value	**Reported measure**
	Time for production	5 hours	4.5 hours
	Time for disassembling	7.8 hours	6.6 hours
	No. of different materials in the product	14	19
Volume index	Quantity of recovered plastics	6.346 tons	8.650 tons
	SOx	423 tons	532 tons
	NOx	312 tons	395 tons
Process efficiency	Electrical energy	345,000 Mwh	430,000 Mwh
	Oil	1,383 tons	2,250 tons
	COD	25,500 tons	23,000 tons
	Sulphates	168,000 tons	269,500 tons

Table 2. Measures expressing a company's impact on the state of natural resources

From a financial perspective (see Table 3), the program affects expenditure related to the internal efficiency of operations, e.g. the reduction of energy, raw materials and environmental regulations related costs (regarding both waste water and solid wastes), as well as other operating costs associated to the take back and recycling of bumpers, higher labor costs to implement the recycling process internally, and increased expense for the recycling process itself. In addition, the introduction of new cigarettes produced an increase in volume (50,000 units).

	Forecast Value (RMB)	**Reported measure (RMB)**
Revenue		
Total Revenue per Period	4,450,000,000	4,645,000,000
Total Cost per Period		
Total Profit per Period	65,500,000,000	67,450,000,000
Operational Cost	38,150,000,000	37,650,000,000
Energy costs	7,640,000,000	75,527,000,000
Other environmental costs		
Recycling costs	835,720,000	828,780,000
Costs related to environmental regulations	693,400,000	793,300,000

Table 3. The economic items affected by the initiative

In the light of the above analysis, it can be concluded that the company respected its own targets: indeed, the increase in actual labour costs over standard costs is only marginal and, above all, the result of the growth in production volumes.

The above discussion highlights that there are significant differences in the deployment and assessment of a pro-active or a re-active tobacco supply-chain strategy. In particular, both the design of the GSCM and the gathering of data present different operating problems which depend on the adopted pattern of environmental behaviour.

In general terms, the design of an effective GSCM is more complex within pro-active companies than within re-active organizations. It must be noted that the assessment of a pro-active tobacco supply-chain strategy requires identification of physical and economic indicators which well describe a company's potential environment-related sources of competitive advantage. This implies significant changes in the traditional systems adopted to monitor the evolution of environmental performance. Indeed, the latter were usually designed to verify compliance with existing regulations. A re-active tobacco supply-chain strategy simply demands verification of whether environmental performance of the company's products and/or processes are consistent with the stakeholders', i.e. regulators' and/or customers', requirements. The implementation of the suggested approach in FA (the re-active firm) did not in fact require the definition of new measures, as the company's GSCM already considered compliance indicators.

It is evident that, apart from managers' skills and the effectiveness of the information system, the deployment of innovation-based tobacco supply-chain strategies (evangelist, pro-active and responsive) is more complex than passive patterns of environmental behavior. A key point in the effective assessment of innovative environmental policies is the identification of measures clarifying how the company positions itself with respect to competitors, and how the adopted programmes affect the company's profitability. In this respect, a growing body of literature highlights that the failure of some ambitious environmental strategies is a direct consequence of an incorrect selection of the indicators to be used in the GSCM.

6. Concluding remarks

The suggested framework is an effective tool for operations managers wishing to design GSCMs. The operational guidelines on PMS architecture and the appropriate measurement techniques provide support in devising performance indicators that best suit the intended tobacco supply-chain strategy. An important benefit gained from the DMTSCM approach is that the interaction of the factors can be clearly identified and expressed in quantitative terms. This identification will bring us one step forward in understanding the dynamic behavior of factors affecting Environmental Performance.

This chapter extends the concept of supply chain coordination in risk-averse environments, specifically, we consider a supply chain with one risk-neutral supplier and one risk-averse retailer where the retailer takes CVaR as his performance measure. And we find that the supply chain can also be coordinated under properly designed contracts. Furthermore, the problem of supply chain coordination in risk-neutral setting is a special case of ours. Our results extend the supply chain coordination to the risk-averse setting. By analytic optimal solutions obtained in this chapter, the proposed coordinating policies can be easily implemented when the retailer is risk-averse. Supply chain coordination in risk-averse setting is a quite important issue in academic and practice. We all know that CVaR is a conservative risk measure, another possible extension is that the retailer takes mean-variance as his performance measure. When both the supplier and the retailer are risk-averse, can we still find proper contracts to coordinate the supply chain? This will be another topic of our further research.

Moreover, the approach can be used in a "dynamic perspective", i.e. to analyze whether to change the adopted pattern of environmental behavior from a passive/re-active to a pro-active strategic attitude. In operational terms, this implies that a re-active firm has to design a GSCM which includes indicators highlighting how the company's economic value may change with the introduction of innovation-based environmental strategies.

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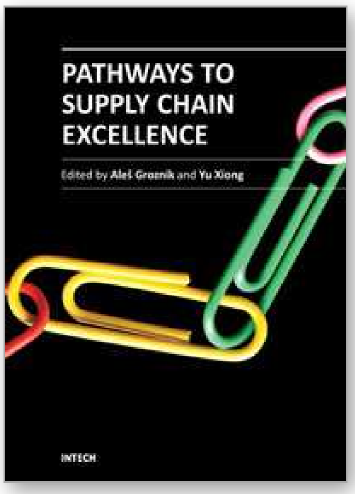

Pathways to Supply Chain Excellence
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Over the last decade, supply chain management has advanced from the warehouse and logistics to strategic management. Integrating theory and practices of supply chain management, this book incorporates hands-on literature on selected topics of Value Creation, Supply Chain Management Optimization and Mass-Customization. These topics represent key building blocks in management decisions and highlight the increasing importance of the supply chains supporting the global economy. The coverage focuses on how to build a competitive supply chain using viable management strategies, operational models, and information technology. It includes a core presentation on supply chain management, collaborative planning, advanced planning and budgeting system, risk management and new initiatives such as incorporating anthropometry into design of products.

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