國立交通大學

交通運輸研究所

博士論文

No.057

筆記型電腦產業營運模式分析與供應鏈設計

Operation Model Analysis and Supply Chain Design for Notebook-Computer Industry

研 究 生 ： 陳其華
指導教授 ： 馮正民 博士

中華民國九十七年九月

筆記型電腦產業營運模式分析與供應鏈設計

Operation Model Analysis and Supply Chain Design for Notebook-Computer Industry

研究生：陳其華　　Student : Chi-Hwa Chern

指導教授：馮正民 博士　　Advisor : Dr. Cheng-Min Feng

國立交通大學
交通運輸研究所
博士論文

A Dissertation
Submitted to Institute of Traffic and Transportation
College of Management
National Chiao Tung University
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy
in
Management

September 2008
Taipei, Taiwan, Republic of China

中華民國九十七年九月

誌　謝

謹將此論文獻給我親愛的父母、美智、亮伃、致鋼及所有關心我的親朋好友，誠摯地感謝大家

攻讀博士學位六年期間，承蒙恩師　馮教授正民的悉心指導，不論是在研究方向的或觀念的啟發等方面，均使我獲益良多，也因為有恩師的教誨，本論文才能得以順利完成。博士論文計畫書口試期間，承蒙黃教授台生、許教授鉅秉等師長惠予詳加細審並不吝提供寶貴意見；論文學位口試時，陳教授武正、徐教授淵靜、關貿網路陳總經理振楠、黃教授台生、許教授鉅秉等師長的指導並惠賜諸多指正意見，均使本論文更臻嚴謹，在此謹深致謝忱。

求學期間，由衷感謝黃教授承傳、徐教授淵靜、黃教授台生、汪教授進財、藍教授武王、陳教授穆臻及邱教授裕鈞等師長的授業與解惑。此外，更要感謝交研所辦公室洪櫻櫻小姐及何玉鳳小姐的各項協助(從碩士到博士求學期間)。而博班同學益三、奕文、慧娟、孟佑以及學弟彥衡、易詩與沛儒等不論是在學業上的相互砥礪或生活上的相互關懷，均讓我感到彌足珍貴。

能夠以在職身份拿到博士學位更要感謝工作上的長官，包括交通部運輸研究所　黃所長德治、吳副所長玉珍、林主任繼國、林組長國顯、王組長穆衡、黃組長運貴、蘇副組長振維、張副組長贊育、黃副組長新薰、許秘書蕙蘭以及運管組同仁一平、習平、佩蓁、世龍、立欽、欽同、美娟、銘韻、幸敏，由於有大家的支持、體諒與協助，我才能夠在工作之餘進入博士班繼續深造。特別感謝運研所長官給我各種歷練與成長的舞台，並讓我得以在工作之餘順利完成學業。

博士論文撰寫期間，我最敬愛的父母親給予永恆不變的殷殷關懷與生活上的扶持；岳父及岳母(雖然您在天堂，願藉此告慰慈祥的您)在精神上支持與鼓勵；美智在我碩士班時相識與結合，更進而督促我取得博士學位，無怨無悔的操持所有家務，照顧亮伃、致鋼，使我在修業期間無後顧之憂，能夠與摯愛家人一起分享這些成果，本論文的完成也才有真正的意義。

最後願將此論文獻給我親愛的家人以及時時關心我的親朋好友！

陳其華　　謹誌

民國九十七年九月

於溫暖的家

Acknowledgements

The immense gratitude is given to my doctoral adviser, professor Cheng-Min Feng, for his patient instruction and endless encouragement. Special thanks are also given to the committee during my dissertation defense, without their penetrating and helpful opinions, this dissertation can not be completed. Moreover, I appreciate all the professors in the doctoral program, due to their edifying tuition; the research abilities of mine can hence be improved. And finally, I would like to appreciate my parents and wife, owing to all your support and love to give me a fulfilled Ph.D. study life.

Chi-Hwa Chern
National Chiao Tung University
Taipei, Taiwan
September, 2008

筆記型電腦產業營運模式分析與供應鏈設計

學生：陳其華　　　　　　　指導教授：馮正民 博士

國立交通大學　交通運輸研究所

摘要

國內筆記型電腦產業在全球市場中佔有重要地位，長久以來為各國際品牌廠商重要的生產代工夥伴，憑藉優異的產品品質、設計能力及快速因應市場變化之作業彈性，在全球筆記型電腦供應鏈益發扮演舉足輕重之角色，從過去僅為供應鏈製造商逐步轉變為提供國際品牌廠商全面性供應鏈解決方案之事業夥伴。筆記型電腦產業之全球供應鏈營運模式係由商業模式(OEM/ODM)及流程模式(BTF/BTO/CTO)所構成，本研究首先針對不同營運模式加以分析，透過國內領導廠商調查作業與深度訪談，藉以瞭解不同營運模式之共通特性與差異性。調查內容主要針對供應鏈內涵設計「供應鏈營運目標」、「供應鏈管理效率」、「關聯產業策略聯盟」及「物流設施區位選擇」等四個層面之重要影響要素，針對各要素重要程度調查結果透過灰關聯分析定義現行各種不同營運模式之關鍵要素群並建立其對應之參考模式，進一步探討其特性異同點，透過營運模式探討與分析，將有助於供應鏈佈局之策略應用。

全球筆記型電腦競爭非常激烈，為縮短產品供應之前置時間及快速回應市場差異化需求以因應市場挑戰，國際品牌廠商與國內代工廠商將更著重於建立更加整合與協調之營運模式。為了爭取國際品牌廠商穩定的訂單，驅使國內代工製造商努力重新建構其供應鏈體系，俾取得競爭優勢且充分支援國際品牌廠商面對市場挑戰，其中如何妥適進行供應鏈佈局為國內代工製造商所面臨之重要課題之一。供應鏈規劃模式可區分為策略面規劃模式及營運面規劃模式二大類，過去相關文獻中針對此二類模式均有相當的探討與觀點提出，惟僅少部分文獻針對策略面與營運面規劃關係進行概念性探討，在規劃模式的整合上則較少觸及。本研究將以國內筆記型電腦產業支援國際品牌廠商之供應鏈營運特性與發展趨勢分析為基礎，藉由策略與營運互動關係探討，提出整合型多目標供應鏈設計模式概念，同時於模式中考量策略面規劃與營運面規劃課題，充分反映在供應鏈設計上策略面與規劃面之相互影響關係。

供應鏈各環節之不確定性對企業而言為一必須正視之關鍵課題，對於實務供應鏈管理績效分析上亦產生相當的影響,在供應鏈設計之規劃作業上應予納入考量，本研究於模式建構中引用彈性之概念，以反映製造商吸收生產與市場需求不確定性之能力。該供應鏈設計模式係以探討策略面規劃決策與營運面規劃決策間之權衡關係為基礎，藉以尋求合理之供應鏈佈局型態，並透過多目標決策分析方法建立一多面向之供應鏈績效(包括供應鏈成本、顧客服務水準、生產彈性與配送彈性等)衡量系統。本研究提出之供應鏈設計模式將有助於國內代工筆記型電腦廠商進行有效率及彈性之供應鏈佈局,並可應用於選擇及評估不同之供應鏈佈局方案。

關鍵詞 ： 灰關聯分析、供應鏈設計、筆記型電腦產業、多目標決策分析

Operation Model Analysis and Supply Chain Design for Notebook-Computer Industry

Student: Chi-Hwa Chern **Advisors: Dr. Cheng-Min Feng**

Institute of Traffic and Transportation
National Chiao Tung University

ABSTRACT

The operational models of global supply chain primarily include the business model (OEM/ODM) and the process model (BTF/BTO/CTO). This research aims to understand the specific characteristics within different operational models used to achieve firm operational targets. An empirical study in Taiwan is illustrated through the questionnaires and depth-interviews. The Data were collected by means of in-depth interviews with senior managers in the relevant area in 12 notebook computer manufacturers in Taiwan. In the Interviews we asked the managers in terms of 4 dimensions inclusive of “supply chain targets”, “supply chain management efficiency”, “strategic alliance” and “logistics facility locations”, totally there are 64 initial factors, which they used to analyze and compare each of six main operational models, and thus to help them decide whether or not they should use the model in their attempts to achieve their various targets. Grey Relation Analysis (GRA) method is used to identify the key factors in global supply chain; different factors stresses in different operational models are chosen and comprise reference models reflecting practical global operations. These reference models provide more concrete description of the differences in global operational decisions. The hidden knowledge of the cooperative relationship between manufacturers and multinational brand companies can then be systematically described. These findings could be helpful to further strategic analysis.

More integrated and coordinated operations are necessary for contract manufacturers and multinational Brands in shortening lead-time and quickly responding to customers’ needs. These challenges drive Taiwanese manufacturers to make efforts to redesign the supply chain for the purpose of gaining successive advantages in global operations. Supply chain can be divided into strategic level and operational level. Models had been developed for optimizing supply chain operations at these two levels. Supply chain literature reveals a gap in the integration of strategic and operational supply chain models. Strategic and operational considerations have not been extensively discussed and integrated in a comprehensive way of thinking and model formulation. In this research, the characteristics and developments in different supply chain models are introduced based on the coordination between contract manufacturers and multinational brand companies. Based on the key factors selected from different operational models, we further explore the interactive activities and developing trend in global operations in a comprehensive way of thinking. Concepts of an integrated multi-objective supply chain design model are developed for simultaneously considering strategic-level and operational-level planning. Decisions in strategic-level planning have direct impacts on operational-level planning, and vice versa.

As an extremely challenging but significant issue in SCM, uncertainty represents a primary difficulty in the practical analysis of supply chain performance. Supply chain planning should address flexibility, reflecting the ability to absorb uncertainty from randomness in material/product supply and market demand. This research proposes a supply chain design model based on the decisions tradeoffs in strategic-level and operational-level planning. Multi-objective decision analysis is performed so that a performance measurement system based on cost, customer service levels (fill rates), and Flexibility (volume or delivery) can be adopted. This measurement system provides more comprehensive measurement of supply chain system performance. The proposed model herein helps in (1) the design of efficient, effective, and flexible supply chain systems and (2) the evaluation of competing supply chain for the notebook-computer industry.

Keywords: Grey Relational Analysis (GRA), Supply Chain Design,
Notebook-computer, Multi-objective Decision

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

Chapter 1 Introduction

1.1 Research Background

Modern enterprises face almost unpredictable impacts from globalization, technology innovation, short product lifecycle, high operational cost and market demand diversity. Such impacts force enterprises to involve in a highly competitive environment. Product supply speed and product quality have become the critical competences in the need of global operations. The operational targets of enterprises commonly refer to right product in the right time and right place delivered to right customer. That means a successful modern business model must depend on the cooperation and coordination in different regional markets, and even vertical and horizontal integration in relative industries. Enterprises need to establish a flexible, speed-oriented and competitive operational model for the purposes of reducing the operational risk and cost through the whole supply chain. The abilities in logistics management and supply chain management have become critical in global competiveness.

The notebook-computer industry is one of the high-tech industries in Taiwan. Innovative global supply chain management operations are critical for Taiwanese manufacturers aspiring to work in multinational business activities. However, the multinational brand companies play the leading roles in the global market of notebook-computer. Taiwanese contract manufacturers are extremely advantageous on OEM and ODM business model in supporting brands' global operations. The proportion of made-in-Taiwan notebook-computers keeps increasing in global market share. Taiwanese contract manufacturers have been the brands' most important partners in global supply chain operations. In addition, the contract manufacturers' process model also changes from Build-to-Forecast, Build-to-Order and Configuration-to-order following the brand's global operational strategies. With this tendency, contract manufacturers need to alter and establish a competitive global supply chain structure for the purpose of responding clients' needs/requirements quickly and achieving superior global supply chain management performance.

OEM/ODM contract manufacturing is the major business model in Taiwanese notebook-computer industry. The functionalities of contract manufacturers are not only in constructing supply-production system, but also extending to production-distribution and inventory-distribution systems. The role of Taiwanese manufacturers in global supply chain changes from contract manufacturing to total solution provider because that the multinational brands pay much more attentions on marketing and customer-relationship management. The logistics activities in procurement, production and distribution have to rely on the efficient and flexible supply chain structure established by Taiwanese leading contract manufacturers.

Different business model combined with various process models form different operational models. It is very important for decision makers to clearly identify the supply chain structure and operational performance in satisfying and supporting multinational brands' global operations. In the face of globalization, decision makers of contract manufacturers need to understand the key characteristics within the existing operational models. Such understanding will equip them to make effective managerial decisions regarding global operations and accommodate themselves to the dynamically changing business environment. On the other hand, any decision in strategic level will have direct impacts in operational level from the views of practical operations. Therefore, there exists the trade-off relationship between supply chain structure and supply chain performance.

In the future, global notebook-computer market will be dominated by multinational brands as usual. OEM/ODM contract manufacturing is still the major business model. However, following the tendency of brands much focusing on the aspects of potential market exploitation, brand marketing and customer-relationship management, the contract manufacturers must have the ability to dominate the whole supply chain. The relationship between Taiwanese contract manufacturers and multinational brands must be more closely. The design of better supply chain configuration consider the operational performance simultaneously would be beneficial to the development of Taiwanese notebook-computer contract manufacturers for keep receiving multinational brands' contract manufacturing orders.

1.2 Motivation and Objectives

Global competition, short product life cycle, assets concentration and demand diversification are major challenges to notebook-computer industry. Multinational Brands keep playing the leading roles in global market. Supply chain configurations also keep changing in last decades for the purpose of quick response to customers' needs and cost reduction. Such tendency makes contract manufacturers in Taiwan to pay more contribution in global supply chain operations. To build competitive advantages in supply chain process control and efficient logistics infrastructure configuration, contract manufacturers can keep gaining the Brands' orders.

In the past, "Build To Forecast (BTF)" model make these contract manufacturers have excellent OEM/ODM abilities and win the growing global market share. Now, most of leading Taiwanese notebook-computer manufacturers has been developing "Build To Order (BTO)" model and actively extend it into "Configure To Order (CTO)" model. There exists intensively cooperation and coordination in supporting multinational Brands' global operations. The nature of supply chain management (SCM) is pursuing the cooperative efficiency and effectiveness. In recent years, Brand Companies focus on the achievements of "zero touch" and "one-stop shopping" for lead-time shortening and cost reduction. That means contract manufacturers are authorized to products final configuration and distribution instead of original contract manufacturing. They will predominate over the process and activities of procurement, production and distribution under the cooperation with multinational Brands.

In order to meet the dynamic changing business environment, decision makers of contract manufacturers are required to understand what are the key factors and characteristics within existing operation models of supply chain management. It is often not easy to obtain complete business data to explore the different operation models and the factors that affecting the choice of these models. This study will conduct survey and to identify the reference model in which a set of factors and their effects could be obtained from the respondents in Taiwanese leading contract manufacturers. The reference model could provide valuable information to decision makers to make quick and wise decision in the changeable business environment.

Uncertainty is one of the most challenging but important problems in SCM. It is a primary difficulty in the practical analysis of supply chain performance. Supply chain flexibility, reflecting the ability to absorb uncertainty from randomness in material/product supply and market demand should be taken into consideration in supply chain planning. In this study, the concepts of an integrated multi-objective supply chain model are further developed based on the analysis of previous reference models. Then a supply chain design model that facilitates simultaneous strategic and operational planning is proposed. This model incorporates production, delivery, and demand uncertainty, and provides a suitable performance measure by using a multi-objective analysis for the entire SC network. The proposed model will be valuable for designing efficient, effective, and flexible supply chains and for assessing competing SC networks.

1.3 Problem Analysis and Research Issues

Excellent process control and products quality make Taiwanese contract manufacturers enable continuing growth in global notebook-computer market share via cooperation with multinational brands. More integrated and coordinated operations are required in shortening lead-time and responding quickly to customers' needs. These challenges motivate Taiwanese manufacturers to make efforts to redesign the supply chain in order to gain successive advantages in global operations and satisfy the multinational brands needs.

Supply-production, production-distribution, and inventory-distribution systems have been examined for many years with most studies focusing only on a single component of the overall supply-production-distribution system, such as procurement, production, transportation, or scheduling. Limited progress has been made towards integrating these components in a single supply chain. Supply chain management (SCM) can be divided into strategic and operational levels. Models have been presented for optimizing supply chain operations at each of these levels. Strategic optimization models determine the most cost-effective location of facilities, flow of goods throughout the supply chain, and assignment of customers to distribution centers. Operational optimization models focus on determining the safety stock for every product at each location, the size and frequency of the product batches that are replenished or assembled, the replenishment transport and production lead times, and the customer service levels. However, these strategic optimization models do not attempt to identify the impacts in operational parameters such as required inventory levels, and customer service levels. Based on the purpose of exploring the influential factors in supply chain design and developing a integrated model for Taiwanese notebook-computer contract manufacturers, the research issues are included in the following:

- Issue 1: To explorer and analyze the key factors emphasized by different operation model. The operation models of supply chain mainly include the business model (OEM/ODM) and the process model (BTF/BTO/CTO). The reference model of different operation model is developed to represent the critical factors' structure in each aspect of supply chain activities.
- Issue 2: To develop a conceptual framework in supply chain design, based on the tradeoffs identification between the decisions in strategic-level planning and operational-level planning. Such concepts are established in the views of notebook-computer contract manufacturers.
- Issue 3: To propose an integrated multi-objective supply chain design

model. Multi-objective decision analysis is performed so that a performance measurement system based on cost, customer service level (fill rate), and flexibility (volume or delivery) can be adopted.

1.4 Dissertation Framework

This dissertation is organized as follows. Chapter 1 is the introduction, which gives an overview of this research in terms of background, motivation and objectives, problem analysis and research issues, and the framework of this dissertation. Chapter 2 contains a briefly review of past researches for grey relational analysis method, supply chain flexibility, and supply chain models. Chapter 3 explores the operational characteristics of Taiwanese notebook-computer industry, the developments in supply chain model, and supply chain configuration in different operational model. Chapter 4 analyzes key factors used by notebook-computer contract manufacturers with reference to different operational model. In Chapter 5, a conceptual framework in supply chain design is developed to represent how the decision in strategic-level gives direct impacts in operational-level. Chapter 6 focuses on supply chain modeling and application. An integrated multi-objective supply chain design model is proposed to clearly define the impacts in operational performance from reconfiguration in the supply chain. The final chapter concludes the research and provides suggestions for future empirical studies. The flow chart of this dissertation is shown in Figure 1.1.

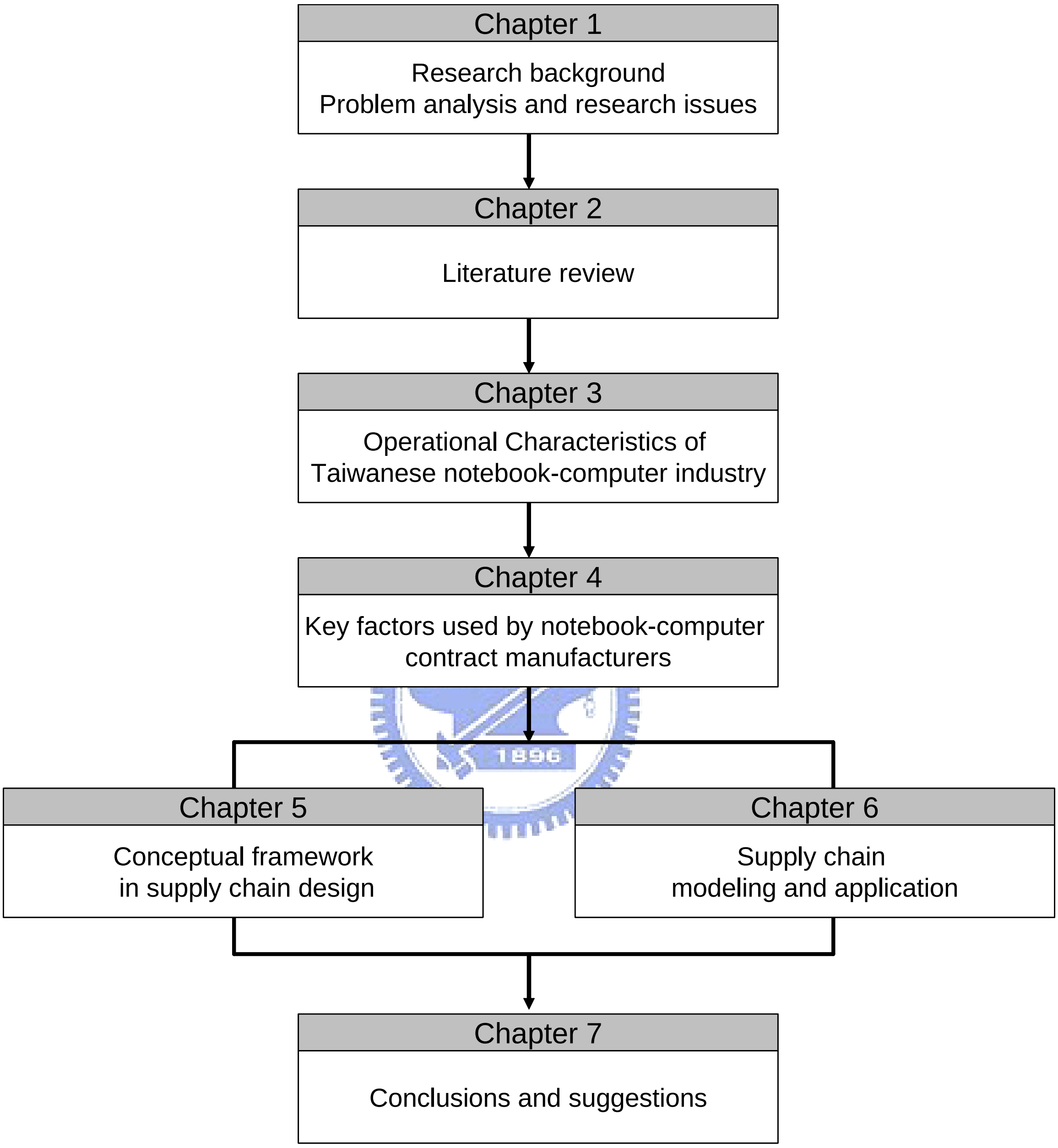


Figure 1.1 Flow-chart of Dissertation

Chapter 2 Literature Review

2.1 Grey Relational Analysis Method

Grey theory, proposed by Deng in 1982, is an effective mathematical means to deal with systems analysis characterized by incomplete information. Grey relation refers to the uncertain relations among things, among elements of systems, or among elements and behaviors. The relational analysis in the grey system theory is a kind of quantitative analysis for the evaluation of alternatives. Grey theory is widely applied in fields such as systems analysis, data processing, modeling and prediction, as well as control and decision-making (Deng, 1989; Fu et al., 2001; Liang, 1999).

Due to the presence of incomplete information and uncertain relations in a system, it is difficult to analyze it by using ordinary methods. On the other hand, grey system theory presents a grey relation space, and a series of nonfunctional type models are established in this space so as to overcome the obstacles of needing a massive amount of samples in general statistical methods, or the typical distribution and large amount of calculation work. The mathematics of GRA is derived from space theory by Deng (1988). The purpose of grey relational analysis is to measure the relative influence of the compared series on the reference series. In other words, the calculation of GRA reveals the relationship between two discrete series in a grey space. According to the definition of grey theory, the grey relational grade must satisfy four axioms, including norm interval, duality symmetric, wholeness and approachability (Feng and Wang, 2000; Wang et al., 2004; Lin et al., 2007).

Let X be a decision factor set of grey relations, $x_0 \in X$ the referential sequence, and $x_i \in X$ the comparative sequence, with $x_0(k)$ and $x_i(k)$ representing, respectively, the numerals at point k for x_0 and x_i. If $\gamma(x_0(k), x_i(k))$ and $\gamma(x_0, x_i)$ are real numbers, and satisfy the given four grey axioms, then we call $\gamma(x_0(k), x_i(k))$ the grey relation coefficient of these factors in point k, and the grade of grey relation $\gamma(x_0, x_i)$ is the average value of $\gamma(x_0(k), x_i(k))$. Deng also proposed a mathematical equation, which satisfies the four axioms of grey relation, and for the grey relation coefficient is expressed as

$$\gamma(x_0(k), x_i(k)) = \frac{\min_i \min_k | x_0(k) - x_i(k) | + \varsigma \max_i \max_k | x_0(k) - x_i(k) |}{| x_0(k) - x_i(k) | + \varsigma \max_i \max_k | x_0(k) - x_i(k) |}, \quad (1)$$

Where $| x_0(k) - x_i(k) | = \Delta_i(k)$, And ς is the distinguished coefficient $(\varsigma \in [0\,,1])$.

1. Norm interval

$$0 < \gamma(x_0\ , x_i) \le 1\,,\quad \forall k\,;\quad \gamma(x_0\ , x_i) = 1,\quad iff\ \ x_0 = x_i\ ; \tag{2}$$

$$\gamma(x_0\ , x_i) = 0,\quad iff\ \ x_0\ , x_i \in \phi \ \text{ Where } \phi \text{ is an empty set.} \tag{3}$$

2. Duality symmetric

$$x\,,y \in X \quad \Rightarrow \quad \gamma(x\,, y) = \gamma(y\,, x)\,,\quad iff\ \ X = \{x\,, y\}. \tag{4}$$

3. Wholeness

$$\gamma(x_i\ , x_j) \ne \gamma(x_j\ , x_i)\,,\quad iff\ \ X = \{x_i \mid i = 0, 1, 2, \ldots\ldots, n\}\,,\quad n > 2\,. \tag{5}$$

4. Approachability

$$\gamma(x_0(k)\,, x_i(k)) \ \text{ decreasing along with } \ \left|\,(x_0(k) - x_i(k))\,\right| \ \text{ increasing.} \tag{6}$$

GRA calculations compare the geometric relationships between time series data in the relational space. In other words, the grey relational grade represents the relative variations between one major factor and all other factors in a given system. If the relative variations between two factors are basically consistent during their development process, then the grey relational grade is large and vice versa. Thus, the relational grade between two sequences can be expressed by dividing the relational coefficient by its average value, in order to show the whole relationship for the system.

2.2 Supply Chain Flexibility

Each of the preceding supply chain models is deterministic, but in reality, Supply chain lie in an uncertain environment. Uncertainty is associated with customer demand, and internal and external supply deliveries throughout the SC. The following literatures try to capture the uncertainty of the supply chain environment based on the flexibility consideration.

Operations flexibility can be considered a crucial weapon to increase competitiveness in such a complex and turbulent marketplace (Upton, 1994). Flexibility becomes particularly relevant when the whole supply chain is considered, consisting of a network of supply, production, and delivering firms (Christopher, 1992). In this case, many sources of uncertainty have to be handled, such as market demand, supplier lead time, product quality, and information delay (Giannoccaro et al., 2003). Flexibility allows to switch production among different plants and suppliers, so that management can cope with internal and external variability (Chen et al., 1994).

Flexibility is a complex and multidimensional concept, difficult to summarize (Upton, 1994; Gupta and Buzacott, 1996). According to a broad definition, flexibility reflects the ability of a system to properly and rapidly respond to changes, coming from inside as well as outside the system. Referring to the several papers which have proposed useful taxonomies, different aspects of flexibility can be outlined, such as functional aspects, i.e. flexibility in operations, marketing, logistics, etc. (Kim, 1991), hierarchical aspects, i.e. flexibility at shop, plant or company level (Gupta, 1993; Koste and Malhotra, 1999), strategic aspects, centered on the strategic relevance of flexibility (Gerwin, 1993). From an operational perspective, however, the most interesting aspect of flexibility is probably the one concerning the object of change, i.e. flexibility of product, mix, volume, etc. (Vokurka and O'Leary-Kelly, 2000).

2.3 Supply Chain Models

The supply chain (SC) has been viewed as a network of facilities that performs the procurement of raw material, the transformation of raw material to intermediate and end products, and the distribution of finished products to customers. These facilities consist of production plants, distribution centers, and end-product stockpiles. They are integrated in an interactive network that a change in any one of them affects the performance of others. Substantial studies have been done in the field of optimal SC control. Various SC strategies and different aspects of SCM have been illustrated in the literature.

A. Deterministic Supply Chain Models

The production/distribution model (PILOT) of Cohen and Lee (1987) is global, deterministic, periodic, mixed integer mathematical program with a nonlinear objective function. This model extends the classic, multi-commodity distribution system model of Geoffrion et al. (1978). PILOT is concerned with the global supply strategy for manufacturing, and it determines the number and locations of plants and distribution centers, material (raw material, intermediate, and finished products) flows, plant production volumes, and the allocation of customers to distribution centers. Cohen and Moon (1990, 1991) use PILOT to investigate the effects of certain variables (unit transport costs and plant fixed cost) on the optimal supply chain structure. The objective function minimizes total cost subject to constraints on demand, raw material supply, production and distribution center (DC) capacities, production- distribution network structure, and customer location.

Cohen and Lee (1988) introduce a deterministic, non-linear model that uses a cost objective that considers before- and after-tax profitability. The authors also add trades balance constraint to the model because in some countries where exist a minimum level of manufacturing inside these countries for gaining entry into their markets. The major contribution of this model is the inclusion of fixed vendor costs and trade balance constraints. Robinson et al. (1993) develop a mixed-integer programming, cost function model for a two-echelon un-capacitated distribution location problem. The authors provide sensitivity, cost-service tradeoffs, and what-if analyses to clarify all major costs and service tradeoffs. A fixed-charge network programming technique is used to determine the best shipment routings and shipment size through the distribution system.

Camm et al. (1996) provide an interactive tool for re-engineering P&G's North American product sourcing and distribution system. The authors use a decomposition approach to divide the overall SC problem into two easily-solved sub-models: an ordinary un-capacitated distribution location mix integer model and transportation linear model. Near-optimal solutions are generated to help in coupling the two sub-models. Voudouris (1996) presents a mixed integer linear programming model to streamline operations and improve the scheduling process, while avoiding material stock-out or resource violation for a formulation and packaging chemical plant. The objective function is formulated to maximize flexibility, which is represented by capacity slacks, to absorb unexpected demand.

B. Stochastic Supply Chain Model

Cohen et al. (1986) presented a non-linear, stochastic, multi-echelon inventory model to identify the optimal stocking policy for a spare parts stocking system, based on accomplishing an optimal trade-off between holding costs and transportation costs, subject to response time constraints. Among the unique features of this service system include low demand rates, a complex echelon structure, and the existence of emergency shipments to comply with unforeseen demand. Cohen and Lee (1988) presented a stochastic optimization supply chain model that applies raw material, production, inventory, and distribution sub-models. All locations utilize (s, S) or (Q, R) control policies. A decomposition approach is adopted to optimize each sub-model individually. These sub-models are linked together by target fill rates, but these sub-models are not optimized simultaneously. In this work, the network in this study is restricted to a single manufacturing site.

Lee and Billington (1993) presented a stochastic heuristic model for managing material flows in decentralized supply chains by determining either stock levels subject to a target service level (the fill rate) or the service level performance in given stock levels. The authors assume a pull-type, periodic base stock inventory system and a normally distributed demand pattern. Newhart et al. (1993) presented a two-phase design model to help access various production/inventory location strategies. The first phase employs mathematical programming and heuristic techniques to minimize the number of product types. The second phase employs a spreadsheet inventory model to estimate the minimum safety stock based on the service level, demand level, lead-time, demand variability, lead-time variability, and product size flexibility. Finally, capital investment and competitors' strategies are also addressed before finally recommending the best strategy.

Lee and Feitzinger (1995) examined the impacts of postponement strategy on SC cost. They presented a simplified analytical model to locate the optimal decoupling point, which means the point of product differentiation, by minimizing the cost function. The problem addresses a supply chain with one factory serving multiple distribution centers (DC). The authors concluded, from the case example, that the inventory level is the main factor in locating the product configuration (decoupling) point, dwarfing the fixed costs of enhancing DC postponement capabilities.

2.4 Review Comments

The existing SC literature identifies a gap in the development of comprehensive supply chain models. Models that assume that demand is stochastic (Cohen et al.,1986; Lee and Billington, 1993; Lee and Feitzinger, 1995) either consider only two echelons or consider the operational level of the supply chain exclusively. Other models that deal with larger networks at the strategic level do not consider supply chain uncertainty. Other important observations that can be obtained from the existing literature review are:

- Only few papers consider SC flexibility as a performance measure, which is represented by capacity slacks of operational resources, although these slacks are the only performance measure used.

- All strategic-level models are deterministic (Cohen and Lee, 1987; Cohen and Moon, 1990, 1991; Geoffrion et al., 1978 and Robinson et al., 1993). All deterministic models have been established either for optimizing SC cost alone or maximizing profitability. Other performance measures are not considered.
- Strategic and operational considerations have not been extensively discussed and integrated in a comprehensive way of thinking and model formulation.
- Despite flexibility and SC management have been among the leading concerns of operations managers for several years, there are not many specific studies on the SC flexibility in the literature.

Chapter 3 Operational Characteristics of Taiwanese Notebook-Computer Industry

3.1 The Role of Taiwanese Notebook Industry in Global Market

Excellent process control in manufacturing and products quality is the most important competitive advantages for Taiwanese firms in the global notebook-computer market. These characteristics have driven the continue growth of Taiwanese notebook firms and helped them achieve a 74.7% global market share through cooperation with major international brands such as HPQ, Dell, IBM, Fujitsu, NEC, Sony, Acer, Apple, and Gateway which together have a combined market share of 80%. OEM/ODM (OEM is an abbreviation of “Original Equipment Manufacturing” and ODM is an abbreviation of “Original Design Manufacturing”) are the main business models in Taiwan and together account for 94% of domestic production volume. Table 3.1 shows the global market share of Taiwanese notebook-computer manufacturers. Such manufacturers play an important role in supporting multinational brands in their global logistics operations due to their flexibility, efficiency and quality.

Facing a changeable and competitive global market, Taiwanese notebook-computer manufacturers must establish strong competences to satisfy the different requirements of multinational brands in terms of global logistics. Simultaneously, how to reduce the costs associated with purchasing, manufacturing, assembling, warehousing and marketing is also important. Differentiated strategies need to be implemented to integrate and support the global supply chain operations of global brands. This study attempts to distinguish the key factors involved in different dimensions of global operations by using this complicated system. Nevertheless, factors respected by decision makers among global supply chain operations involve intricate interrelations. Thus, an empirical study of 12 notebook-computer manufacturers located in Taiwan is illustrated through the questionnaires and depth-interviews to gain more comprehensive information. Additionally, a conceptual reference model based on factor relational structure is formulated to identify the links with global supply chain operations.

Table 3.1 Global Market Share of Taiwanese Notebook-Computer Manufacturers

Unit: 1,000 items

Years	1998	1999	2000	2001	2002	2003	2004	2005
Production Volume in Taiwan	6,088	9,710	12,707	14,161	18,380	25,240	34,654	41,779
Global Market Demand	15,610	19,816	24,437	25,747	30,033	37,857	47,372	55,907
Global Market Share of Taiwan	39.0%	49.0%	52.0%	55,0%	61.2%	66.7%	73.1%	74.7%

Source: Market Intelligence Center, http://mic.iii.org.tw/index.asp

3.2 Characteristics of Different Operational Models

Based on the in-depth interviews with key managers, this section summarizes the characteristics of existing operational models. The various operational models adopted by notebook-computer manufacturers are characterized using their business and process models. The business model reflects the relationship focused on creating value-added activities between manufacturers and multinational brand companies. OEM and ODM are the main business models adopted by notebook-computer manufacturers in Taiwan. In the case of the OEM model, manufacturer production planning is conducted based on brand company directions such as material selection, product specifications and processing control to satisfy customer needs. Generally, OEM manufacturers are generally not involved in marketing. The advantages of OEM manufacturers derive from low manufacturing cost and flexibility in mass customization. ODM manufacturers are responsible for new product design and manufacturing according to brand company needs and requirements. After receiving orders from brand companies, the process of procurement, manufacturing, assembling and delivering is re-arranged and re-integrated. The advantages of ODM firms derive from their abilities in product design and process integration, but these R&D investments are characterized by high risk.

Process model types are strongly connected to the relationship between materials management based on MRP (material requirements planning) and distribution management activity based on DRP (distribution requirements planning). Figure 3.1 represents relationship between materials and distribution management.

The buffer between the two functions is a major stock point. Downstream (to the right) no further stock besides demand would be held and upstream (to the left) stock would be held only if it is economically justified to do so. Distribution activity is frequently driven by brand company orders, while materials management activity is driven by a demand forecast. The major stock point can be termed the decoupling point, since it decouples order and forecast driven activity. The decoupling point can also change depending upon market requirements/needs and product characteristics/features. Market requirements/needs dictate delivery times and required reliability, while product characteristics dictate throughput time during production and distribution. The different positions of major stock points result in different process models.

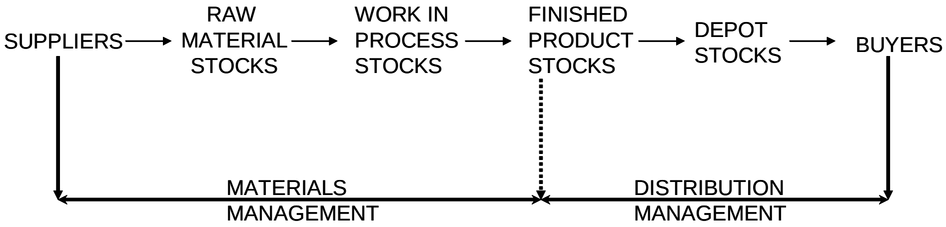


Figure 3.1 Relationship between Materials and Distribution Management

Process models are characterized by process arrangements and integrations. These models can be seen as manufacturer's internally operational control. Process control efficiency results in competitive advantages in the dimensions of cost, quality, speed and flexibility. BTF (Build To Forecast), BTO (Build To Order) and CTO (Configure To Order) are the main process models employed in Taiwan. Manufacturers implementing the BTF model directly deliver products to buyers from finished-product stock point, the position of decoupling point, after receiving orders. Manufacturers perform material purchasing and production process planning based on market forecasts to increase production efficiency and reduce inventory costs. Finished products are produced and delivered to stock. Manufacturers implementing the BTO model activate the production process after receiving buyer orders. First purchase partial materials according to buyer demand forecasts and then purchase other materials and components after confirming those orders. All products are manufactured according to buyer requirements/needs. Only raw materials and components based on MRP are held in stock. Upon receiving brand company orders, products are manufactured and then shipped. No stock of finished products is held. Manufacturers implementing the CTO model emphasize the differentiate components being finally configured to buyers' orders. The stocks are held during work in process. No finished product stock is held. The manufacturing process can be separated into two parts. First, general types of semi-products and components are produced in advance. Second, key components that satisfy different end customer needs are purchased and assembled into final products. The first part resembles a BTF model. Meanwhile, the second part resembles the BTO model. Final products are assembled to buyer requirements/needs.

Process models adopted by manufacturers depend on order driven activity being decoupled from forecast driven activity. These two types of activity differ essentially. Order driven activity is based on the known requirements of brand companies, meaning that manufacturers are managing certainty. In contrast, forecast driven activity involves an attempt to manage uncertainty. Manufacturers pay more attention to this uncertain part of the manufacturing process. The position of decoupling point in the supply chain strongly influences process model selection. It depends on considerations of inventory holding, resource requirements and time limitations.

Six operational models can be derived from the combination of business models (OEM/ODM) and process models (BTF/BTO/CTO). Based on the above discussion, the relevant activities in different operational models can be summarized in Table 3.2. Only ODM with BTF/BTO/CTO models participate in product design under the requirements of brand companies. For all operational models, “Demand Forecast”, “Purchase”, “Manufacture” and “Delivery” are general activities. Such activities differ from the relationship between manufacturers and brand companies. The OEM/CTO and ODM/ CTO models focus on customization following essential assembly activity. Stock points and types vary with different operational models. According to the process diagram shown in Figure 3.2, finished product inventory is possessed in OEM/BTF and ODM/BTF models, material inventory is possessed in OEM/BTO and ODM/BTO models, as well as component inventory is possessed in OEM/CTO and ODM/CTO models. Furthermore, purchase activity is divided into two steps in the OEM/BTO and ODM/BTO models. Manufacturers purchase partial materials based on demand forecast. After receiving orders from brand companies, purchase materials again and then manufacture products to meet those orders. Customization is the core competence in the OEM/CTO and ODM/CTO models. The manufacturing process comprises two parts. The first part is component manufacturing for differentiated product configuration. Meanwhile, the second part is driven by the orders from brand companies. Manufacturers start purchasing differentiated key components and assembling final products to satisfy custom-made orders.

Table 3.2 Activities Involved in Various Operational Models

TYPE	Product Design	Demand Forecast	Purchase	Manufacture	Assembly	Delivery	Material Stock	Semi-Product Stock	Finished Product Stock
OEM/BTF	--	◎	◎	◎	--	◎	--	--	◎
OEM/BTO	--	◎	◎	◎	--	◎	◎	--	--
OEM/CTO	--	◎	◎	◎	◎	◎	--	◎	--
ODM/BTF	◎	◎	◎	◎	--	◎	--	--	◎
ODM/BTO	◎	◎	◎	◎	--	◎	◎	--	--
ODM/CTO	◎	◎	◎	◎	◎	◎	--	◎	--

Note: ◎ means having this activity

Business models represent the cooperative relationship between notebook-computer manufacturers and multinational brand companies in global operations. Quick and precise responses to brand company orders are undoubtedly important and form the basis of cooperation. Consequently, “Strategic Alliance” and “Logistics Facilities Locations” are important to manufacturers for purposes of forming a rapidly responsive supply chain. To support the global operations of brand companies, the process model is important in representing process control efficiency, including purchasing, manufacturing, inventory management, delivery scheduling and customer service. Restated, different operational models adopted by manufacturers form seamless and efficient logistics activities to assist brand companies in global marketing and extension.

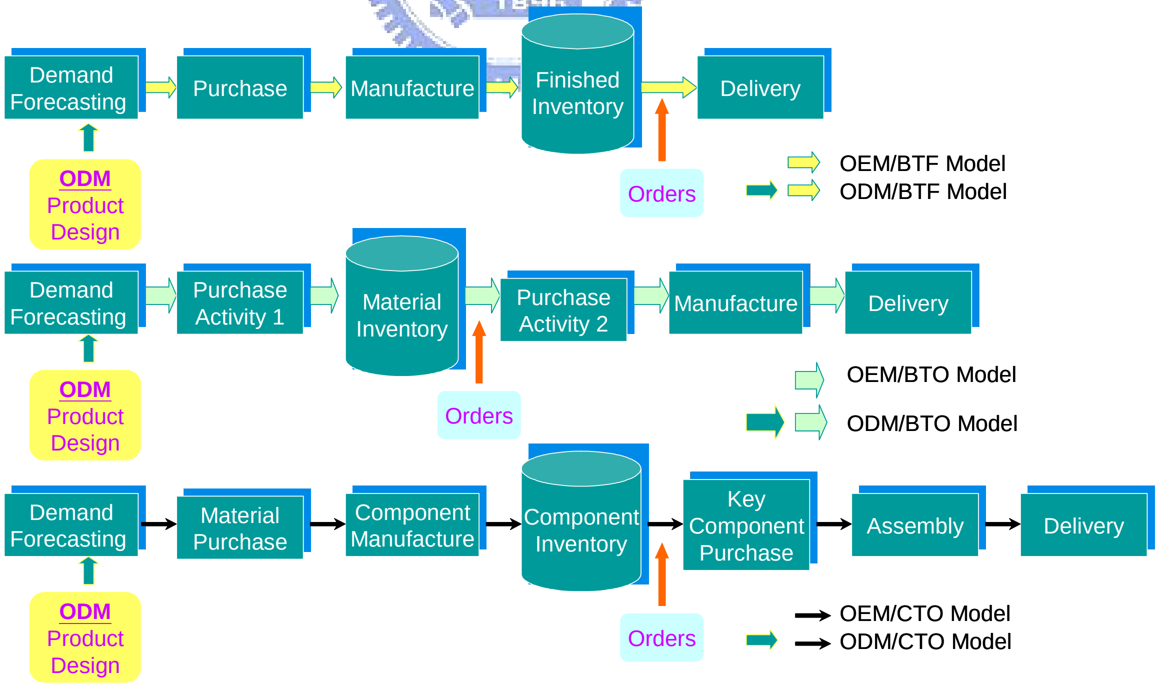


Figure 3.2 Process in Different Operational Models

3.3 Development in Supply Chain Model

In the early stage of contract manufacturing, Taiwanese notebook-computer manufacturers (NBMs) were responsible for low-level module assembly based on the BTF operational model, and Brand Companies focused on key-components final configuration and full-set distribution. Brands had to bear high risk in financial affairs and supply chain uncertainty. For the purpose of quickly responding to market demand diversity and transferring global operational risks, “global logistics” comes to prevail over the whole notebook-computer industry. BTO/CTO has been becoming the major type of operational model instead of BTF model.

The differences in BTF, BTO and CTO model in Taiwan are shown as Table 3.3. BTF model focuses on low-level module assembly comparing with bare-bone assembly in BTO model and full-set assembly in CTO model. BTF model also accompanies with low operational risks, but BTO/CTO model face high operational risks due to the fulfillment requirements from Brand Companies. BTO/CTO models bring impacts to manufacturers having the local configuration ability under the consideration of quick response to regional markets. The trigger of supply chain operations comes from Brands’ long-term product forecasts in BTF model, Brands short-term order forecasts in BTO model, and customer EDI orders via internet in CTO model.

Following the progressive track in supply chain operational models, as shown is Figure 3.3, it could be found that OEM/ODM business model and BTF operational model were developed in 1993, referring to multinational Brands started to move their manufacturing bases to South-East Asia. Notebook-manufacturers in Taiwan began to receive OEM/ODM orders from Brands.

Table 3.3 Differences in BTF, BTO and CTO Models in Taiwan

Items	Operational Model		
	BTF	BTO	CTO
Assembly Product	Low-level Module	Bare-bone	Full-set
Product Type	Standard models	Specific models	Diverse Models
Operational Risks	Low	High	High
Lead Time	Long	Short	Short
Local Configuration Ability	NO	Yes	Yes
Trigger of supply chain operations	Brands’ Long-term Product Forecasts	Brands’ short-term Order Forecasts	Customer EDI Orders

Compaq proposed BTO/CTO model in 1997, it made Taiwanese contract manufacturers innovated their ability in manufacturing and SCM, and globally extended logistics facilities to meet Brands' requirements and needs. Such innovation also speeded up the development of global logistics in NBMs.

BTO model has been commonly adopted by Taiwanese NBMs since 1998. Based on the excellent performance in BTO operations, Brands begin to cooperate with leading NBMs for constructing the CTO+TDS (CTO and Taiwan Direct Shipment) model, such as Quanta/Apple, Compal/HP in 1999 and Compal/Dell in 2001. In recent years, Dell proposed custom factory integration (CFI) model in desktop computer, it cooperates with powerful contract manufacturers to construct CTO+DS (Direct Shipment) +Customized IT Solutions operational model. Focus on providing customers one-stop shopping services and building closer customer-relationship management by shortening the supply chain.

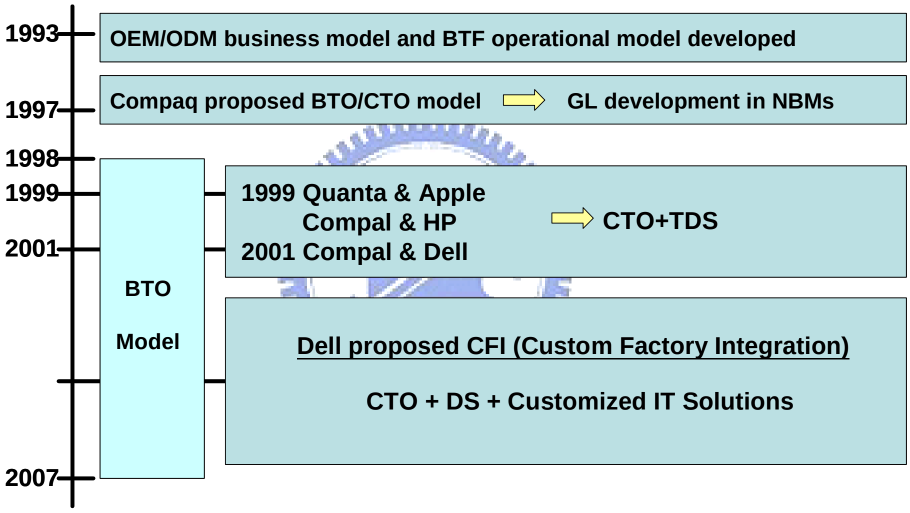


Figure 3.3 Progressive Track in Supply Chain Operational Models

3.4 Supply Chain Configuration in Notebook-computer Industry

According to depth-interview in notebook-computer industry and papers review, the supply chain configurations about different operational models are sketched as Figure 3.4 to Figure 3.7. Figure 3.4 shows the earlier configuration in BTO model, NBMs assembled the general components (GC) into bare-bone and then delivered to configuration hub which runs by Brand Company. Brands were responsible for the full-set final configuration and distribution to customer zones.

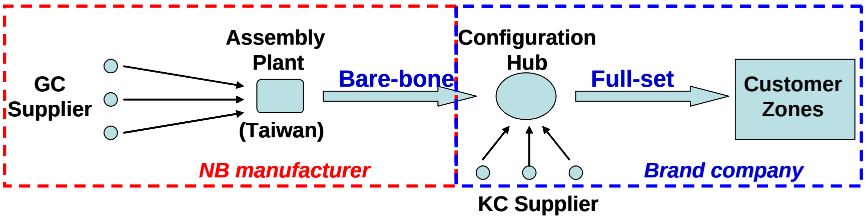


Figure 3.4 Supply Chain Configuration in BTO Model

The specific CTO+TDS model in Taiwan is shown in Figure 3.5. NBM's receive full-set orders from Brands. Full-sets final configurations are finished in their assembly plant in Taiwan. Based on the requirements of 2 or 3 days duration in products assembling, it's necessary to setup supplier hub with vendor management inventory (VMI) operations for precisely controlling the supply of different general components (GC) and key components (KC). Air transport is also essential for quick delivering products to customers in different regional markets. Such model makes the total lead-time reduced to 5 to 7 days.

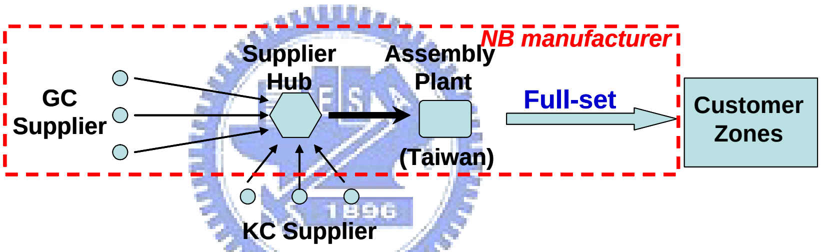


Figure 3.5 Supply Chain Configuration in CTO+TDS Specific Model

BTO/CTO general model is commonly adopted by leading NBMs in Taiwan, as shown in Figure 3.6. Based on excellent SCM abilities and global facilities networks, such as assembly plants in South-East Asia, Mainland China, and South America followed extensive connections with regional configuration hubs, NBMs deal with full-set orders during the process of GC procurement, bare-bone assembly and full-set configuration. KC modules are designated by Brand Companies. Such model establishes a quick-responsive network in supporting Brands' global operations.

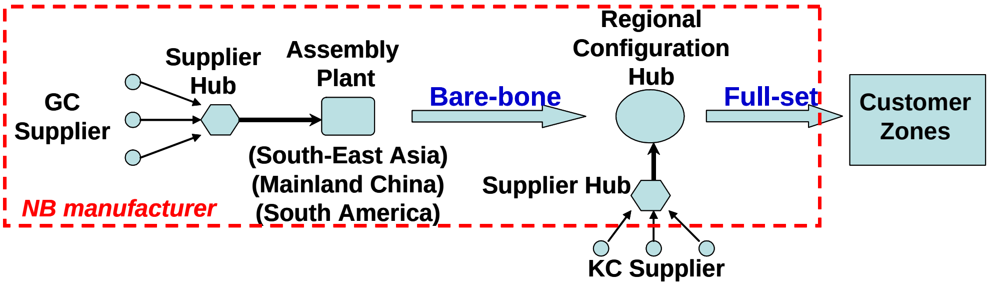


Figure 3.6 Supply Chain Configuration in BTO/CTO General Model

Dell has been proposed the BTO/CTO+DS model, as shown in Figure 3.7, in desktop computer industry. It would be extended to notebook-computer industry in the near future. Powerful notebook-computer contract manufacturers are going to be responsible for full-set final configuration and total IT solution provision via the global network of regional assembly plants and strong linkages with well-integrated GC-suppliers and KC-suppliers.

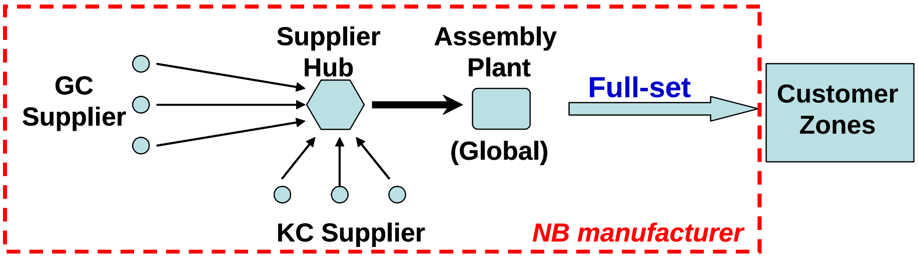


Figure 3.7 Supply Chain Configuration in BTO/CTO+DS Model

BTO/CTO model emphasizes short lead-time, use of supplier Hub (VMI), quick transportation mode and IT applications are necessary. BTO/CTO general model and CTO+TDS specific model is commonly adopted by Taiwanese NBMs in the past few years. Following the trend of manufacturing base moving to Mainland China, CTO+CDS model has been developed in recent years.

CTO+TDS model brings US$30-US$50 profit per NB, accompanying increasing CTO orders with higher assembly cost, transportation cost and low NB price tendencies, the profit and competitive advantages are challenged. Reconsidering the global supply chain configuration is going to be one of the critical issues. Taiwanese NBMs need to copy the BTO/CTO executive experience to global operations for satisfying Brands requirements in the near future.

Chapter 4 Key Factors Used by Notebook-Computer Contract Manufacturers

4.1 Conceptual Framework

Flexibility, efficiency, quality and cost control are the main competitive advantages of Taiwanese notebook-computer manufacturers. These advantages provide close cooperation that assist multinational firms compete. Such competences also help ensure a steady inflow of OEM/ODM orders. Figure 4.1 shows the conceptual framework of this study.

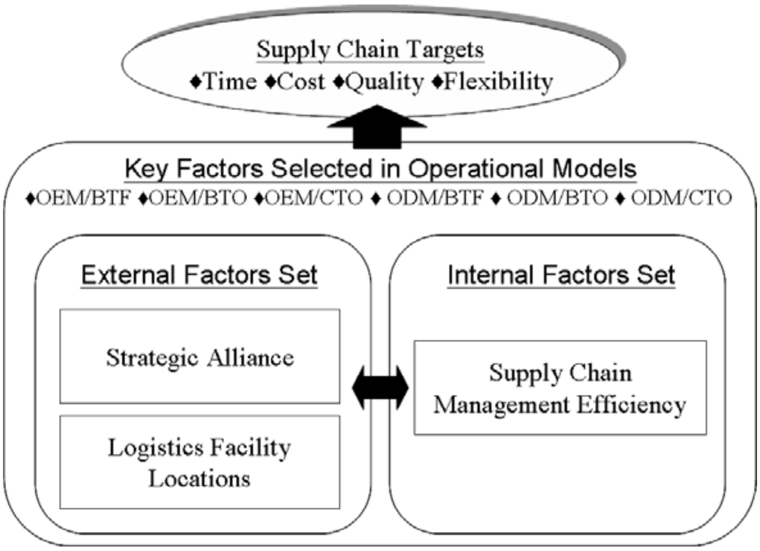


Figure 4.1 Conceptual Framework for Analyzing Key Factors in Notebook-Computer Manufacturers

To sustain long-term and profitable cooperation with brand companies, manufacturers set supply chain targets. Achieving these targets demonstrates firm abilities to support global operations. Furthermore, the operational model adopted to establish an effective supply chain framework is a critical point. It is necessary to identify the key factors for describing the operational characteristics of different operational models.

For this study, the questionnaire was developed based on grey relational analysis method to collect data of expert judgments. The content of questionnaire was confirmed through an intensive literature review and significant discussions with some experts. The questionnaire contains two major parts. Part A is the overall basic data collections including “general information of your company”, “market segmentation and facility locations”, “business model and process model” and “objectives of your company”. Part B investigates the different factors with reference to global supply chain operations. This study summarizes the possible factors obtained from literature review and depth-interview survey into the following dimensions: “Supply Chain Targets”, “Supply Chain Management Efficiency”, “Strategic Alliance” and “Logistics Facility Locations”. There are some questions in four classified dimensions, reflecting the important factors within each dimension among different kind of operation models. Data were collected through the nominal scale with the values (from 1 to 5) representing the significance level in different factors shown in each dimension. Figure 4.2 shows the factors set in different dimensions.

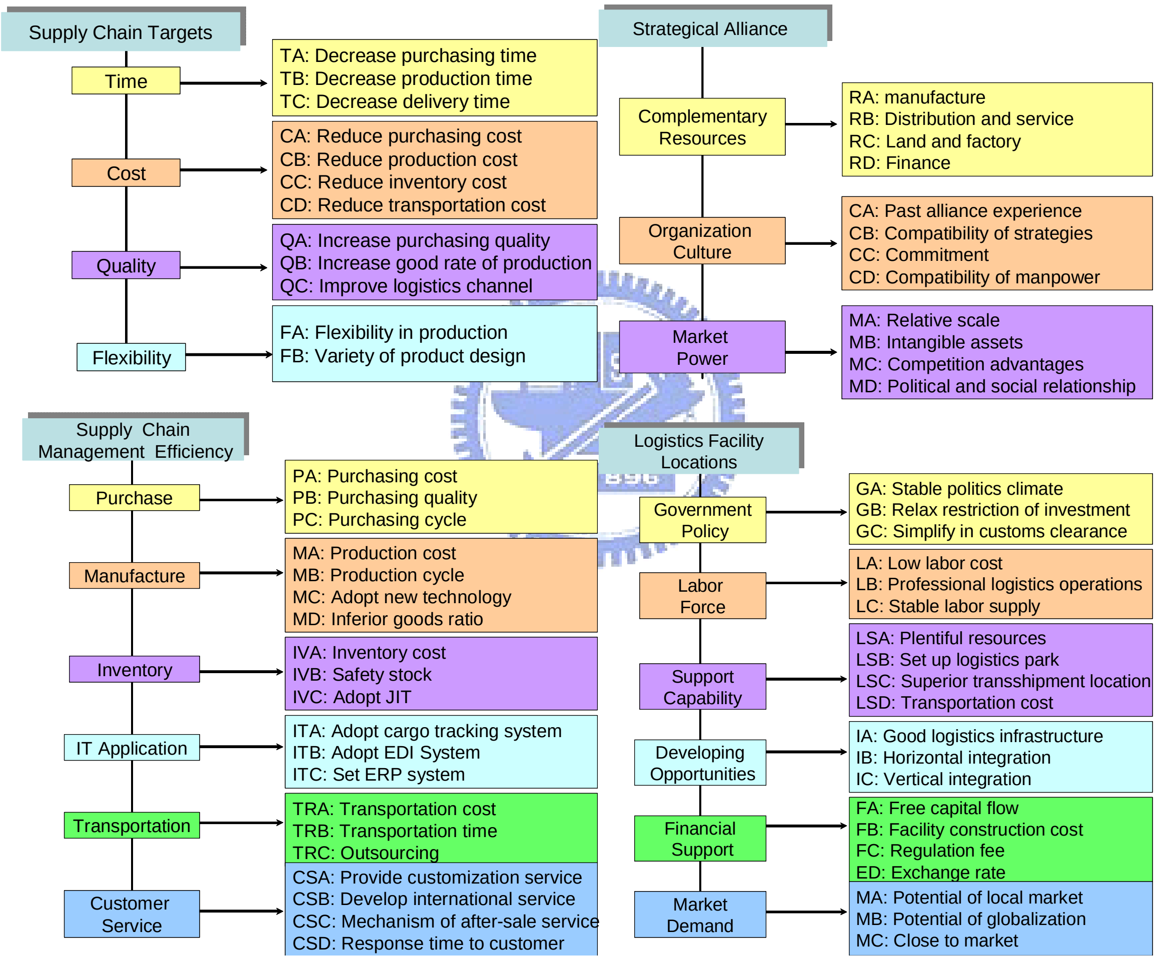


Figure 4.2 Factor Sets in Different Dimensions

The Dimension “Supply Chain Targets” is quoted as being representative of the optimization of global operations regarding the issues the satisfying brand company requirements, coordinating distribution channels, control costs and risks, and shortening lead-times. Twelve factors were introduced and classified into four sub-dimensions of time, cost, quality, and flexibility. The partnership was motivated by the desire to increase efficiency, reduce costs and control risk. Twelve factors in the “Strategic Alliance” dimension are divided into three sub-dimensions of complementary resources, organization culture, and market power. All the operational processes should be controlled to meet the practical requirements and the need for advance planning. To explore the influences on each major process involved in supply chain operations, 20 factors in the dimension of “Supply Chain Management Efficiency” are divided into six sub-dimensions including purchase, manufacture, inventory, IT application, transportation, and customer service. To explore what external environmental factors influence operational effectiveness in global supply chains, 20 factors from the dimension of “Logistics Facility Locations” are divided into six sub-dimensions of government policy, labor force, support capability, development opportunities, financial support, and market demand.

The operational models of global supply chain for notebook-computer manufacturers are highly complex. The need to preserve commercial secrecy makes it difficult to analyse practical operational data. Therefore, key factors are searched to represent the characteristics of different operational models. This methodology must be applied to analyse the incomplete information gathered from questionnaire survey and in-depth interviews. Grey system theory, proposed by Deng in 1982, is an effective mathematical method of dealing with systems analysis characterized by incomplete information. The fundamental definition of “greyness” is information that is incomplete and unknown, and thus an element that forms an incomplete message is considered a grey element. “Grey relation” indicates the measurements of changing relations between two systems or two elements that occur in a system over time. The analysis method, which measures the relation among elements based on the degree of similarity of difference of development trends among these elements, is known as “grey relation analysis”. More precisely, during system development, given a consistent trend of change between two elements, it means that they have a higher grade of synchronized change and can be considered to have a greater grade of relation, otherwise, the grade of relation would be smaller. This study investigated 36 key managers at the strategic decision-making level in 12 leading notebook-computer manufacturers in Taiwan. Grey relation analysis was applied to select key factors from each dimension for analyzing the global operating characteristics based on respondent macroscopic views.

4.2 Key Factors Selected from Each Dimension in Different Models

Based on the basic information on Taiwanese notebook-computer manufacturers, there are seven manufacturers with capital exceeding 10 billion, five manufacturers with annual revenue exceeding 100 billion, and six manufacturers with more than 4000 employees. All of the manufacturers operate global supply chains in cooperation with multinational brand companies in major markets such as Europe, United States and Mainland China. Table 4.1 lists the operational model classification, and differs from cooperative relationship with different multinational brand companies.

Table 4.1 Operation Model Classifications in Taiwan

Type of operation model		Process Model		
		BTF	BTO	CTO
Business Model	OEM	BenQ, Asus, Uniwill, ECS	Inventec, FIC, Asus, BenQ, Twinhead , ECS, Arima, Uniwill, Clevo	Mitac, Inventec, FIC, Asus, ECS, Twinhead, Arima, Uniwill, Clevo
	ODM	Compal, BenQ, Asus, Uniwill, ECS	Twinhead, Compal, Quata, FIC, Uniwill, Clevo, Inventec, BenQ, Asus, ECS	Twinhead, Compal, FIC Uniwill, Mitac, Clevo, Inventec, Asus, ECS

According to the questionnaire investigation, OEM/ODM business models and BTF/BTO/ CTO process models are combined to produce six model types. Following the process of grey relation matrix construction, eigenvalue and eigenvector calculation and weighted sorting by each factor in different dimensions, an example is presented as follows. Table 4.2 lists the weighted value of each factor in the dimension of "supply chain targets". The weighting priority demonstrates that the supply chain targets of OEM/BTF manufacturers focus on "Decrease delivery time", "Reduce purchasing cost", "Increase good rate of production" and "Improve logistics channel". Based on grey relation analysis, the key factor in each sub-dimension is chosen for the purpose of to clarify how manufacturers pay much more attention in decision level for supporting brand company global operations. Figure 4.3 shows the key factor relational structure in different operational models, and represents the hidden knowledge possessed by the respondents. It describes how manufacturers reach their supply chain targets based on the characteristics of the dimensions of "Supply Chain Management Efficiency", "Strategic Alliance" and "Logistics Facility Locations". Such structures can be considered reference models which draw the operational outline of different operational models in leading Taiwanese notebook manufacturers. The key factor in each sub-dimension is described in the form of "(Name of key factor) / (Name of sub-dimension)".

For OEM/BTF manufacturers reaching the targets, shown in fig. 5, “Purchasing cost/Purchase”, “Inferior goods ratio/Manufacture”, “Inventory cost/Inventory”, “Adopt EDI system/IT Application”, “Transportation time/Transportation” and “Response time to customer/Customer Service” are the key factors reflecting the attention paid by manufacturers to improving their management efficiency in each operational process. Furthermore, to enhance cooperative efficiency, reduce costs and control risk, “Manufacture/Complementary Resources”, “Commitment/Organization Culture” and “Competitive advantages/Market Power” are the key factors reflecting the importance placed by manufacturers on strategic alliances. On the other hand, the external environment directly influences the effectiveness of global supply chain operations. “Stable politics climate/Government Policy”, “Low labor cost/Labor Force”, “Superior transshipment location/Support Capability”, “Vertical integration/Developing Opportunities”, “Exchange rate/Financial Support” and “Potential of local market/Market Demand” are the key factors reflecting the concern of manufacturers with logistics facility locations. Different types of key factor relational structures regarding different operational models are shown in Fig. 5. All of the key factor relational structures are further described in the discussion of managerial implications at the end of this section.

Table 4.2 Weighted Value of Each Factor in The Dimension of “Supply Chain Targets”

Sub-dimension	Factors Description	OEM			ODM		
		BTF	BTO	CTO	BTF	BTO	CTO
Time	Decrease purchasing time	0.2465	0.2883	0.2942	0.2323	0.2734	0.2990
	Decrease production time	0.2952	0.3099	0.2863	0.2506	0.2899	0.2911
	Decrease delivery time	0.3022	0.2639	0.2971	0.3139	0.2602	0.2974
Cost	Reduce purchasing cost	0.3019	0.2680	0.2761	0.2863	0.2661	0.2679
	Reduce production cost	0.2963	0.2600	0.2782	0.2852	0.2586	0.2670
	Reduce inventory cost	0.2529	0.2603	0.3111	0.2500	0.2596	0.3063
	Reduce transportation cost	0.2957	0.2684	0.2836	0.3000	0.2656	0.2945
Quality	Increase purchasing quality	0.2957	0.3116	0.3090	0.3008	0.2982	0.3036
	Increase good rate of production	0.3084	0.2960	0.3039	0.3014	0.2885	0.3053
	Improve logistics channel	0.2962	0.2908	0.3110	0.2854	0.2988	0.3022
Flexibility	Flexibility in production	0.2809	0.2933	0.3131	0.2587	0.3055	0.3091
	Variety of production design	0.2404	0.3123	0.2914	0.2461	0.3140	0.2912

Comparing the different types of OEM manufacturers reveals that their supply chain targets are different because of the cooperative relationship with brand companies. These targets indicate the commitments to be accomplished to maintain long-term cooperation. Failure to reach the desired level for any specific target results in weakened cooperation. The factor priority of supply chain targets is changed into the “Variety of product design/Flexibility” in OEM/BTO model and

“Flexibility in production/Flexibility” in the OEM/CTO model. Particularly, “Reduce inventory cost/Cost” is concerned in OEM/CTO manufacturers for differentiated components storage. On the other hand, the same key factors in “supply chain management efficiency” dimension are “Inferior goods ratio/Manufacture”, “Inventory cost/Inventory”, “Adopt EDI system/IT Application” and “Transportation time/Transportation”. Differences exist in the sub-dimension of “Purchase” and “customer service”. “Purchasing cost/Purchase” and “Response time to customer/Customer Service” are concerned in OEM/BTF manufacturers. “Purchasing quality/Purchase” and “Provide customization service” are similarly concerned in OEM/BTO and OEM/CTO manufacturers.

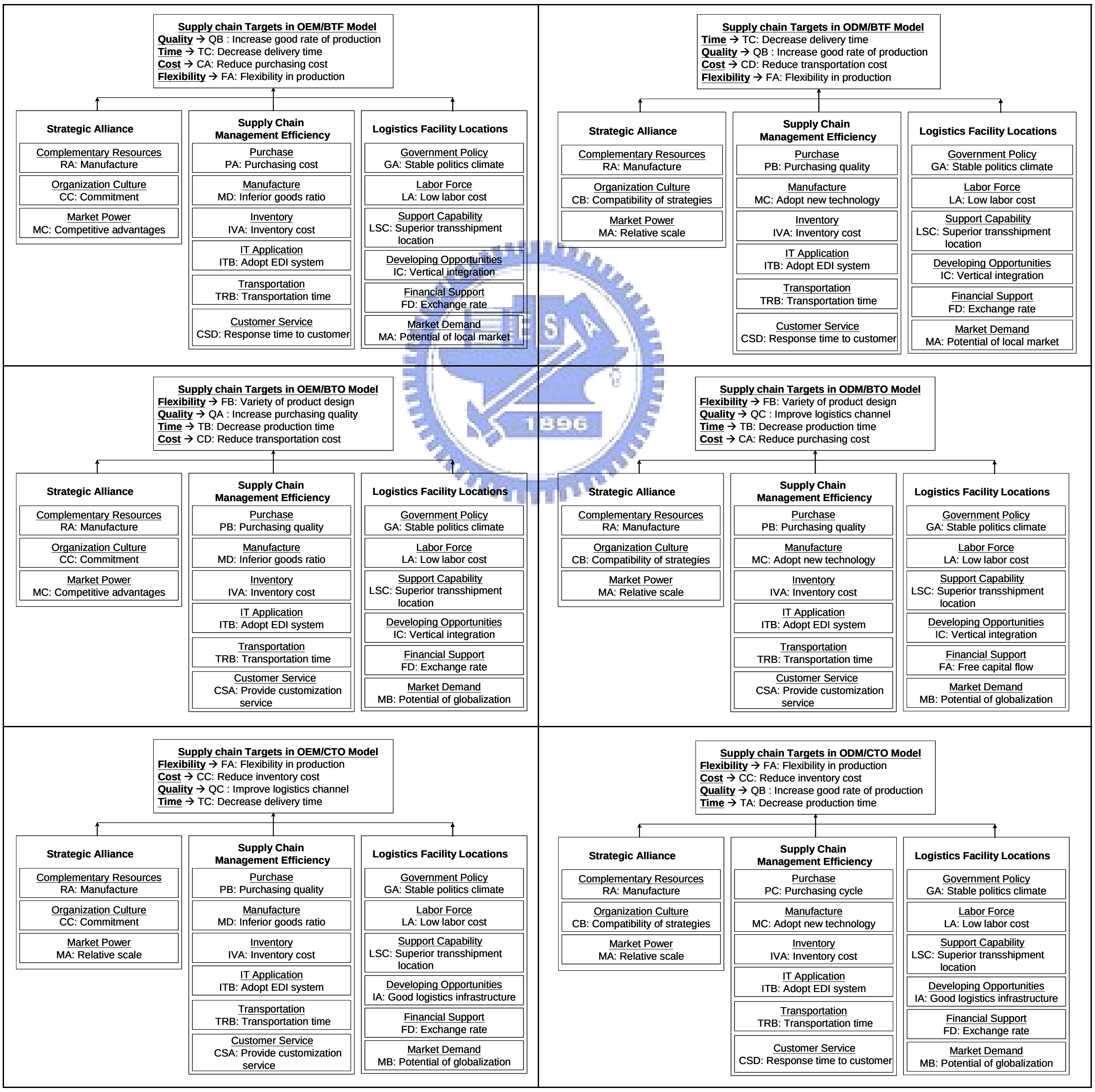


Figure 4.3 Key Factors Relational Structures in Different Operational Models

Tables 4.3 and 4.4 list the common and different factors, respectively, emphasized in different OEM and ODM models. The tables can be used to identify the common and different factors involved in global supply chain decisions from the perspectives of different OEM/ODM manufacturers. For all types of OEM manufacturers, as shown in Table 4.3, a total of ten common key factors were established in three dimensions, including four in the “Supply Chain Management Efficiency” dimension, two in the “Strategic Alliance” dimension and four in the “Logistics Facility Location” dimension. It means that such factors are equally important in global supply chain operations. Furthermore, five different representative factors exist due to the different process model types (BTF/BTO/CTO). These factors also reflect the differentiated decisions made by OEM manufacturers while supporting] brand company global operations under different cooperative relationships.

Table 4.3 Common Factors and Different Factors Stressed in Different OEM Models

Classification		OEM		
		BTF	BTO	CTO
Common Key Factors	Supply Chain Management Efficiency	**Manufacture** – Inferior goods ratio **Inventory** – Inventory cost **IT Application** – Adopt EDI system **Transportation** – Transportation time		
	Strategic Alliance	**Complementary Resources** - Manufacture **Organization culture** - Commitment		
	Logistics Facility Locations	**Government Policy** - Stable politics climate **Labor Force** – Low labor cost **Support Capability** Superior transshipment location **Financial Support** – exchange rate		

Classification		OEM		
		BTF	BTO	CTO
Different Key Factors	Supply Chain Management Efficiency	**Purchase** Purchasing cost **Customer Service** Response time to customer	**Purchase** Purchasing quality **Customer Service** Provide customization service	**Purchase** Purchasing quality **Customer Service** Provide customization service
	Strategic Alliance	**Market Power** Competitive advantages	**Market Power** Competitive advantages	**Market Power** Relative Scale
	Logistics Facility Locations	**Developing Opportunities** Vertical integration **Market Demand** Potential of local market	**Developing Opportunities** Vertical integration **Market Demand** Potential of globalization	**Developing Opportunities** Good logistics infrastructure **Market Demand** Potential of globalization

In all types of ODM manufacturers, as listed in Table 4.4, there are a total of ten common key factors based on three dimensions, including four factors in the dimension of “Supply Chain Management Efficiency”, three factors in the dimension of “Strategic Alliance” and three factors in the dimension of “Logistics Facility Locations”. Furthermore, five different key factors exist due to the characteristics of different process model types (BTF/BTO/CTO). Comparing the OEM and ODM models reveals that only three factors differ between the two groups of common key factors. “Inferior goods ratio/Manufacture” in the OEM model and “Adopt new technology/Manufacture” in the ODM model are diverse within the dimension of “Supply Chain Management Efficiency”. Moreover, “Relative scale/Market Power” is diverse in the ODM model within the dimension of “Strategic Alliance” and “Exchange rate/Financial support” is diverse in the OEM model within the dimension of “Logistics Facility Locations”. Restated, seven factors are identical for all OEM and ODM manufacturers.

Table 4.4 Common Factors and Different Factors Stressed in Different ODM models

Classification		ODM		
		BTF	BTO	CTO
Common Key Factors	Supply Chain Management Efficiency	**Manufacture** – Adopt new technology **Inventory** – Inventory cost **IT Application** – Adopt EDI system **Transportation** – Transportation time		
	Strategic Alliance	**Complementary Resources** - Manufacture **Organization culture** - Commitment **Market Power** – Relative Scale		
	Logistics Facility Locations	**Government Policy** - Stable politics climate **Labor Force** – Low labor cost **Support Capability** Superior transshipment location		

Classification		ODM		
		BTF	BTO	CTO
Different Key Factors	Supply Chain Management Efficiency	**Purchase** Purchasing quality **Customer Service** Response time to customer	**Purchase** Purchasing quality **Customer Service** Provide customization service	**Purchase** Purchasing cycle **Customer Service** Response time to customer
	Strategic Alliance	--	--	--
	Logistics Facility Locations	**Developing Opportunities** Vertical integration **Financial Support** Exchange rate **Market Demand** Potential of local market	**Developing Opportunities** Vertical integration **Financial Support** Free capital flow **Market Demand** Potential of globalization	**Developing Opportunities** Good logistics infrastructure **Financial Support** Exchange rate **Market Demand** Potential of globalization

4.3 Conclusion Remarks

In the global notebook-computer market, Taiwanese OEM/ODM manufacturers are focused on supporting the global operations of multinational brand companies. It is extremely difficult to continue generating benefits from brand companies in the long-run, due to the risks of shortening product lifecycles declining product prices. Recently low profits and intense competition have increased the need for manufacturers to adjust strategies to focus on innovation, flexibility, efficiency, quality and cost control and cooperate more closely with brand companies. This study applied a questionnaire survey and in-depth interviews to leading notebook-computer manufacturers to explore and understand the key factors involved in global operations. Based on the analysis and results, the managerial implications and suggestions are presented below:

1. OEM manufacturers typically emphasize orders fulfillment and production quality control for quick response to multinational brand companies, and focus on improving manufacturing process to reduce the inferior goods rate, control inventory costs, establish an EDI system and reduce transportation time. In the aspect of logistics facilities locations, low labor cost, stable politics climate, superior transshipment location and exchange rate are all influences on logistics. In the aspect of strategic alliance, commitments in coordinated operations and complementary resource in manufacture are emphasized for establishing a quick response system to satisfy the requirements of brand companies.

2. ODM manufacturers activate the process of product design, purchase, and manufacture according to the requirements of brand companies. Technological innovation, inventory cost control, EDI system application and reducing transportation time are important in supply chain management. ODM manufacturers thus support the supply chain of brand firms based on their ability and efficiency in innovative manufacturing. The main influences on supply chain layout are stable politics climate, low labor cost and superior transshipment location. The main determinants of strategic alliance formation include complementary manufacturing resources, commitment to coordinated operations, and relative scale between partners in terms of market power.

3. BTF manufacturers are characterized by forecasting production. Order fulfillment is based on the comprehensive inventory of finished goods. Therefore, minimizing the ratio of inferior goods is necessary to maintain acceptable supply quantity and quality. Meanwhile, it brings the risks associated with high inventory and manufacturing cost. Effective manufacturing process control is

necessary to pay more attention to shortening lead times and reducing costs.

4. Establishing a professional integration system is extremely important to BTO manufacturers. It makes them to react to the changeable market demand quickly. Based on consideration of cost and flexibility, delivery time must be shortened to a few days. Simultaneously, manufacturing strategies need to be adjusted from mass production to small batches to satisfy more frequent orders from brand companies. Consequently, efficiency and cost must be balanced to meet short-term global market demand. Additionally, the modular production mode is also necessary for BTO manufacturers to enhance supply chain operational efficiency. IT is indispensable in achieving seamless integration in monitoring stock levels and operational information.

5. CTO manufacturers stress customization to end-customers. Most products have no fixed specifications, increasing the importance of production flexibility and commitment to clients. Limited quantity supply of a diverse range of products makes manufacturers inseparable from suppliers. Close communication and coordination is necessary to ensure smooth manufacturing process operation. The key to successful CTO model is well-organized strategic alliances, while vendor-managed inventory is necessary not only to avoid declining component prices, but also to increase efficiency through in-time reordering. Additionally, under pressure from uncertain orders and quick delivery requirements, it is essential for CTO manufacturers to establish a quick response logistics facility.

6. This investigation is a pilot study that aims to understand the characteristics of Taiwanese notebook-computer manufacturers as they face global competition while supporting multinational brand companies' operations. The construction of reference models is helpful in describing and analyzing the global operations of such manufacturers from a macro perspective. However, based on the findings, a practical operation model representing the interaction between manufacturers and multinational companies in relation to cost and performance can be established. It is useful to evaluate and discuss which operational strategies can efficiently support global supply chain operations.

7. Cost, flexibility, customer service (fill rate), lead-time are the core factors emphasized by contract manufacturers in quickly responding customers' needs and supporting brands' global operations. Such factors would be incorporated into supply chain design model.

Chapter 5 Conceptual Framework in Supply Chain Design

5.1 Scope and Assumptions

Facing a changeable and competitive global market, Taiwanese notebook-computer manufacturers must establish strong competences to satisfy the different requirements of multinational brands in terms of global logistics. Simultaneously, how to reduce the costs associated with purchasing, manufacturing, assembling, warehousing and marketing is also important. Differentiated strategies need to be implemented to integrate and support the global supply chain operations of global Brands. Effective supply chain design is necessary to contract manufacturers, different competing supply chain configurations need to be precisely evaluated based on the tradeoffs between the decisions in strategic-level (focused on optimal SC configuration) and targets in operational-level (focused on operational performance). Therefore, we further well-define and present the linkages in strategic-level and operational-level planning.

This research attempts to propose concepts of simultaneously strategic and operational planning in supply chain design which reflects the characteristics of Taiwanese NB industry. Conceptual framework is established according to BTO/CTO general model based on views of NB manufacturer. The research scope is shown as Figure 5.1. NB manufacturer receives orders from different Brands. Logistics activities, such as component modules procurement, bare-bone assembly and full-set configuration can be arranged according to the bill of materials (BOM). Supply Chain Flexibility is taken into consideration in planning stage, and then NB manufacturer has the ability of quick reaction to uncertainty from market demand. All the components are supplied in module items, the supply of GC-modules and KC-modules are based on VMI in supplier hub. All component module suppliers operate following NB manufacturer’s inventory control policy.

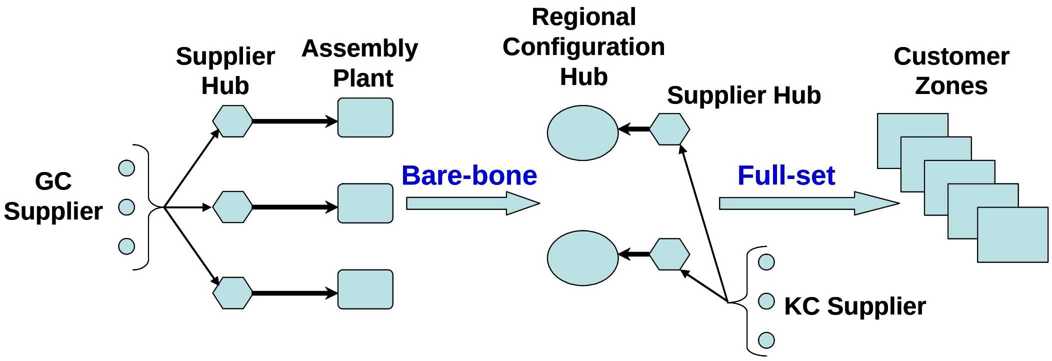


Figure 5.1 Conceptual Framework of NB Supply Chain

Supply chain configuration of assembly plants, configuration hubs, and customer zone assignments are determined in the strategic-level planning stage, outputs (decisions) in this level are going to be as inputs in operational-level planning stage for measuring the strategic impacts in operational performance. A process-oriented, analytical, and decomposed operational model is adopted in operational-level planning. It consists of “ module Control”, “Bare-bone Assembly Control”, “Bare-bone Stockpile Control”, and “Full-set Configuration Control” activities.

5.2 Tradeoffs in Strategic-level and Operational-level Planning

The objective of the strategic-level planning is to optimize the SC configuration and material flow. Since there are numerous sources of uncertainty in a typical supply chain, applying deterministic supply chain models is unrealistic. A stochastic operational-level planning model must be integrated into the solution approach in order to accommodate uncertainty and to give insight into the tradeoffs among cost, customer service level, and flexibility. Within the operational-level planning, various sources of uncertainty must be considered, such as customer demand, production lead-time, and supply lead times throughout the SC. According to the production-distribution process in notebook-computer industry, it is decomposed into “Component-module Control”, “Bare-bone Assembly Control”, “Bare-bone Stockpile Control”, and “Full-set Configuration Control” subsystems. The work of estimating the actual production, distribution and transportation costs can be implemented by simultaneously optimizing the entire SC system. Tradeoffs between strategic-level and operational-level are depicted as Figure 5.2.

Some outputs of Decision variables (quantity of bare-bone assembled at assembly plant, and quantity of bare-bone shipped from assembly plant to configuration hub) through optimizing strategic-level planning model will be as inputs in operational-level planning model. These decisions start the activities in each operational subsystem; performance in each upstream/downstream subsystem is dependent. Based on these initial decisions, the total cost and relative performance measures are determined by optimal operations in each control sub-model. Values of operational parameters, such as unit cost in each control activities, will be as inputs in strategic-level planning model. Such relationship forms an iterative feedback control system until the optimal solution is reached.

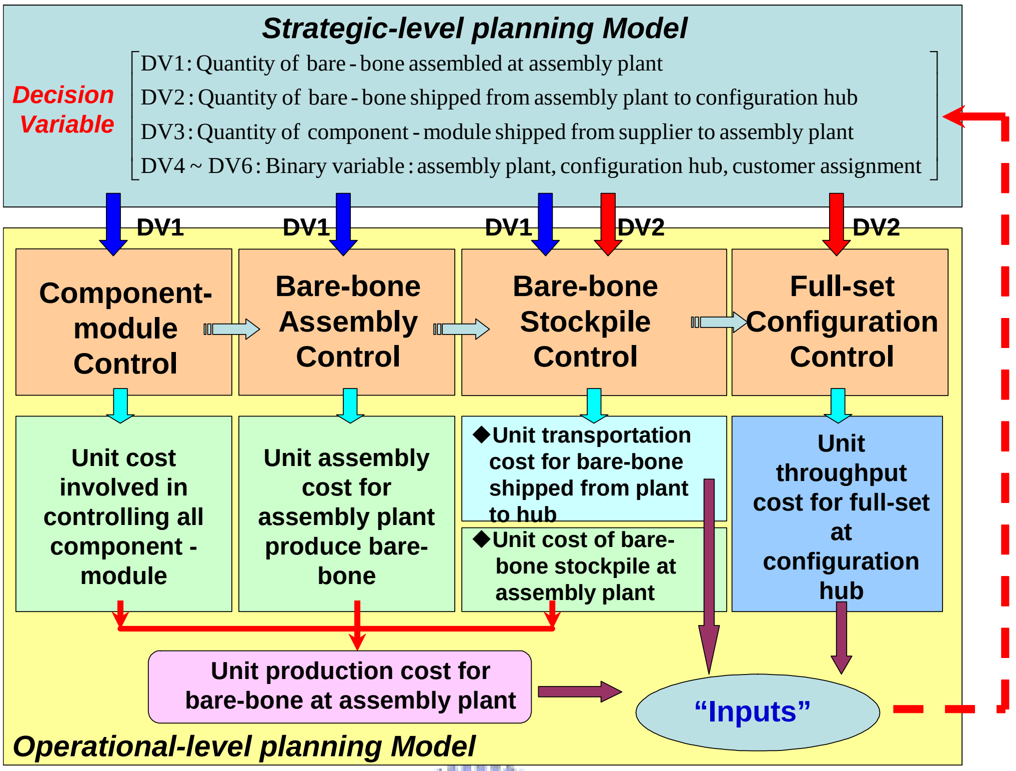


Figure 5.2 Tradeoffs between Strategic-level and Operational-level Planning

The fill rate is a common measure of service level performance (Feng and Chern, 2008; Lee and Billington, 1992) and measures the percentage of orders fulfilled immediately. The flexibility is defined as the ability to respond to customer requirements (Feng and Chern, 2008; Slack, 1987). This study addresses two types of flexibility, which depend on the SC configuration: (1) volume flexibility, and (2) delivery flexibility (Slack, 1987). Volume flexibility, which is measured by capacity slack, is commonly adopted in industry. However, delivery flexibility, which is measured by lead-time slack, is not often applied in either industry or literature. This is because the majority of inventory and SC models in literature assume fixed lead times. However, in many practical situations, lead-time, whether probabilistic or deterministic, may be controllable, and thus must be addressed as a decision variable as in this research. Lead-time is defined as the length of time between the time when an order for an item is placed, and when it is actually available to comply with customer demands (Liao and Shyu, 1991).

This model involves a multi-objective problem due to consideration of multiple performance measures at each sub-model. This study adopts the ε-constraint method (Goicoecha et al., 1982) for the following reasons: (1) it can solve non-linear models; (2) it requires no specific conditions to achieve the solutions, and (3) it is simple, since it converts the multi-objective problem into a single-objective optimization problem. This algorithm enables the analyst the ability to specify bounds on the objectives sequentially. The magnitude of ε reflects the relative significance of the various objectives to decision-makers.

5.3 Critical Issues in Conceptual Model Structure

The supply chain structure of NB industry consists of four echelons: (1) GC- and KC-suppliers, (2) assembly plants, (3) configuration hubs, and (4) customer zones. Each SC echelon has a set of control parameters that affects the performance of other components. Some critical issues concerning developing conceptual model are discussed as follows:

A. Model Structure in Strategic-level Planning

Notebook-comuter industry is characterized by multi-product, multi-echelon, and component procurement/bare-bones assembly/full-set configuration/full-set distribution system. Supply chain design in strategic-level planning can be considered as an integrated and flexible facility network configuration. It optimizes bare-bone and full-set flows throughout the supply chain, gives the optimal number and locations for assembly plants, and regional configuration hubs, and provides the best assignment of configuration hubs to customer zones. A multi-objective function, conceptual structure is shown as Figure 5.3, can be formulated to minimize cost, while ensuring a sufficient amount of volume flexibility.

The first objective function (Z) minimizes the total fixed and variable costs. The second objective function (W) represents the volume flexibility, which can be calculated by the sum of the following flexibility performance measures:

(1) Assembly plant volume flexibility, which is measured as the differences between plant capacity and plant capacity utilization, and thus represents the available plant capacity.
(2) Configuration hub volume flexibility, which is calculated as the differences between the available throughput and demand requirements, and thus represents the available configuration capacity.

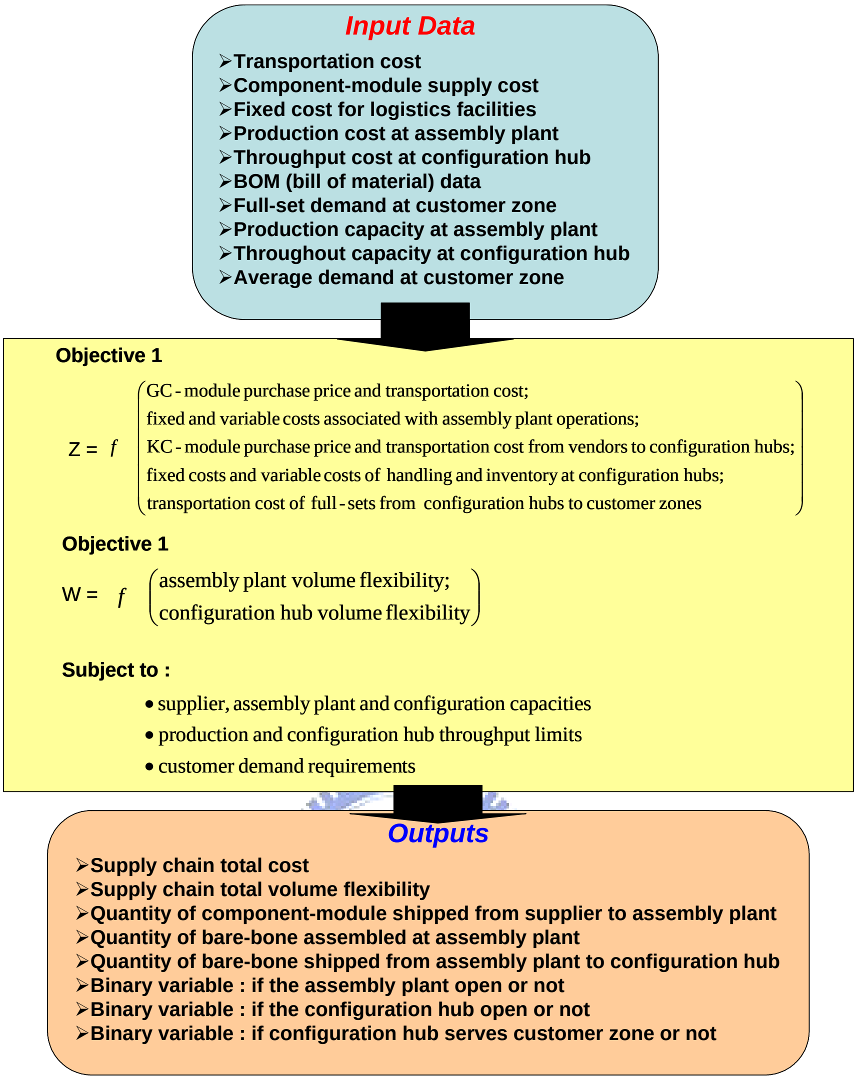


Figure 5.3 Conceptual Structure in Strategic-level Planning Model

B. Model Structure in Operational-level Planning

Given the output (decision variables) of the strategic-level sub-model, customer demand requirements, minimum required service and flexibility levels, cost and lead-time data, and bill of material data, variable costs can be estimated under uncertainty. Also, various operational variables can be determined by optimizing inventory variables such as lot sizes, reorder points, and safety stock. Four sub-models are considered in operational level: (1) GC-module control, (2) bare-bone assembly control, (3) bare-bone stockpile control, and (4) full-set configuration control. The GC-module control and full-set configuration control sub-models are solved using analytical techniques, while the bare-bone assembly control and bare-bone stockpile control sub-models are simultaneously optimized using non-linear programming (A multi-objective function should be developed to incorporate all cost, customer service level (fill rate), and flexibility (delivery) tradeoffs). The interactive relationships between each control sub-model are presented in Figure 5.4.

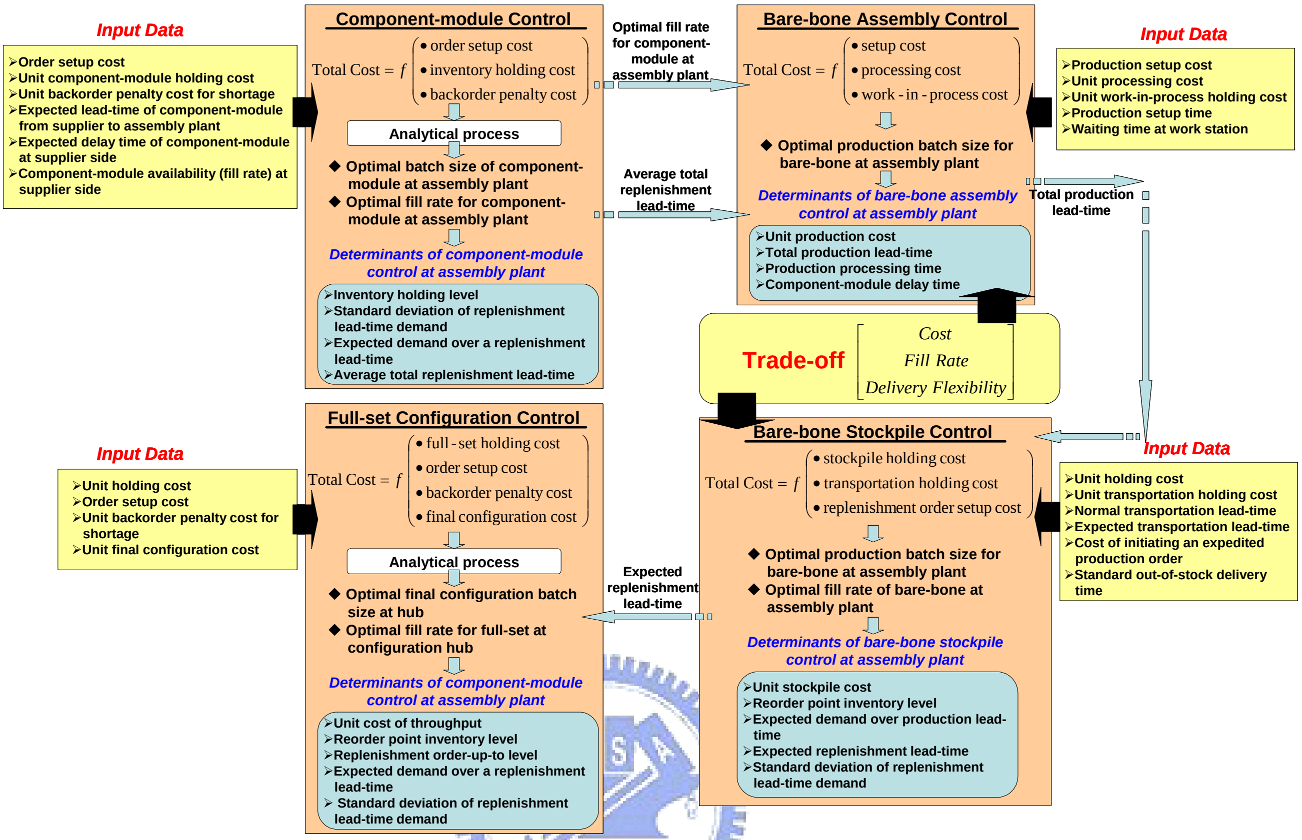


Figure 5.4 Interactive Relationships between Each Control Sub-model

In component-module control sub-model, the optimal values of “optimal batch size” and “optimal fill rate” can be determined by the first derivative of the total cost function in this subsystem, and then relative parameters, such as “unit cost involved in module control”, “inventory holding level”, “reorder point”, “expected demand over a replenishment lead-time” and “average total replenishment lead-time” can be calculated via analytical process. “optimal fill rate” and “average total replenishment lead-time” are inputs in bare-bone assembly control sub-model.

In bare-bone assembly and stockpile control sub-models, the optimal values of “optimal production batch size”, “optimal fill rate” and “expected replenishment lead-time” are determined by considering the cost, fill rate, and delivery flexibility tradeoffs. Then, the relative parameters “unit production cost” and “total production lead-time” can be calculated and “total production lead-time” is the input in bare-bone stockpile control sub-model. Similarly, parameters like “unit stockpile cost”, “reorder point”, “expected demand over a replenishment lead-time” and “expected replenishment lead-time” can be calculated in bare-bone stockpile control sub-model. “Expected replenishment lead-time” is the input in full-set configuration control sub-model.

In full-set configuration control sub-model, similar to the analytical process in component-module control sub-model, the optimal values of “optimal final configuration batch size” and “optimal fill rate” can be determined and then relative parameters, such as “unit throughput cost”, “reorder point”, “replenishment order-up-to-level”, and “expected demand over a replenishment lead-time” are calculated. Then, we can summarize the actual unit variable production cost for bare-bone at assembly plant (the sum of “unit cost involved in module control”, “unit production cost” and “unit throughput cost”), “unit cost of bare-bone stockpile at assembly plant” and “unit transportation cost for bare-bone shipped from assembly plant to configuration hub”, which will be used as inputs to the strategic-level planning model.

Chapter 6 Modeling and Application in Supply Chain Design

In this work, the supply chain structure of NB industry consists of four components: (1) GC- and KC-suppliers, (2) assembly plants, (3) configuration hubs, and (4) customer zones. Each SC echelon has a set of control parameters that influences the performance of other components. The strategic-level and operational-level models simultaneously optimize the performance of each echelon.

6.1 The Strategic-level Planning Model

The strategic-level planning model addresses an integrated, multi-product, multi-echelon problem in a flexible facility network configuration, consisting of component procurement, bare-bones assembly, full-set configuration and full-set distribution system design. It optimizes bare-bone and full-set flows throughout the supply chain, gives the optimal number and locations of assembly plants and regional configuration hubs, and provides the ideal assignment of configuration hubs to customer zones. A multi-objective function is formulated to minimize cost, while ensuring a sufficient level of volume flexibility, subject to supplier, assembly plant and configuration capacities, production and configuration hub throughput limits and customer demand requirements. The total costs include production and distribution fixed costs, and production, distribution and transportation variable costs. This model is integrated with the operational -level planning model to incorporate the uncertainty and variable production, distribution, and transportation costs. These variable costs have different values derived from the strategical-level decisions. This model addresses four echelons: (1) GC- amd KC-component suppliers (vendors), (2) assembly plants (bare-bone production), (3) regional configuration hubs (full-set production), and (4) customer zones. Table 6.1 presents the notations utilized in the operational sub-model.

The strategic-level planning model is formulated as follows:

$$
\begin{aligned}
Z \; = & \sum_r \sum_v \sum_k (a_{rvk} + \lambda_{rv}) A_{rvk} \\
& + \sum_k f_k q_k + \sum_i \sum_k U_{ik} X_{ik} + \sum_i \sum_k \sum_m c_{ikm} B_{ikm} \\
& + \sum_s \sum_m \{ [a_{sm} + \lambda_s] \left[e_{si} (\sum_k B_{ikm}) \right]] \} \\
& + \sum_m f_m q_m + \sum_j \sum_m U_{jm} (\sum_z D_{jz} y_{mz}) \\
& + \sum_j \sum_m \sum_z d_{jmz} (D_{jz} y_{mz})
\end{aligned}
\tag{1}
$$

$$W = \left[\sum_k \left(q_k \Phi_k - \sum_i \delta_{ik} X_{ik} \right)\right] w_k + \left[\sum_m \left(q_m \beta_m - \sum_j \sum_z \delta_{jm} D_{jz} y_{mz} \right)\right] w_m \geq \varepsilon \tag{2}$$

Subject to:

$$\sum_k A_{rvk} \leq \Psi_{rv} \quad \forall(r,v) \tag{3}$$

$$\sum_m \left[e_{si} \sum_k B_{ikm} \right] \leq \Psi_s \quad \forall(s) \tag{4}$$

$$\sum_i \tau_{ri} X_{ik} \leq \sum_v A_{rvk} \quad \forall(r,k) \tag{5}$$

$$\sum_j \tau_{sj} D_{jz} y_{mz} \leq e_{si} \sum_k B_{ikm} \quad \forall(s,m) \tag{6}$$

$$\sum_i \delta_{ik} X_{ik} \leq \Phi_k q_k \quad \forall(k) \tag{7}$$

$$\zeta_{ik} q_k \leq X_{ik} \leq \xi_{ik} q_k \quad \forall(i,k) \tag{8}$$

$$\sum_j \sum_z \delta_{jm} D_{jm} y_{mz} \leq \beta_m q_m \quad \forall(m) \tag{9}$$

$$\alpha_{jm} q_m \leq \sum_z D_{jz} y_{mz} \leq \gamma_{jm} q_m \quad \forall(j,m) \tag{10}$$

$$X_{ik} = \sum_m B_{ikm} \quad \forall(i,k) \tag{11}$$

$$\sum_k \sum_m B_{ikm} = \sum_j R_{ij} \left(\sum_m \sum_z D_{jz} y_{mz} \right) \quad \forall(i) \tag{12}$$

$$\sum_k B_{ikm} = \sum_z R_{ij} D_{jz} y_{mz} \quad \forall(i,m) \tag{13}$$

$$\sum_m y_{mz} = 1 \quad \forall(z) \tag{14}$$

$$A_{rvk},\, X_{ik},\, B_{ikm} \geq 0 \quad \forall(r,v,k,i,m) \tag{15}$$

$$q_k,\, q_m,\, y_{mz} = 0,1 \quad \forall(k,m,z) \tag{16}$$

The first mixed-integer linear objective function (Z) minimizes the total fixed and variable costs, and is divided into five components: (1) the GC-module purchase price and transportation cost from vendors to assembly plants; (2) the fixed and variable costs associated with assembly plant operations (bare-bone assembly), and transportation cost from assembly plant to configuration hub; (3) the KC-module purchase price and transportation cost from vendors to configuration hubs; (4) the fixed costs and variable costs of handling and inventory at configuration hubs, and (5) the transportation cost of full-sets from configuration hubs to customer zones.

The second linear objective function (W) indicates the volume flexibility, which is the sum of the following flexibility performance measures:

1. Assembly plant volume flexibility, which is calculated as the differences between the plant capacity and plant capacity utilization, and thus represents the available plant capacity.
2. Configuration hub volume flexibility, which is calculated as the differences between the available throughput and demand requirements, and thus represents the available configuration capacity.

Table 6.1 Notations for Strategic-level Planning Model

Variables	**Definitions**		
i	Bare-bone type index, *i = 1.............I*	v	General-component module supplier index, *v = 1..........V*
j	Full-set type index, *j = 1………...J*	r	General-component module type index, *r = 1..............R*
k	Assembly plant index, *k = 1............K*	s	Key-component module type index, *s =1..............S*
m	Configuration hub index, *m = 1............M*	z	Customer zone index, *z = 1..........Z*
Inputs	**Definitions**		
ε	Volume flexibility performance index	Φ_k	Production capacity at assembly plant *k* (units/period)
w_k , w_m	Weight factors for capacity utilization [0, 1]	δ_{ik}	Standard (Equivalent) unit at assembly plant *k* for unit of bare-bone *i*
a_{rvk}	Unit transportation cost from *v* to *k* for GC-module *r* ($/unit)	β_m	Maximum configuration throughput at hub *m* (units/period)
λ_{rv}	Unit cost of GC-module *r* for supplier *v* ($/unit)	δ_{jm}	Standard (Equivalent) unit at hub *m* for unit of full-set j
f_k	Fixed charges for assembly plant *k* ($/period)	ψ_{rv}	Production capacity of GC-supplier *v* for GC-module *r* (units/period)
U_{ik}	Unit production cost for bare-bone *i* at plant *k* ($/unit)	ψ_s	Production capacity of KC-module s (units/period)
c_{ikm}	Unit transportation cost from *k* to *m* for bare-bone *i* ($/unit)	τ_{ri}	Utilization rate for each *r* per unit of bare-bone *i*
a_{sm}	Unit transportation cost for KC-module *s* shipped to hub *m* ($/unit)	τ_{sj}	Utilization rate for each *s* per unit of full-set j
λ_s	Unit cost of KC-module *s* ($/unit)	ζ_{ik}	Minimum production volume for bare-bone *i* at plant *k* (units/period)
e_{si}	Utilization rate of KC-module *s* for bare-bone *i* (BOM)	ξ_{ik}	Maximum production volume for bare-bone *i* at plant *k* (units/period)
f_m	Fixed charges for configuration hub *m* ($/period)	α_{jm}	Minimum throughput at configuration hum *m* (units/period)
U_{jm}	Unit cost of throughput (final configuration and inventory) for full-set *j* at hub *m* ($/unit)	γ_{jm}	Maximum throughput at configuration hum *m* (units/period)
D_{jz}	Average demand for full-set *j* at customer zone *z* (units/period)	R_{ij}	Transfer index for full-set *j* and bare-bone *i*
d_{jmz}	Unit transportation cost from m to z for full-set j ($/unit)		
Outputs	**Definitions**		
A_{rvk}	Quantity of GC-module *r* shipped from supplier *v* to plant *k* (units/period)	Z	Total cost ($/period)
X_{ik}	Quantity of bare-bone *i* assembled at plant *k* (units/period)	W	Volume flexibility
B_{ikm}	Quantity of bare-bone *i* shipped from plant k to hub m (units/period)		
Binary	**Definitions**		
q_k	1, if assembly plant *k* is open; 0 otherwise	y_{mz}	1, if hub *m* serves customer zone *z*; 0 otherwise
q_m	1, if configuration hub *m* is open; 0 otherwise		

Eqs. (3)－(16) of the strategic level sub-model are described as follows. Eq. (3)/Eq. (4) ensure that the required quantities of GC-modules/KC-modules are within the supplier's capabilities. Eq. (5)/Eq. (6) match GC-modules/KC-modules to the requirements of bare-bone assembly/full-set configuration. Eq. (7) specifies that the total production quantities must not exceed the assembly plant capacity. Eq. (8) enforces the minimum and maximum production capacities for assembly plants. Eq. (9) specifies that the total throughput must not exceed configuration hub capacity. Eq. (10) enforces the minimum and maximum throughput capacities for configuration hubs. Eq. (11) ensures that the amount shipped from assembly plant is equal to what is available at that plant. Eq. (12) ensures that all demand requirements are satisfied (i.e., that total shipments to customer zones are exactly equal to the forecasted demands there). Eq. (13) ensures that the demand requirements at each configuration hub be satisfied. Eq. (14) specifies that each customer zone must be assigned to exactly one single configuration hub. Eq. (15) ensures that all variables are non-negative. Eq. (16) restricts the binary variables to assembly plants, regional configuration hubs and the assignments of customer zones.

6.2 The Operational-level Planning Model

The variable costs are estimated from the output (decision variables) of the strategic-level sub-model, customer demand requirements, minimum required service and flexibility levels, cost and lead-time data, and bill of material data. Additionally, variable costs are estimated under uncertainty. Also, various operational variables are calculated by optimizing inventory variables including lot sizes, reorder points and safety stock. A multi-objective function is developed incorporating all tradeoffs in cost, customer service level (fill rate), and flexibility (delivery). Four sub-models are addressed at the operational level: (1) GC-module control, (2) bare-bone assembly control, (3) bare-bone stockpile control, and (4) full-set configuration control. The GC-module control and full-set configuration control sub-models are solved with analytical techniques, while the bare-bone assembly control and bare-bone configuration control sub-models are simultaneously optimized using non-linear programming. A single solution for the operational-level planning model is derived by a heuristic approach, as described in the following subsections. Table 6.2 presents the notations utilized in the operational sub-model.

A. GC-module Control sub-model

This model assumes continuous review of the inventory position for each GC-module r involved in producing bare-bone set F_{rk} at plant k, using an (s, Q) inventory control policy. A fixed quantity (Q_{rk}) is ordered whenever the inventory position drops to the exact reorder point s. The demand requirement for GC-module *r* is calculated from the assembly requirement of bare-bone *i* at plant *k* (X_{ik}), which is determined at the strategic level, and the unit usage rate of *r* in *i* (τ_{ri}) is specified in the BOM data. The GC-module shortages are assumed to be back-ordered. The GC-module control analytical sub-model is formulated as the following equations.

To simplify the computations, a normal lead-time demand distribution is also assumed. Using standard terms, as in Silver and Peterson (1985), Eq. (17) indicates the total cost of controlling GC-module inventory at assembly plant *k*, which involves setup, holding, and backorder (delay) costs. Eq. (18) calculated the on-hand inventory level (average inventory level plus safety stock) is given by. The safety factor n_{rk} is selected to control the safety stock associated with a specified customer service level.

$$TC_{rk}^{G} = q_k \left[\left(\sum_{i \in F_{rk}} \frac{\tau_{ri} X_{ik}}{Q_{rk}} \right) \theta_{rk} + H_{rk} I_{rk} + \pi_{rk} \sigma_{rk} \right] \tag{17}$$

$$I_{rk} = \frac{Q_{rk}}{2} + n_{rk} \sigma_{rk} \ , \quad n_{rk} \approx \left(\frac{1}{2} \sqrt{\frac{\pi}{2}} \right) \ln \left(\frac{p_{rk}}{1 - p_{rk}} \right) \tag{18}$$

The approximate expression for n_{rk} is given as Silver and Peterson (1985) and Johnson et al. (1996). The required reorder point s_{rk} can be calculated directly using Eq. (19), where L_{rk} indicates the expected demand over a replenishment lead-time, and Θ_{rk} indicates the average total replenishment lead-time of *r* at *k*. Θ_{rk} is calculated as the sum of the GC-module lead-time and delay time, considering all suppliers.

$$\begin{aligned} s_{rk} &= L_{rk} + n_{rk} \sigma_{rk} \\ L_{rk} &= \left[\sum_{i \in F_{rk}} \tau_{ri} X_{ik} \right] \Theta_{rk} \, , \quad \Theta_{rk} = \frac{\sum_{v} \left[u_{rvk} + \rho_{rv} \left(1 - p_{rv} \right) \right]}{v} \end{aligned} \tag{19}$$

Table 6.2 Notations for operational-level planning model

Inputs	**Definitions – GC-module control sub-model**		
θ_{rk}	Order setup cost of replenishing *r* at *k* ($)	u_{rvk}	Expected lead-time of *r* from *v* to *k* (period)
H_{rk}	Unit holding cost of *r* at *k* ($/period/unit)	ρ_{rv}	Expected delay time of *r* at *v* (period)
π_{rk}	Unit backorder penalty cost for shortage *r* at *k* ($/unit)	p_{rv}	Module availability (fill rate) for *r* at *v*
Outputs	**Definitions**		
Q^*_{rk}	Optimal batch size of module *r* at plant *k* (units)	P^*_{rk}	Optimal fill rate for *r* at *k*
I_{rk}	Inventory holding level of *r* at *k* (units/period)	n_{rk}	Safety stock factor of *r* at *k*
σ_{rk}	Standard deviation of replenishment lead-time demand of *r* at *k*	S_{rk}	Reorder point for *r* at *k* (units)
L_{rk}	Expected demand of *r* over a replenishment lead-time at *k*	u_{rk}	Unit cost involved in controlling *r* required at *k* ($/unit)
Θ_{rk}	Average total replenishment lead-time for *r* at *k*	u^G_{ik}	Unit cost involved in controlling all *r* required at *k* for *i* ($/unit)
Inputs	**Definitions -- Bare-bone assembly control and Bare-bone stockpile control sub-models**		
θ_{ik}	Production setup cost of *i* at *k* ($)	H_{ik}	Unit holding cost of *i* at *k* ($/period/unit)
Γ_{ik}	Unit processing cost of *i* at *k* ($/unit)	x_{ikm}	Unit holding cost for *i* en-route from *k* to *m* ($/period/unit)
Ω_{ik}	Unit work-in-process holding cost for *i* at *k* ($/period/unit)	N_{ikm}	Normal transportation lead-time for *i* from *k* to *m* (period)
g_{ik}	Production setup time for *i* at *k* (period)	E_{ikm}	Expedited transportation lead-time for *i* from *k* to *m* (period)
l_{ik}	Waiting time at the work station for *i* at *k* (period)	e_{ik}	Cost of initiating an expedited production order for *i* at *k*
η	Customer service performance index	T'_{ikm}	Standard delivery time at *k* when *i* is out of stock at *m* (period)
υ	Delivery flexibility performance index		
Output	**Definitions**		
TC^p_{ik}	Total cost of assembling *i* at *k*	TC^S_{ik}	Total cost of stockpile for *i* at *k*
Q^*_{ik}	Optimal production batch size for *i* at *k* (units)	P^*_{ik}	Optimal fill rate of *i* at *k*
u^p_{ik}	Unit production cost for *i* at *k* ($/unit)	u^S_{ik}	Unit cost of stockpile for *i* at *k*
t_{ik}	Total production lead-time for *i* at *k* (period)	s_{ik}	Reorder point of *i* at *k* (units)
h_{ik}	Production processing time for *i* at *k* (period)	L_{ik}	Expected demand of i over production lead-time at k
Θ_{ik}	Module supply delay time for *i* at *k* (period)	T_{ikm}	Expected replenishment lead-time for *i* from *k* to *m*
TC_{ik}	Total expected cost of production and stockpile of *i* at *k*	n_{ik}	Safety stock factor of *i* at *k*
PS_{ik}	Customer service (fill rate) availability of *i* at *k*	σ_{ik}	Standard deviation of replenishment lead-time demand of *i* at *k*
PD_{ikm}	Delivery flexibility availability of *i* from *k* to *m*		
Inputs	**Definitions – Full-set configuration control sub-model**		
H_{jm}	Unit holding cost of *j* at *m* ($/period/unit)	I_{jm}	Unit final assembly cost of *j* at *m* ($/unit)
θ_{jm}	Order setup cost of *j* at *m* ($)	Ω_{sj}	Utilization rate for each KC-module *s* per unit of *j*
π_{jm}	Unit backorder penalty cost for shortage *j* at *m* ($/unit)		
Outputs	**Definitions**		
TC^F_{jm}	Total cost of full-set configuration of *j* at *m*	S_{jm}	Order-up-to level for *j* at *m* (units)
Q^*_{jm}	Optimal final assembly batch size of *j* at *m* (units)	L_{jm}	Expected demand of *j* over a replenishment lead-time at *m*
U_{jm}	Unit cost of throughput for *j* at *m* ($/unit)	n_{jm}	Safety stock factor of *j* at *m*
s_{jm}	Reorder point for *j* at *m* (units)	σ_{jm}	Standard deviation of replenishment lead-time demand of j at *m*

The variance of Θ_{rk} is calculated as Eq. (20). The variance of L_{rk} is calculated as Eq. (21). The optimal lot size (Q_{rk}^{*}) is then considered by Eq. (22), by finding the first derivative of the total cost with respect to Q_{rk}, and setting it equal to zero.

$$\operatorname{var}(\Theta_{rk}) = \operatorname{var}\left(\frac{\sum_{v} u_{rvk}}{v}\right) + \operatorname{var}\left(\frac{\sum_{v} \rho_{rv}(1-p_{rv})}{v}\right) \tag{20}$$

$$\operatorname{var}(L_{rk}) = \left[\sum_{i} \tau_{ri} X_{ik}\right]^{2} \operatorname{var}(\Theta_{rk}), \quad \sigma_{rk} = \sqrt{\operatorname{var}(L_{rk})} \tag{21}$$

$$Q_{rk}^{*} = \frac{\partial TC_{rk}^{G}}{\partial Q_{rk}} = \sqrt{\frac{2\theta_{rk} \sum_{i} \tau_{ri} X_{ik}}{H_{rk}}} \tag{22}$$

The optimal service level (P_{rk}^{*}) for GC-module r at assembly plant k is calculated as Eq. (23). The unit cost associated with GC-module r control at plant k is given by Eq. (24). The unit cost associated with controlling all GC-module required for bare-bone i at assembly plant k is given by Eq. (25).

$$P_{rk}^{*} = \frac{\partial TC_{rk}^{G}}{\partial p_{rk}} = 1 - \frac{H_{rk}}{\pi_{rk}} \tag{23}$$

$$u_{rk} = \frac{TC_{rk}^{G}}{\sum_{i} \tau_{ri} X_{ik}} \tag{24}$$

$$u_{ik}^{G} = \sum_{r} \tau_{ri} u_{rk} \tag{25}$$

B. Bare-bone Assembly Control and Bare-bone Stockpile Control sub-models

Eq. (26) indicates the cost function to be minimized of controlling bare-bone assembly system, which involves setup costs, processing costs and work-in-process carrying costs. More specifically, the total costs for the production of bare-bone i at assembly plant k per period can be specified.

$$TC_{ik}^{P} = q_k\left[\theta_{ik}\left(\frac{X_{ik}}{Q_{ik}}\right) + \Gamma_{ik}X_{ik} + \Omega_{ik}X_{ik}t_{ik}\right] \tag{26}$$

The total production lead-time (t_{ik}) is given by Eq. (27), which determines the sum of the setup time (g_{ik}), the waiting time at the workstations (l_{ik}), the processing time (h_{ik}) and the GC-module delay time (Θ_{ik}).

$$t_{ik} = g_{ik} + h_{ik} + l_{ik} + \Theta_{ik} \tag{27}$$

The processing time of a batch of bare-bone i at plant k can be calculated as Eq. (28), where r_{ik} denotes the average work rate for the processing of bare-bone *i* at plant *j*. As long as *r* >1, then bare-bone *i* utilizes more than one GC-module type, and if the manufacturer cannot begin production until all GC-modules have been received, then the lead-time or delay-time in the model is given by the maximum average realized lead-time or delay-time from suppliers. The material delay time can be then determined from Eq. (28). Additionally, the unit cost of producing bare-bone *i* at plant *k* is given by Eq. (29).

$$h_{ik} = \frac{Q_{ik}}{r_{ik}}, \quad \Theta_{ik} = \underset{r \in Y_i}{Max}\left[\Theta_{rk}\left(1 - p_{rk}^{*}\right)\right] \tag{28}$$

$$u_{ik}^{p} = \frac{TC_{ik}^{P}}{X_{ik}} \tag{29}$$

An (*s*, *Q*) inventory control policy is adopted to operate the bare-bone stockpile control system. The distribution demand shortages are assumed to be met by expedited shipment. Using standard terms, as in Cohen and Lee (1988), the total costs related to the stockpile for bare-bone *i* at plant *k* per period are given by Eq. (30), where the total cost is the sum of the stockpile holding cost, transportation holding cost from plant *k* to the configuration hubs and the expedited order setup cost.

$$TC_{ik}^{S} = q_k\left\{\begin{array}{l} H_{ik}\left(\dfrac{Q_{ik}}{2} + n_{ik}\sigma_{ik}\right) \\ + \displaystyle\sum_{m} x_{ikm}B_{ikm}\left[N_{ikm}P_{ik} + E_{ikm}\left(1 - p_{ik}\right)\right] \\ + e_{ik}\dfrac{X_{ik}}{Q_{ik}}\left(1 - p_{ik}\right) \end{array}\right\} \tag{30}$$

The relative parameters for the bare-bone stockpile are calculated similarly to those in the GC-module control sub-model. These parameters, including reorder point (s_{ik}), variance of expected demand over production lead-time ($\mathrm{var}(L_{ik})$), the expected replenishment lead-time or bare-bone *i* from plant *k* to configuration hub m (T_{ikm}) and the unit bare-bone stockpile cost (u_{ik}^{S}) are given by Eq. (31)—(35).

$$s_{ik} = L_{ik} + n_{ik}\sigma_{ik} = X_{ik}t_{ik} + \frac{1}{2}\sqrt{\frac{2}{\pi}}\ln\left(\frac{P_{ik}}{1-p_{ik}}\right)\sqrt{\mathrm{var}(L_{ik})} \tag{31}$$

$$\mathrm{var}(L_{ik}) = (X_{ik})^2\,\mathrm{var}(t_{ik}) \tag{32}$$

$$T_{ikm} = N_{ikm}P_{ik} + (t_{ik} + E_{ikm})(1-p_{ik}) \tag{33}$$

$$c_{ikm} = x_{ikm}\left[N_{ikm}P_{ik} + E_{ikm}(1-P_{ik})\right] \tag{34}$$

$$u_{ik}^{S} = \frac{TC_{ik}^{S}}{X_{ik}} \tag{35}$$

A multiple objective function that addresses cost, customer service level (fill rate), and delivery flexibility tradeoffs is proposed to find the optimal Q_{ik}, P_{ik}, T_{ikm}. The first objective function applies cost as a performance measure, and is given by Eq. (36).

$$TC_{ik} = TC_{ik}^{P} + TC_{ik}^{S} \tag{36}$$

The second objective function represents service levels (fill rates) for replenishing the configuration hubs from the bare-bone stockpile at plant *k*, and is given by Eq. (37). Finally, the delivery flexibility objective function is given by Eq. (38).

$$PS_{ik} = P_{ik} - P'_{ik} \tag{37}$$

$$PD_{ikm} = T'_{ikm} - T_{ikm} \tag{38}$$

Using the ε-constraint method, the multi-objective is formulated as Eq. (39)-Eq. (41). The values of η, ν are specified to ensure the desired minimum levels of fill rate and delivery flexibility.

$$\begin{aligned} &Min \quad TC_{ik} && (39)\\ &St. \quad PS_{ik} \geq \eta \quad \forall (i,k) && (40)\\ &\qquad\; PD_{ikm} \geq \upsilon \quad \forall (i,k,m) && (41) \end{aligned}$$

C. Full-set Configuration Control sub-model

The full-set configuration control sub-model is formulated as the following equations. A continuous-review (*s*, *S*) inventory control policy is assumed, in which a replenishment quantity is made whenever the inventory position drops exactly to the reorder point *s*. The replenishment quantity is large enough to increase the inventory position to the order-up-to level *S*.

The simple sequential determination algorithm is adopted to determine the order-up-to level *S*. Demand is periodic, stochastic, and independently distributed among customer zones and over time. Additionally, the lead-time demand at each configuration hub is assumed to be normally distributed. Further, customer demand shortages are assumed to be backordered. The total cost of the full-set configuration system, which consists of holding cost, reorder, backorder cost, and configuration cost for full-set *j* at configuration hub *m* per period, is given by Eq. (42).

$$TC_{jm}^{F} = q_m \left[H_{jm}\left(\frac{Q_{jm}}{2} + n_{jm}\sigma_{jm} \right) + \theta_{jm} \frac{\sum_z D_{jz} y_{mz}}{Q_{jm}} + \pi_{jm}\sigma_{jm} + I_{jm}\left(\sum_s \Omega_{sj} B_{jkm} \right) \right] \tag{42}$$

Relevant parameters, including expected replenishment lead-time for full-set *j* at configuration hub *m* (t_{jm}), expected demand of *j* over a replenishment lead-time at *m* (L_{jm}), reorder point (s_{jm}), and order-up-to level (S_{jm}), are also calculated similarly to those in the previous sub-model, and are given by Eq. (43)-Eq. (47).

$$t_{jm} = \frac{\sum_k q_k T_{jkm}}{\sum_k q_k}, \quad T_{jkm} = \frac{\sum_i R_{ij} T_{ikm}}{\sum_i R_{ij}}, \quad B_{jkm} = \frac{\sum_i R_{ij} B_{ikm}}{\sum_i R_{ij}} \tag{43}$$

$$L_{jm} = t_{jm} \sum_z D_{jz} y_{mz} \tag{44}$$

$$\operatorname{var}(L_{jm}) = \left(\sum_z D_{jz} y_{mz} \right)^2 \operatorname{var}(t_{jm}), \quad \sigma_{jm} = \sqrt{\operatorname{var}(L_{jm})} \tag{45}$$

$$s_{jm} = L_{jm} + n_{jm}\sigma_{jm} \;\; = L_{jm} + \frac{1}{2}\sqrt{\frac{2}{\pi}}\ln\left(\frac{p_{jm}}{1-p_{jm}}\right)\sqrt{\mathrm{var}\left(L_{jm}\right)} \tag{46}$$

$$S_{jm} = s_{jm} + Q_{jm} \tag{47}$$

To calculate the optimal batch size for full-set *j* at configuration hub *m*, the total cost equation is differentiated with respect to Q_{jm}, and set equal to zero (Eq. (48)). Additionally, the optimal service level for full-set *j* at configuration hub *m* is calculated by setting the derivative (with respect to P_{jm}) of the total cost equation (Eq. (49)). Unit cost of throughput for full-set *j* at configuration hub *m* is calculated by Eq. (50).

$$Q_{jm}^{*} = \frac{\partial TC_{jm}^{F}}{\partial Q_{jm}} = \sqrt{\frac{2\theta_{jm}\left(\sum_{z} D_{jz} y_{mz}\right)}{H_{jm}}} \tag{48}$$

$$P_{jm}^{*} = \frac{\partial TC_{jm}^{F}}{\partial p_{jm}} = 1 - \frac{H_{jm}}{\pi_{jm}} \tag{49}$$

$$U_{jm} = \frac{TC_{jm}^{F}}{\sum_{k} B_{jkm}} \tag{50}$$

Figure 6.1 summarizes the interactive relationships between each control sub-model, according to these descriptions of operational-level planning model. The GC-module control sub-model calculates the optimal values of Q_{rk}^{*}, P_{rk}^{*}, and calculates the relative parameters $(u_{ik}^{G}, I_{rk}, s_{rk}, L_{rk}, \Theta_{rk})$ by an analytical process. p_{rk}^{*} and Θ_{rk} indicate inputs in the bare-bone assembly control sub-model. In the bare-bone assembly and stockpile control sub-models, the optimal values of $Q_{ik}^{*}, p_{ik}^{*}, T_{ikm}$ are calculated from the cost, fill rate, and delivery flexibility tradeoffs. The relative parameters (u_{ik}^{p}, t_{ik}) can then be calculated, and t_{ik} is input in the bare-bone stockpile control sub-model. Parameters $(u_{ik}^{S}, s_{ik}, L_{ik}, c_{ikm})$ are calculated in the bare-bone stockpile control sub-model, and T_{ikm} is input in the full-set configuration control sub-model. Additionally, the optimal values of Q_{jm}, P_{jm} are calculated, from which the relative parameters $(U_{jm}, s_{jm}, S_{jm}, L_{jm})$ can be calculated. Now, we can summarize the actual unit variable costs $(U_{ik} = u^G_{ik} + u^P_{ik} + u^S_{ik}, U_{jm}, c_{ikm})$, which are adopted as inputs to the strategic-level planning model.

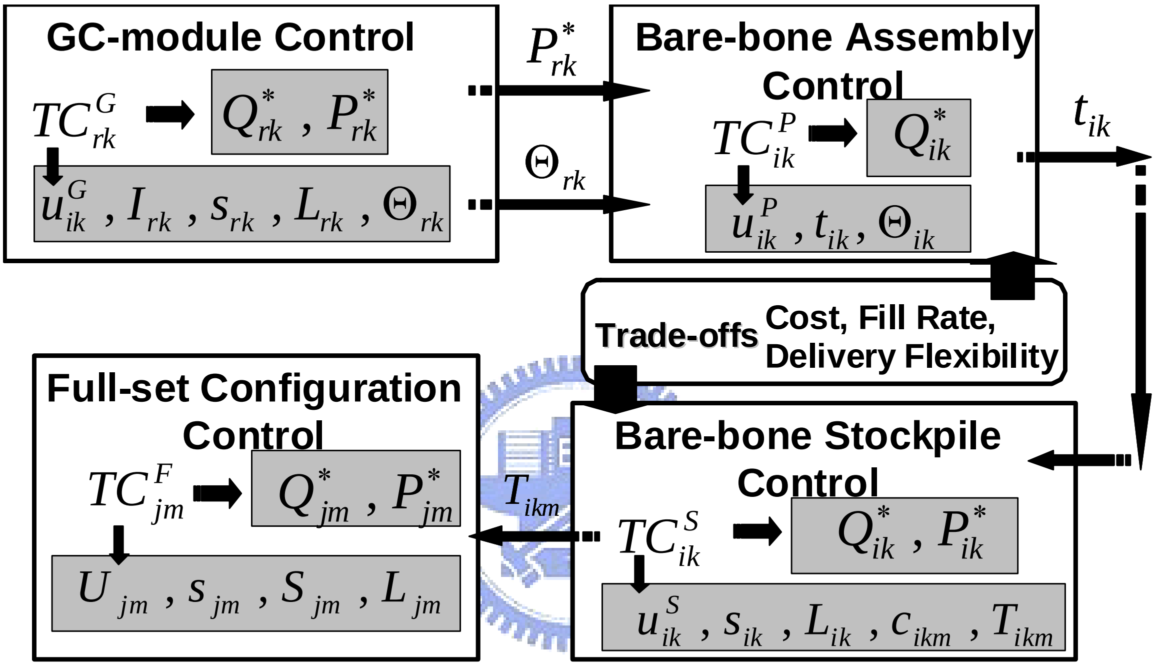


Figure 6.1 Interactive Relationships in Operational Parameters

6.3 Solution Methodology

This section describes an iterative procedure in which the strategic-level optimization planning model is combined with the operational-level optimization planning model to calculate the optimal SC performance index. The steps of the algorithm are presented below and illustrated in Figure 6.2.

Step 1: Optimize the strategic-level planning model for an existing or proposed SC network to obtain the initial optimal configuration, using mixed integer linear programming by considering the base-case (initial) values for production, distribution, and transportation unit variable costs.

Step 2: Adopt the decision variable outputs of the strategic-level model as input data to the operational-level planning model, after dividing by the review period factor (number of operational review periods per strategic review period).

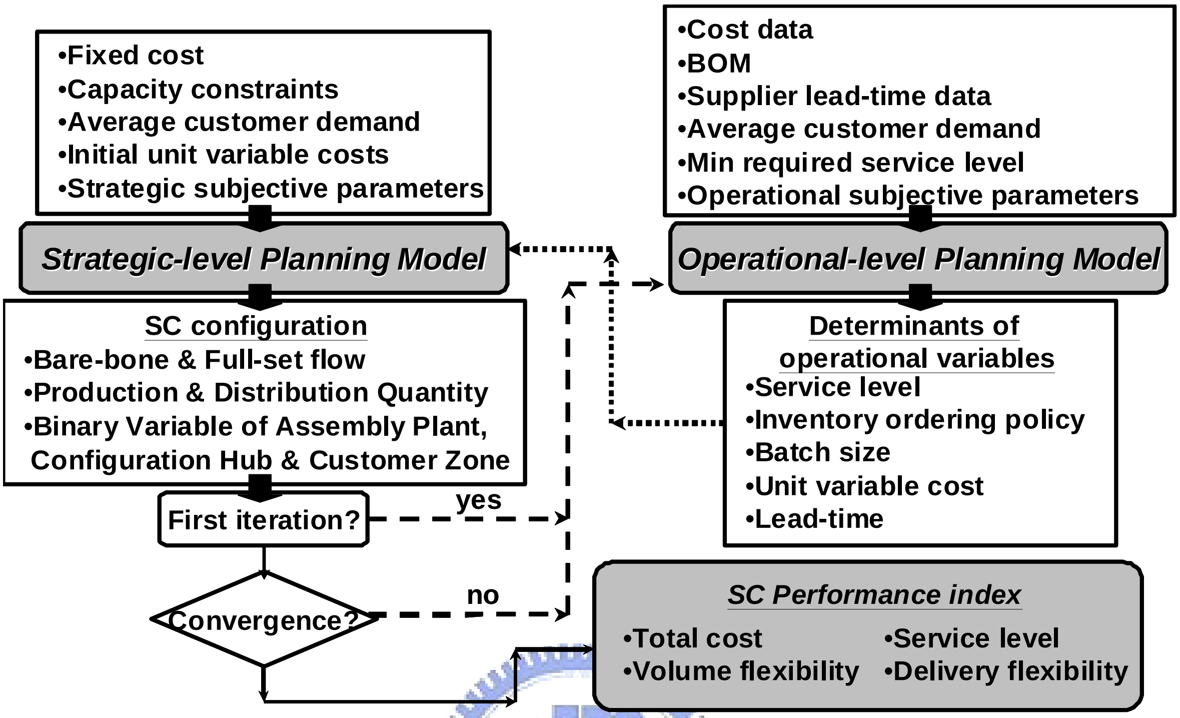


Figure 6.2 The Strategic-Operational Optimization Solution Algorithm

Step 3: Optimize the operational-level model based on the configuration obtained in Step 2 above.

Step 4: Optimize the strategic-level model with the new actual unit variable costs calculated in Step 3, after multiplying them by the review period factor.

Step 5: Verify whether the new unit costs have a significant influence on the optimal configuration, (i.e., check the binary decision variables for convergence). If all binary variables are equal, then go to Step 6; otherwise, go to Step 2.

Step 6: Calculate the values of the SC performance index.

Step 7: Stop.

6.4 Numerical Example and Model Performance

The example developed herein illustrates the algorithm presented in previous section, as well as the applicability and effectiveness of the model. The example case consists of three GC-modules with three vendors, two KC-modules with two vendors, two bare-bones, two full-sets, three assembly plants, four regional configuration hubs, and five customer zones. For this example system, five different scenarios were examined, and the performance index (total cost, volume flexibility, fill rate and expected lead-time) and final supply chain configurations were determined, as shown in Table 6.3.

Table 6.3 The Performance Index and SC Configuration for The Example Scenarios

Scenario	ε	w_k, w_m	η , υ	Performance index (Z, W, P_{ik}, T_{ikm})	SC configuration (q_k, q_m, y_{mz})
1	0	0.5, 0.5	0, 0	(16337,35,0.8,0.04)	$[0,0,1],[0,1,1,0],\begin{bmatrix}0,0,0,0,0\\1,0,1,0,1\\0,1,0,1,0\\0,0,0,0,0\end{bmatrix}$
2	0	0.5, 0.5	0.15, 0.015	(16685,35,0.95,0.025)	$[0,0,1],[0,1,1,0],\begin{bmatrix}0,0,0,0,0\\1,0,0,1,1\\0,1,1,0,0\\0,0,0,0,0\end{bmatrix}$
3	100	0.5, 0.5	0, 0	(16575,135,0.8,0.04)	$[0,0,1],[1,1,1,0],\begin{bmatrix}0,1,0,0,0\\1,0,1,0,1\\0,0,0,1,0\\0,0,0,0,0\end{bmatrix}$
4	100	0.5, 0.5	0.15, 0.015	(16823,135,0.95,0.025)	$[0,0,1],[1,1,1,0],\begin{bmatrix}0,1,0,0,0\\1,0,0,1,1\\0,0,1,1,0\\0,0,0,0,0\end{bmatrix}$
5	100	0.9, 0.1	0, 0	(19649,127,0.8,0.04)	$[0,1,1],[0,1,1,0]\begin{bmatrix}0,0,0,0,0\\1,0,0,1,1\\0,1,1,0,0\\0,0,0,0,0\end{bmatrix}$

A. Sensitivity Analysis

No constraints on flexibility and customer service levels were included for the base case (scenario 1). The performance index and final SC configuration were obtained, resulting in one assembly plant and two configuration hubs. Several sensitivity analysis runs were then conducted. The volume flexibility (ε) was fixed, while the customer service level and delivery flexibility were increased simultaneously to explore the sensitivity to these performance parameters (scenario 2), leading to an increase in the total cost and a change in the customer zone-configuration hub assignments. The customer service level and delivery flexibility were increased by selecting appropriate values for the customer service index (η=0.15) and delivery flexibility index (υ=0.015). This resulted in customer service levels greater than or equal to 0.95 (the minimum required service level was 0.8 for this example), and expected lead times from assembly plants to configurations hubs less or equal to 0.025 periods (the standard delivery time was assumed to be 0.04 periods).

Scenario 3 examined the sensitivity to volume flexibility. In this scenario, the volume flexibility requirement was increased, and no service level or delivery flexibility improvements were required. However, an additional configuration hub was necessary, resulting in an additional cost to accommodate the increase in volume flexibility. In scenario 4, the flexibility (volume and delivery) and customer service level (fill rates) were increased to test the joint effect of these performance parameters, producing the highest total cost among the first four scenarios.

Equal weight was given to the assembly plant volume flexibility and configuration hub volume flexibility in each of the first four scenarios. Scenario 5 gave more weight to the assembly plant volume flexibility, resulting in the addition of another assembly plant. Interestingly, in scenario 3, an additional configuration hub was opened (instead of a plant) when volume flexibility was increased. Scenario 5 had a higher total cost than scenario 3, since the fixed cost associated with the additional assembly plant exceeded that for an additional configuration hub.

Although the example was intended to test the performance of the solution algorithm, this example was used also adopted to test the effectiveness of the model formulation by measuring cost, customer service and flexibility tradeoffs among the various scenarios. Table 6.4 summarizes the results for the five scenarios of this example system.

Table 6.4 Numerical Example Summary Results (Sensitivity Analysis)

	Scenario #				
	1	2	3	4	5
# Assembly Plants	1	1	1	1	2
# Configuration Hubs	2	2	3	3	2
Volume Flexibility	35	35	135	135	127
Average Customer Service	0.93	0.983	0.93	0.983	0.93
Average Delivery Flexibility	0	0.015	0	0.015	0
Total Cost	16,337	16,685	16,575	16,823	19,649

In the next phase of the study, the effect of eight different levels of volume flexibility on the total cost is evaluated. The volume flexibility index was varied from $\varepsilon = 0$ to 200 units. Fig. 6.3 shows the results of this analysis. This graph illustrates the cost-volume flexibility index tradeoffs, and provides evidence to support decisions affecting SC performance. For example, total cost increased slightly from 16685 to 16689 (0.03%) when e was increased from 0 to 75 units. This may support management's preference for a $\varepsilon = 75$ because large increases in flexibility for values between 0 and 175 results in a small cost penalty.

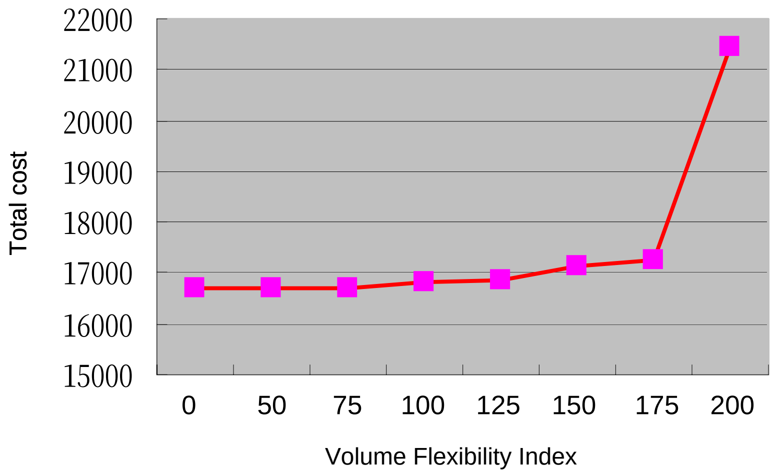


Fig 6.3 The Total cost — Volume Flexibility Index Curve

Similarly, Figure 6.4 and Figure 6.5 show the relationship between the total cost and customer service performance index and delivery flexibility performance index, respectively. Moreover, from these figures, it appears that the total cost is more dramatically affected by changes in the customer service index and delivery flexibility index for smaller ranges and then levels out. These flexibility measures have large cost increases for increases in smaller index values and small cost increases beyond given (larger) index values; in contrast, for volume flexibility, there appears to be small cost increases for small volume flexibility values, and then large cost increases beyond a given (larger) flexibility value.

This example illustrates the effects of operational variables (such as fill rates, and lead times) on the strategic variables, which demonstrates the importance of simultaneously specifying the operational and strategic solutions. Increasing the stockpile fill rate or decreasing distribution replenishment lead times (increasing delivery flexibility), increases production unit cost, which then increases the total cost. In this example, although the number of plants and DCs is insensitive, to changes in customer service or delivery flexibility parameters, these parameters do affect the SC configuration (Table 3).

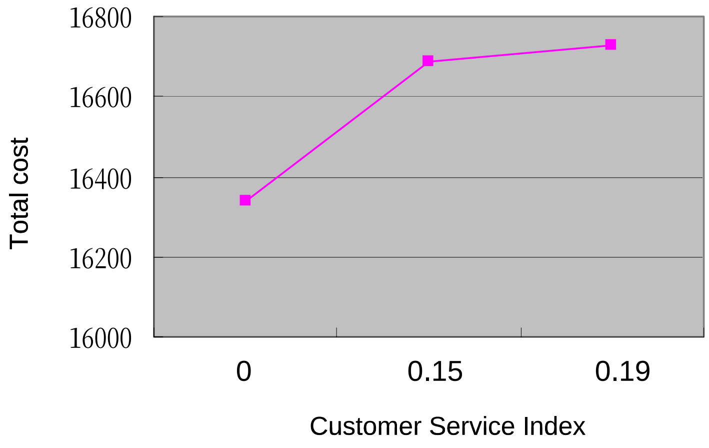


Figure 6.4 The Total cost — Customer Service Index Curve

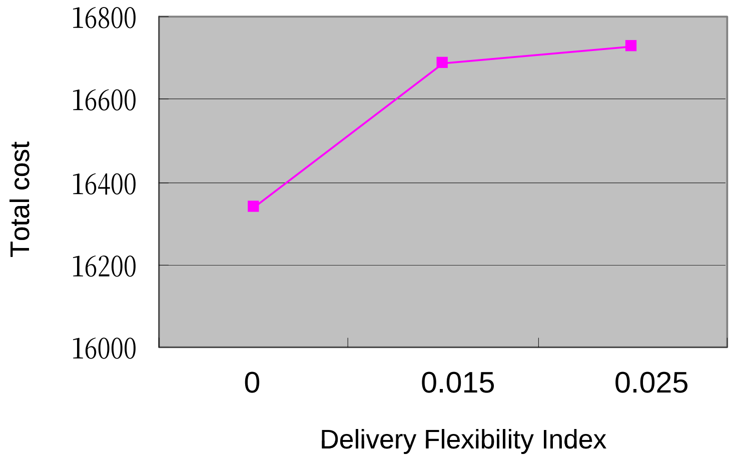


Figure 6.5 The Total cost — Delivery Flexibility Index Curve

Applying this model to large-scale problems (recall that in the example considered, the SC structure considers three GC-modules , two KC-modules , two bare-bones and two full-sets), is not expected to present major problems since there are only two major issues of concern in a large-scale application of the model:

- The performance (speed and memory) of optimizing strategic-level (mixed integer linear programming) and operational-level (nonlinear programming) sub-models.

  The extended version of LINGO no longer places limits of the number of constraints and variables. Also, LINGO's nonlinear solver handles large model more efficiently.
- Reasonable convergence time of the iterative procedure on binary variables between the strategic-level and operational-level sub-models.

By setting the convergence limit in the algorithm to equal binary variables instead of equal unit costs hastens convergence, and is designed to result in reasonably small convergence times for even large scale applications.

B. Regression Analysis

A regression analysis was carried out to analyze the relationships among the total cost parameter, the volume Flexibility, customer service, delivery Flexibility, and the weight factor of the volume flexibility. Additional runs were executed to develop these relationships. These results appear in Table 6.5.

The first column of Table 5 represents the independent variables, while the cost is the dependent variable. Thus, the relationship is represented in the following linear functional form:

$$Cost = C_0 + C_1(VF) + C_2(CS) + C_3(DF) + C_4(WF) \tag{51}$$

The coefficient values（C_i）can be obtained from the second column of Table 5. Each coefficient has been tested using a t-test (column 3). It is found that all the estimated coefficients were significant (at α = 10%) except for delivery flexibility (see the fourth column of Table 6.5). This is due to the high correlation between customer service (stockpile fill rate) and delivery flexibility (lead-time), which means that only one of these factors could be used in this scenario (example). It is also interesting to note that the volume flexibility and its weight factor are dominant parameters for determining the cost.

The linear regression model in Table 6.5 indicates that the independent variables (volume flexibility, customer service, delivery flexibility, and weight factor) explain variation in the dependent variable (total cost) with a high R^2 value of 0.993. These results give the justification to accept this linear regression model to explain the relationship between the cost and other performance measures. This model quantifies the impact of changes in the customer service and flexibility performance on the SC total cost.

Table 6.5 Linear Regression Analysis

$Cost = C_0 + C_1(VF) + C_2(CS) + C_3(DF) + C_4(WF)$

R^2=0.993

Parameter	Estimate （C_i）	T	P-value
Intercept	7945.8	5.856	0.0284
Volume Flexibility（VF）	1.845	4.977	0.0392
Customer Service （CS）	4.4672	2.887	0.0973
Delivery Flexibility (DF)	5847.7	1.873	0.3726
Weight Factor （WF）	2956.4	21.883	0.002

Chapter 7 Conclusions and Suggestions

7.1 Research Findings

This study has applied grey relation analysis to select key factors for different global supply chain operational models adopted by Taiwanese notebook manufacturers. The search for key factors could be complicated for judgments involving different perspectives and dimensions. TO effectively identify these factors, the grey relation analysis method is an effective tool that differs from quantitative statistical techniques. GRA can directly analyze the original data using either quantitative or qualitative factors, and thus offers an effective method of solving qualitative problems.

Based on these key factors, reference models are developed to demonstrate the global operations outline of different operational models in leading manufacturers. These reference models provide more concrete description of the differences in global operational decisions. The hidden knowledge of the cooperative relationship between manufacturers and multinational brand companies can then be systematically described. Meanwhile, some managerial implications are proposed based on the analytical results. These findings could be helpful to further strategic analysis.

In this research, we explore the developments and characteristics in Notebook-computer Industry. Also, different supply chain layouts are discussed for understanding the practical operations about how the Taiwanese contract notebook-computer manufacturers support multinational brand companies in global logistics. Based on the general BTO/CTO supply chain layout, a supply chain conceptual model that facilitates simultaneous strategic-level and operational-level planning is organized by considering iterative relationship between SC strategic decisions and operational performance. These concepts will be helpful to model formulation in next stage.

The concepts of simultaneously strategic and operational planning give valuable insights into the modeling and analysis of complex SC configurations, and facilitate coordinated decision-maker interaction to solve specific problems. The model framework described in this research specifies the characters in note-book computer industry and represent a combination from the standard and optimization methods currently used to analyze SC. The key innovation lies in the integration of strategic and operational levels, and the associated linkages of decisions and performance measures.

This study has examined the trends and features of notebook-computer industry. Additionally, various supply chain layouts were explored in order to understand the practical operations about how Taiwanese contract notebook-computer manufacturers support multinational brand companies in global logistics. A supply chain model that facilitates simultaneous strategic-level and operational-level planning has been developed iteratively from the general BTO/CTO supply chain layout.

The proposed model incorporates production, delivery, and demand uncertainty, and decreases complexity by reasonable simplifications. Additionally, the model provides an appropriate performance measure by adopting multi-objective analysis for the whole SC network. The model developed herein aids in the design of efficient, effective and flexible supply chains, and in the evaluation of competing SC networks for notebook-computer manufacturers.

This model may appear to stipulate the determination of a large number of input parameters. However, the number of required parameters is small, considering that the model is designed to solve a wide range of problems from the strategic-level down to the operational-level. Furthermore, real-world applications can readily obtain most of these inputs from organizational databases.

The developed model (which consists of the conceptual framework, mathematical formulation, and solution algorithm) gives valuable insights into the modeling and analysis of complex SC configurations, and allows specific problems to be solved through coordinated decision-maker interaction. The model formulations described in this study specify the characteristics of the notebook-computer industry, and represent a combination of the standard and optimization methods currently adopted to analyze SC. The main innovation lies in the integration of strategic and operational levels, and the associated linkages of decisions and performance measures.

This model is general at the strategic level, and can accommodate a wide variety of different supply chain strategies (such as BTO/CTO+DS model). These strategies can be examined and compared by determining the performance index of each strategy. Additionally, this model is flexible for modifications and changes at the operational level. Various operational policies can be examined to identify the best policy for a given SC configuration. For instance, such policies could involve the choice between “make to order” and “make to stock”, or between “periodic” and "continuous" review period. An example system, in which "make to stock" and "continuous review period" policies are considered, is described and solved in order to illustrate the applicability of the model. In the example considered, the solution algorithm was very successful in generating solutions. In addition to confirming the significance of cost, customer service and flexibility, results of this study demonstrate the requirement to integrate operational and strategic decisions in SC design.

7.2 Managerial Implications and Suggestions

In the global notebook-computer market, Taiwanese contract manufacturers are focused on supporting the global operations of multinational Brands. It is extremely difficult to continue generating benefits from brand companies in the long-run. Tendencies in short product lifecycle, low price, quick technology innovation and changeable customer preferences cause the vibrations in market demand as well as the exigency to supply chain redesign. Recently, low profits and intense competition have increased the need for manufacturers to adjust strategies to focus on innovation, flexibility, efficiency, quality and cost control and cooperate more closely with Brands. This research focuses on exploring the characteristics in operational models for Taiwanese notebook-computer contract manufacturers. And then proposes a conceptual framework of simultaneously strategic and operational planning in supply chain design. Based on the analysis, the managerial implications and suggestions to notebook-computer industry are presented below:

1. Uncertainty is one of the most challenging but important problem in supply chain management. Indeed, it is a primary difficulty in the practical analysis of SC performance. In the absence of randomness, the problems of material and product supply are eliminated; all demands, production, and distribution behavior would be completely fixed, and therefore, exactly predictable. Nevertheless, it is unrealistic and insufficient in practical global operations. Contact manufacturers need to precisely identify their SC performance for keeping stable and closer cooperation with Brands. That is, decisions in strategic-level planning must be integrated with operational-level planning of a SC. To make sure they could exactly support Brands' global operations based on flexible SC management and excellent SC performance.

2. SC operates in an uncertain environment. Uncertainty is associated with customer demand, internal and external supply deliveries throughout the SC. There exists extensive integration and coordination from upstream to downstream supply chain echelons. Any impact in each echelon may cause enormous fluctuating effect and

may not be controllable. It is essential to keep flexibility, such as volume flexibility in assembly plant and configuration hub as well as delivery flexibility, for easing the impacts from uncertainty. Therefore, contract manufacturers can take quick-responding strategies and satisfy the requirements from Brands.

3. This supply chain design model incorporates production and delivery uncertainty, and reduces complexity via reasonable assumptions. The interactive relationships are well-defined and analyzed in component module control, bare-bone assembly control, bare-bone stockpile control, and full-set configuration control subsystems. Fill rate (service level) and replenishment lead-time in upstream control subsystem have direct impacts in operational performance of downstream control subsystem. The conceptual model developed here aids in the design of efficient, effective, and flexible supply chains, and in the evaluation of competing SC networks for notebook-computer manufacturers.

4. Analytical process is performed in operational-level planning model. It could be more practical based on cost functions calibration in each echelon. Collecting and using the real operation parameters to calibrate the cost function of each control sub-model, it will be very useful for comprehensive supply chain performance measurement.

5. Volume flexibility and delivery flexibility are incorporated in supply chain design modeling for the purpose that proactive supply chains will be more responsive than those which are merely reactive. It is necessary that networks should be design with both flexibility and reduced uncertainty. The decision of supply chain flexibility is decided by the decision maker’s experience, there exists different definitions and scopes in different scenarios. It could be further discussed and modeled in the aspects of operational level (flexibility in machine, automation, labor, routing etc.), strategic level (flexibility in volume, delivery, production, product design and expansion etc.) and network level (flexibility in robustness, relationship and re-configuration etc.).

Bibliography

a) Books

1. Andreas Klose, M. Gracia Speranza, Luk N. Van Wassenhove, *Quantitative approaches to distribution logistics and supply chain management*, Springer-Verlag Berlin Heidelberg, 2002.
2. Cohen M.A., Lee H.L., “Manufacturing strategy: concepts and methods”, In: Kleindorfer PR, editor. *The management of productivity and technology in manufacturing*. New York: Plenum Press, 1987.
3. Christopher, Martin, *Logistics and Supply Chain Management*, Financial Time, Irwin, 1994.
4. Goicoecha A., Hansen D.R., Duckstein L., *Multiobjective decision analysis with engineering and business applications*, New York: Wiley, 1982.
5. Hwang C.L. and Yoon K. *Multiple Attribute Decision Making*, Springer-Verlag, Berlin, 1981.
6. Lewis, J.D., *Partnerships for Profit-Structuring and Managing Strategic Alliances*, New York : The Free Press, 1990.
7. Philippe-Pierre Dornier, Ricardo Ernst, Michel Fender, Panos Kouvelis, Global operations and logistics, John Wiley & Sons, INC., 1998.
8. Sierra M.C., *Managing global alliances* 一 *Key steps for successful collaboration*, New York,NY ：Addision -Wesley Publishing Company, 1995.
9. Silver E.A., Peterson R., *Decision systems for inventory management and production planning*, New York: Wiley, 1985.

b) Journal Paper

1. Adrian E. Coronado M. And Andrew C. Lyons, “Evaluating Operations Flexibility in Industrial Supply Chains to Support Build-To-Order Initiatives”, Business Process Management Journal, Vol.13, No.4, 2007.
2. Alan Smart and Andreas Dudas, “Developing a Decision-Making Framework for Implementing Purchasing Synergy: A Case Study”, International Journal of Physical Distribution & Logistics Management”, Vol.37, No1, 2007.
3. Anthony S.W. and Michael C., “Observations on Modeling Strategies for Vendor-Managed Inventory”, Journal of Manufacturing Technology Management, Vol.17, No.4, pp.496-512, 2006.
4. Arshinder, Arun Kanda and S.G. Deshmukh, “Supply Chain Coordination Issues: An SAP-LAP Framework”, Asia Pacific Journal of Marketing and Logistics, Vol.19, No.3, pp.240-264, 2007.
5. Berman Kayis and Sami Kara, “The Supplier and Customer Contribution to Manufacturing Flexibility”, Journal of Manufacturing Technology Management, Vol.16, No.7, pp.733-752, 2005.
6. Bill Roach, “Origin of The Econpmic Order Quantity Formula; Transcription or

Transformation", Management Decision, Vol.43, No.9, pp.1262-1268, 2005.

7. Brush, T.H., Maritan, C.A., and Karnani, A. "The Plant Location Decision in Multinational Manufacturing Firms: An Empirical Analysis of International Business and Manufacturing Strategy Perspectives", Production and Operations Management, Vol. 8, No. 2, pp. 109-132, 1999.

8. Bulent Sezen, "Relative Effects of Design, Integration and Information Sharing on Supply Chain Performance", Supply Chain Management: An International Journal, Vol.13, No.3, pp.233-240, 2008.

9. Bulent Sezen, "Changes in Performance Under Various Lengths of Review Periods in A Periodic Review Inventory Control System With Lost Sales", International Journal of Physical Distribution & Logistics Management, Vol.36, No.5, pp.360-373, 2006.

10. Camm J.D., Chorman T.E., Dill F.A., Evans J.R., Sweeney D.J., Wegryn G.W., "Restructuring P&G's supply chain", Interfaces, Vol. 27, No. 1, pp. 128-142, 1996.

11. Chang S. C., Lin R.J., Chang F.J. and Chen R.H., "Achieving Manufacturing Flexibility Through Entrepreneurial Orientation", Industrial Management & Data Systems, Vol.107, No.7, pp.997-1017, 2007.

12. Chang, T.C., Lin, S.J. "Grey Relation Analysis of Carbon Dioxide Emissions from Industrial Production and Energy Uses in Taiwan", Journal of Environmental Management, Vol. 56, pp.247-257, 1999.

13. Charles Kelly, "A Framework for Improving Operational Effectiveness and Cost Efficiency in Emergency Planning and Response", Disaster Prevention Management, Vol.4, No.3, pp.25-31, 1995.

14. Chen, M.F. and Tzeng, G.H., "Combining Grey Relation and TOPSIS Concepts for Selecting an Expatriate Host Country", Mathematical and Computer Modelling, Vol. 40, No. 13, pp. 1473-1490, 2004.

15. Chan W.M., Ibrahim R.N. and Lochert P.B., "Economic Production Quantity and Process Quality: A Multivariate Approach", International Journal of Quality & Reliability Management, Vol.22, No.6, pp.591-606, 2005.

16. Chiou, H.K. and Tzeng, G.H., "Fuzzy Hierarchical Evaluation with Grey Relation Model of Green Engineering for Industry", International Journal of Fuzzy Systems, Vol. 3, No. 3, pp. 466-475, 2001.

17. Cohen M.A., Lee H.L., "Strategic analysis of integrated production-distribution systems: models and methods", Operations Research, Vol. 36, No.2, pp. 216-228, 1988.

18. Cohen MA, Kleindorfer P.R., Lee H.L., "Optimal stocking policies for low usage items in multi-echelon inventory systems", Naval Research Logistics Quarterly, Vol.33, pp. 17-38, 1986.

19. Cohen M.A., Moon S., "Impact of production scale economics, manufacturing complexity, and transportation costs on supply chain facility networks", Journal of Manufacturing and Operations Management, Vol. 3, pp. 269-292, 1990.

20. Cohen M.A., Moon S., "An integrated plant loading model with economics of scale and scope", European Journal of Operational Research, Vol.50, pp. 266-279, 1991.

21. Crowe T. J. and Nuno J. P. (1991). “Deciding Manufacturing Priorities: Flexibility, Cost, Quality, and Service”, Long Range Planning, Vol. 24, No. 6, pp.88-95, 1991.

22. Deng J. “Control problems of Grey Systems”, Systems and Control Letters, Vol. 5, No. 2, pp.288-294, 1982.

23. Deng J. “Introduction to Grey Theory System”, The Journal of Grey System, Vol. 1, No. 1, pp.1-24, 1989.

24 Deng J. “Grey Information Space”, The Journal of Grey System, Vol. 1, No. 1, pp.103-117, 1989.

25. Devlin, G., and Bleakley, M. “Strategic Alliances－Guidelines for Success”, Long Range Planning, Vol. 21, No. 5, pp.8-23, 1998.

26. DuBois F.L., Toyne B., Oliff and M.D., “International Manufacturing Strategies of U.S. Multinationals：A conceptual framework based on a four-industry study”, Journal of International Business Studies, Vol. 2, pp. 307-329, 1993.

27. Enrique Ballestero, “Stochastic Goal Programming: A Mean-Variance Approach”, European Journal of Operational Research, Vol.131, pp.476-481, 2001.

28. Feffery M.M., Buter R.F. and Malone L.G., “Determining a Cost-Effective Customer Service Level”, Supply Chain Management: An International Journal, Vol.13, No.3, pp.225-232, 2008.

29. Feng, C.M., Wang, R.T. “Performance Evaluation for Airlines Includes the Consideration of Financial Ratios”, Journal of Air Transport Management, Vol. 6, pp.133-142, 2000.

30. Geringer, J.M., “Strategic determinants of partner selection criteria in international joint ventures,” Journal of International Business Studies, Vol.22, No.1, pp.41-62, 1991.

31. Geringer, J.M., "Selection of Partners for International Joint Venture", Business Quarterly, Vol. 53, No. 2, pp.31-36.23, 1988.

32. Gerwin, D., “Manufacturing flexibility: A strategic perspective”, Management Science, Vol.39 No.4, pp.395-410, 1993.

33. Giannoccaro, I., Pontrantrandolfo, P., Scozzi, B., “Uncertainty in supply chain inventory management: a fuzzy approach”, European Journal of Operational Research, Vol.149, pp.185-196, 2003.

34. Harrington L., “Logistics Agent for Chang：Shaping the Integrated Supply Chain ”, Traffic & Distribution, January, pp.30-34, 1995.

35. Hutt, D.M., E.R. Stafford, B.A. Walker and P.H. Reingen, “Defining the social network of a strategic alliance”, Sloan Management Review, Winter, pp.51-62, 2000.

36. Hu, Yi-Chung, Chen, Ruey-Shun, Hsu, Yen-Tseng, and Tzeng, Gwo-Hshiung, “Grey Self-Organizing Feature Maps”, Neurocomputing, Vol. 48, No. 4, pp. 863-877, 2002.

37. Ian Sadler and Peter Hines, “Strategic Operations Planning Process for Manufacturers with A Supply Chain Focus: Concepts and a Meat Processing Application”, Supply Chain Management: An International Journal, Vol.7, No.4, pp.225-241, 2002.

38. Ian Sadler and Richard Gough, “Applying a Strategic Planning Process to Several Supply Chain Partners”, Journal of Manufacturing Technology Management, Vol.16, No.8, pp.890-908, 2005.

39. Johnson M.E., Davis T., Lee H.L., “Robustness of order reliability models with applications to order ageing”, International Journal of Production Research, Vol. 34. No. 12, pp. 3499-3514, 1996.

40. Kros J.F., Falasca M. and Nadler S.S., “Impact of Just-In-Time Inventory Systems on OEM Supplier”, Industrial Management & Data Systems, Vol/106, No.2, pp.224-241, 2006.

41. Lee H.L., Billington C., “Material management in decentralized supply chains”, Operations Research, Vol.41, No.5, pp. 835-847, 1993.

42. Lee, H.L., Billington, C., “Managing supply chain inventory: pitfalls and opportunities”, Sloan Management Review, pp. 65-73, 1992.

43. Lee H.L., Feitzinger E., “Product configuration and postponement for supply chain efficiency”, In: 4th Industrial Engineering Research Conference, pp. 43-48, 1995.

44. Liao C.J., Shyu C., “An analytical determination of lead-time with normal demand”, International Journal of Operations and Production Management, Vol.11, No. 9, pp. 72-78, 1991.

45. Lin, C.T., P.F. Hsu, ”Selection of Advertising Agencies Using Grey Relational Analysis and Analytic Hierarchy Process”, Journal of International Marketing and Marketing Research, Vol.26, No.3, pp.115-128, 2001.

46. Lokesh Nagar and Karuna Fain, “Supply Chain Planning Using Multi-stage Stochastic Programming”, Supply Chain Management: An International Journal, Vol.13, No.3, pp.251-256, 2008.

47. Luc Cassive, “Collaboration Planning in A Supply Chain”, Supply Chain Management: An International Journal, Vol.11, No.3, pp.249-258, 2006.

48. Marek Pawlak and Elzbieta Malyszek, “A local Collaboration as The Most Successful Coordination Scenario in The Supply Chain”, Industrial Management & Data Systems, Vol.108, No.1, pp.22-42, 2008.

49. Mark Stevenson and Martin Spring, “Flexibility from a Supply Chain Perspective: Definition and Review”, International Journal of Operations & Production Management, Vol.27, No.7, pp.685-713, 2007.

50. Martin R., Niklas K. and Kristoffer K., ”Collaborative Supply Chain Planning Using Electeonic Marketplaces”, Integrated Manufacturing Systems, Vol.13, No.8, pp.596-610, 2002.

51. Massimo Bertolini and Antonio Rizzi, ”A Simulation Approach to Manage Finished Goods Inventory Replenishment Economically in A Mixed Push/Pull Environment”, Logistics Information Management, Vol.15, No.4, pp.281-293, 2002.

52. Mingyuan Chen, “A Model for Integrated Production Planning in Cellular Manufacturing Systems”, Integrated Manufacturing Systems, Vol.12, No.4, pp.275-284, 2001.

53. Myung-Su Chae and John S. Hill, “Determinants and Benefits of Global Strategic

Marketting Planning Formality”, International Marketing Review, Vol.17, No.6, pp.538-562, 2000.

54. Ndubisi N.O., Jantan M., Hing L.C. and Ayub M.S., “Supplier Selection and Management Strategies and Manufacturing Flexibility”, The Journal of Enterprise Information Management, Vol.18, No.3, pp.330-349, 2005.

55. Newhart D.D., Stott K.L., Vasko F.J., “Consolidating product sizes to minimize inventory levels for a multi-stage production and distribution system”, Operational Research Society, Vol.44, No. 7, pp. 637-644, 1993.

56. Nielsen Lise Drewes,Jespersen,Per Homann,Petersen Tina ,Hansen Leif Gjesing, ’’ Freight transport growth-a theoretical and methodological framework’’, European Journal of Operation Research , Vol.144, pp.295-305, 2003.

57. Oyvind Halskau Sr, “EOQ Models for Postponed Payment of Stored Commodities”, International Journal of Physical Distribution & Logistics Management, Vol.33, No.8, pp.686-700, 2003.

58. Patterson Kirk A.,Grimm Curtis M.,Corsi Thomas M., ”Adopting new technologies for supply chain management”, Transportation Research Part E, Vol.39, pp.95-121, 2003.

59. Peter Baker, “An Exploratory Framework of The Role of Inventory and Warehousing in International Supply Chain”, The International Journal of Logistics Management, Vol.18, No.1, 2007.

60. Prater E., Biehl M. And Smith M.A., “Tradeoffs between Flexibility and Uncertainty”, International Journal of Operations & Production Management, Vol.21, No.5, pp.823-839, 2001.

61. Rajesh Piplani and Yonghui Fu, “A Coordination Framework for Supply Chain Inventory Alignment”, Journal of Manufacturing Technology Management, Vol.16, No.6, 2005.

62. Richardson, P. R., and J. R. M. Gordon., "Measuring Total Manufacturing Performance." Sloan Management Review, 21, No.2 , pp.47-58, 1980.

63. Robinson P.E., Goa L.L., Muggenborg S.T., “Designing an integrated distribution system at Dowbrands”, Interfaces, Vol. 23, No. 3, pp. 107-117, 1993.

64. Salvador F., Rungtusanatham M., Forza C. and Trentin A., “Mix Flexibility and Volume Flexibility in a Build-To-Order Environment”, International Journal of Operations & Production Management, Vol.27, No.11, pp.1173-1191, 2007.

65. Sami Kara and Berman Kayis, “ Manufacturing Flexibility and Variability: An Overview”, Journal of Manufacturing Technology Management, Vol.15, No.6, pp.466-478, 2004.

66. Sin-Hoon Hum and Hoon-Hong Sim, “Time-based Competition: Literature Review and Implications for Modeling”, International Journal of Operations & Production Management, Vol.16, No.1, pp.75-90, 1996.

67. Slack N., “The flexibility of manufacturing systems”, International Journal of Operations and Production Management, Vol. 7, No. 4, pp. 35-45, 1987.

68. Stig-Arne Mattsson, “Inventory Control in Environments with Short Lead Times”, International Journal of Physical Distribution & Logistics Management, Vol.37, No.2, pp.115-130, 2007.

69. Sunil Chopra, ’’Designing the distribution network in a supply chain’’, Transportation Research Part E, Vol.39, pp.123-140, 2003.

70. Tachizawa E. M. And Thomsen C. G., “Drivers and Sources of Supply Flexibility: An Exploratory Study”, International Journal of Operations & Production Management, Vol.27, No.10, pp.1115-1136, 2007.

71. Tom Schamp and Dirk Deschoolmeester, “Strategic and Operational Planning Attitudinal Changes and Survival and Growth of Business Start-Ups Revisited”, International Journal of Entrepreneurial Behaviour & Research, Vol.4, No.2, pp.141-177, 1998.

72. Tseng, F.M., Yu, H.C., Tzeng, G.H., “Applied Hybrid Grey Model to Forecast Seasonal Time Series”, Technological Forecasting and Social Change, Vol. 67, No. 2, pp.291-302, 2001.

73. Tzeng G.H. and Tasur S.H., “The Multiple Criteria Evaluation of Grey Relation Model”, The Journal of Grey System, Vol. 6, No. 2, pp.87-108, 1994.

74. Tzeng, G.H., Chang, J.R., Lin, J.D., and Hung, C.T., “Non-additive Grey Relation Model for the Evaluation of Flexible Pavement Condition”, International Journal of Fuzzy Systems, Vol. 4, No. 2, pp. 715-724, 2002.

75. Tyworth J.E. and Zeng A.Z., “Estimating The Effects of Carrier Transit-Time Performance on Logistics Cost and Service”, Transportation Research Part A, Vol.32, No.2, pp.89-97, 1998.

76. Voudouris V.T., “Mathematical programming techniques to debottleneck the supply chain of fine chemical industries”, Computers and Chemical Engineering, Vol.20, pp.1269-1274, 1996.

77. Zhang Q., Vonderembse M.A. and Lim F.S., “Spanning Flexibility: Supply Chain Information Dissemination Drives Strategy Development and Customer Satisfaction”, Supply Chain Management: An International Journal, Vol.11, No.5, pp.390-399, 2006.

Appendix A : Questionnaire

The questionnaire of investing factors affecting the supply chain operations in notebook-computer industry

Part A：General Information and Operational Characteristics of your company

1. Company's name：____________________________________
2. Your name：______________________________Phone：______________________

   E-mail：_______________________
3. Experience in Logistics

   ☐below 1year ☐1~3years☐3~5 years☐5~10 years☐10 years above
4. Your position：______________________________________
5. Total capital of your company

   ☐$5 billions or less

   ☐MORE than $5 billions, up to $10 billions

   ☐MORE than $10 billions, up to $15 billions

   ☐MORE than $15 billions, up to $20 billions

   ☐MORE than $20 billions
6. Total number of employees

   ☐below 1000 ☐1001~2000 ☐2001~3000 ☐3001~4000 ☐4000 above
7. The average annual revenues ：____
8. The types of main products：____
9. What is the relationship type of supply chain cooperations between your company and major cooperative company?

   ☐Global supply chain cooperations

   ☐Domestic supply chain cooperations

   ☐Simply manufacturing and delivering relationship

   ☐Others：____
10. Where are the major markets of your company's product?

    ☐Europe ☐North America ☐South America ☐North-Eastern Asia

    ☐South-Eastern Asia ☐Mainland China ☐ Taiwan

    ☐Others：____
11. What are the facilities located in the major markets?

    ☐Logistics center ☐Assembly center ☐Factory ☐Distribution center

    ☐Customer service center ☐Warehouse ☐Branch company

    ☐Others:____

12. BTF（Build To Forecast），BTO（Build To Order） and CTO (Configure To Order) are different types of production. What is the proportion of each type in your company?

☐BTF（__________%）☐BTO（__________%） ☐CTO（__________%）

☐others:____________________（__________%）

13. OEM（Original Equipment Manufactures）， ODM（Original Design Manufactures） and OBM（Original Brand Manufactures） are major business models. What is the proportion of each type in your company? Who is your cooperation manufacturer?

☐OEM（__________%） cooperation manufacturer:__________________________

☐ODM（__________%） cooperation manufacturer:__________________________

☐OBM（__________%） cooperation manufacturer:__________________________

☐Others:____________（__________%） cooperation manufacturer:____________

14. What is the proportion of different type of products distribution?

☐Fleet owned by your company （__________%）

☐Outsourcing （__________%）

☐Others:_____________（__________%）

15. What is the objective of your company?

☐Cost down ☐Quick response ☐Flexibility

☐Others:______________________________

Part B：

The survey of significance in different indices for supply chain targets

Please indicate the extent to which you agree with the survey statements by choosing your responses using the following scale.

Not at all	Very little	Somewhat	A significant amount	To a great extent
1	2	3	4	5

A. The significance in different dimensions of supply chain targets (please tick “✓”)

1. Major dimensions of performance

	Significance level				
Dimension	**1**	**2**	**3**	**4**	**5**
Time					
Cost					
Quality					
Flexibility					

2. Attributes in each dimension

		Significance level				
Dimension	**Attributes**	**1**	**2**	**3**	**4**	**5**
Time	Decrease purchasing time					
	Decrease production time					
	Decrease delivery time					
Cost	Reduce purchasing cost					
	Reduce production cost					
	Reduce inventory cost					
	Reduce transportation cost					
Quality	Increase purchasing quality					
	Increase good rate of production					
	Improve logistics channel					
Flexibility	Flexibility in production					
	Variety of product design					

B. The significance in different aspects of supply chain operations

1. Major dimensions of supply chain management efficiency

	Significance level				
Dimension	**1**	**2**	**3**	**4**	**5**
Purchase					
Manufacture					
Inventory management					
IT application					
Transportation					
Customer service					

2. Attributes in each dimension

		Significance level				
Dimension	**Attributes**	**1**	**2**	**3**	**4**	**5**
Purchase	Purchasing cost					
	Purchasing quality					
	Purchasing cycle					
Manufacture	Production cost					
	Production cycle					
	Adopt new technology					
	Inferior goods ratio					
Inventory management	Inventory cost					
	Safety stock					
	Adopt JIT					

		Significance level				
Dimension	**Attributes**	**1**	**2**	**3**	**4**	**5**
ICT application	Adopt cargo tracking system					
	Adopt EDI system					
	Set ERP system					
Transportation	Transportation cost					
	Transportation time					
	Outsourcing					
Customer Service	Provide customization service					
	Develop international service					
	Mechanism of after-sales service					
	Response time to customer					

C. The significance of different aspects of deciding logistics facilities location

1. Major dimensions

	Significance level				
Dimension	**1**	**2**	**3**	**4**	**5**
Government policy					
Labor force					
Logistics support capability					
Developing opportunities					
Financial support					
Market demand					

2. Attributes in each dimension

		Significance level				
Dimension	**Attributes**	**1**	**2**	**3**	**4**	**5**
Government policy	Stable politics climate					
	Relax restriction of logistics investment					
	Simplify process of customs clearance					
Labor force	Low labor costs					
	Professional logistics operations					
	Stable labor supply					
Logistics support capability	Plentiful resources					
	Set up logistics park					
	Superiority of transshipment location					
	Transportation cost					
Developing opportunities	Good logistics infrastructures					

		Significance level				
Dimension	**Attributes**	**1**	**2**	**3**	**4**	**5**
	Integrated condition of the same industry (horizontal integration)					
	Integrated condition of the different industry (vertical integration)					
Financial market	Free capital flow					
	Facility construction cost					
	Regulation fee					
	Exchange rate of international finance					
Market demand	Potential of local market					
	Market potential of globalization					
	Close to major consumer market					

D. The significance in partner choice of strategical alliance

1. Major dimensions

	Significance level				
Dimension	**1**	**2**	**3**	**4**	**5**
Complementary Resources					
Organization Culture					
Market power					

2. Attributes in each dimension

		Significance level				
Dimension	**Attributes**	**1**	**2**	**3**	**4**	**5**
Complementary Resources	Complementary manufacture					
	Complementary distribution and after-sale service					
	Complementary land and factory					
	Complementary finance					
Organization Culture	Past alliance experience					
	Compatibility of strategies					
	Commitment					
	Compatibility of manpower					
Market power	Relative scale between partners					
	Intangible assets					
	Competition advantages					
	Polical and social relationship					

Appendix B : Briefing

Operation Model Analysis and Supply Chain Design for Notebook-Computer Industry

Advisor: Cheng-Min Feng

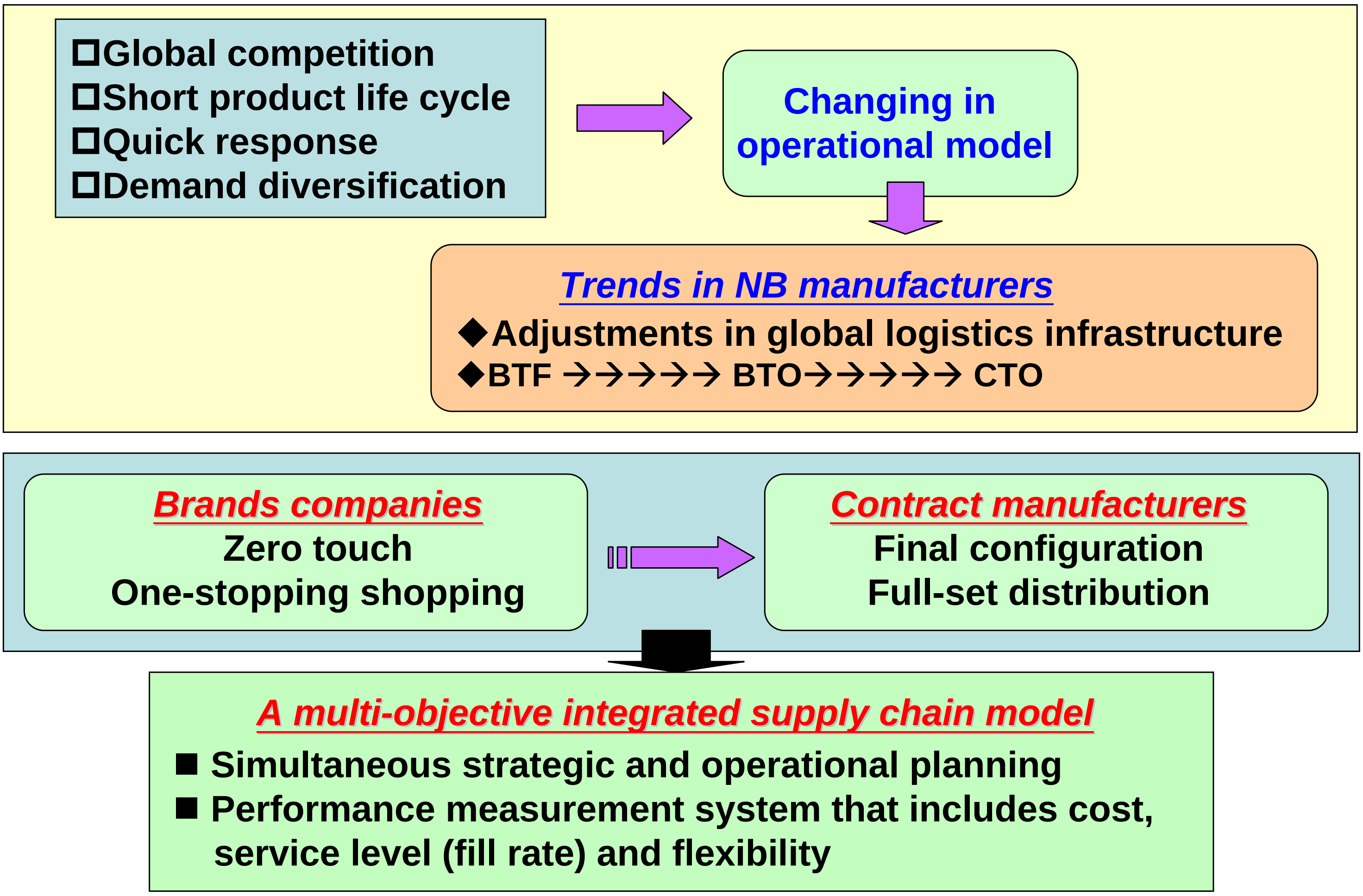
Presenter : Chi-Hwa Chen

09.27.2008

Outline

- *Introduction*
- *Characteristics in NB-computer Industry*
- *Key Factors of Different Operational Model*
- *Conceptual Framework in Supply Chain Design*
- *Modeling and Applications in Supply Chain Design*
- *Conclusions and Suggestions*

Introduction



☐Global competition
☐Short product life cycle
☐Quick response
☐Demand diversification

Changing in operational model

Trends in NB manufacturers

- ◆Adjustments in global logistics infrastructure
- ◆BTF →→→→→ BTO→→→→→ CTO

Brands companies
Zero touch
One-stopping shopping

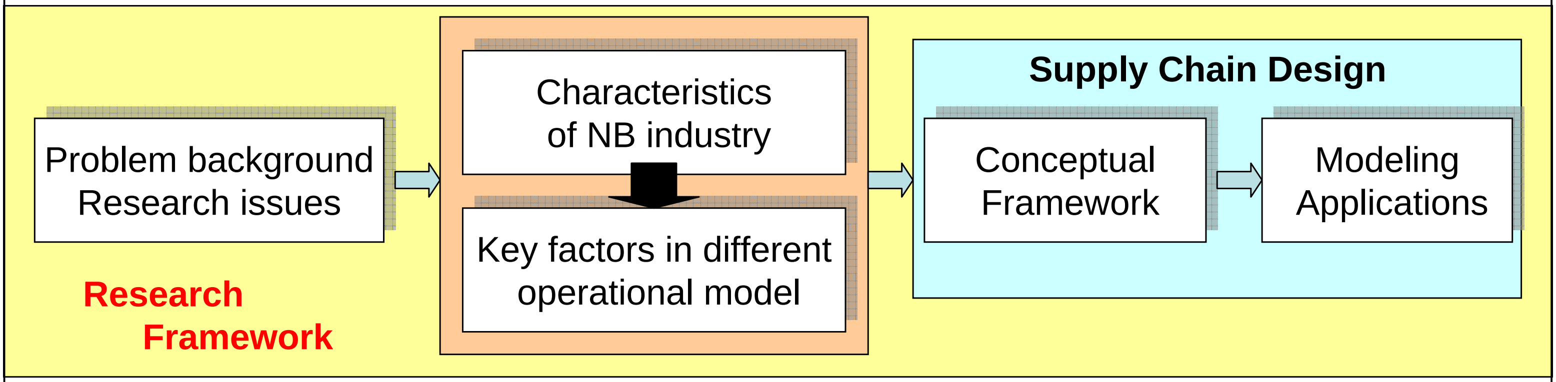
Contract manufacturers
Final configuration
Full-set distribution

A multi-objective integrated supply chain model

- ■ Simultaneous strategic and operational planning
- ■ Performance measurement system that includes cost, service level (fill rate) and flexibility

Research Issues

- Issue 1: To explorer and analyze the key factors emphasized by different operation model. The operation models of supply chain mainly include the business model (OEM/ODM) and the process model (BTF/BTO/CTO).
- Issue 2: To develop a conceptual framework in supply chain design, based on the tradeoffs identification between the decisions in strategic-level planning and operational-level planning. Such concepts are established in the views of notebook-computer contract manufacturers.
- Issue 3: To propose an integrated multi-objective supply chain design model. Multi-objective decision analysis is performed so that a performance measurement system based on cost, customer service level (fill rate), and flexibility (volume or delivery) can be adopted.


Problem background
Research issues

Characteristics
of NB industry

Key factors in different
operational model

Supply Chain Design

Conceptual
Framework

Modeling
Applications

**Research
Framework**

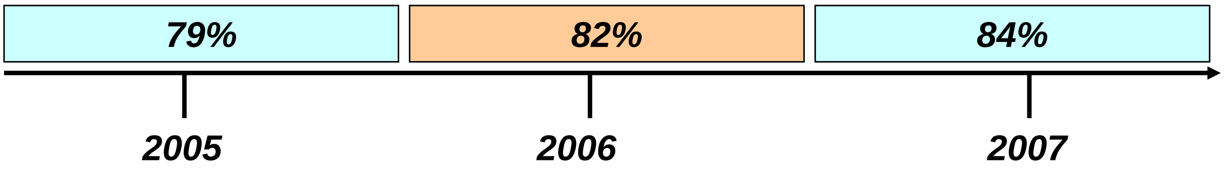
Characteristics in NB-computer Industry

Literature Reviews － Notebook- Computer Industry

1995	林介鵬	探討acer發展之動態，利用概念性動態模型解釋公司政策
1997	林燦偉	利用系統模擬及推論方式探討筆記型電腦產業之產銷體系
1998	李平和	探討BTO生產模式對我國筆記型電腦產業之影響與策略
2000	林紹琪	臺灣筆記型電腦產業競爭策略研究
2001	吳佳倫	臺灣地區個人電腦與筆記型電腦製造業全球運籌模式之探討
2002	林慧玫	我國筆記型電腦代工廠商競爭優勢之探討
2002	張勇毅	CTO生產模式之研究-以我國筆記型電腦為例
2003	張瑞德	臺灣筆記型電腦產業核心能力與經營績效之研究
2003	林明煙	大陸長江三角洲地區建立筆記型電腦產業整合性供應鏈網絡結構模式之研究
2004	朱育廷	大中華區筆記型電腦全球供應鏈價值與物流模式之探討
2005	周立德	以系統思考方式探討品牌與代工角色之互動關係-探討台灣筆記型電腦代工業者毛利率持續壓縮問題
2005	蔡漢章	筆記型電腦代工廠商與品牌廠商動態協力合作演進之研究
2005	黃仁豪	策略成本管理在供應鏈決策之探索性研究-以筆記型電腦產業為例
2006	林易德	從制度理論探討台灣筆記型電腦代工廠商之回應策略

業界訪談　廣達電腦資訊部 方天戟協理，仁寶電腦資訊部 邱文光經理
　　　　　神基電腦物流事業部吳盛台經理
MIC資策會網站資訊

■ *The King of Global OEM/ODM Market*



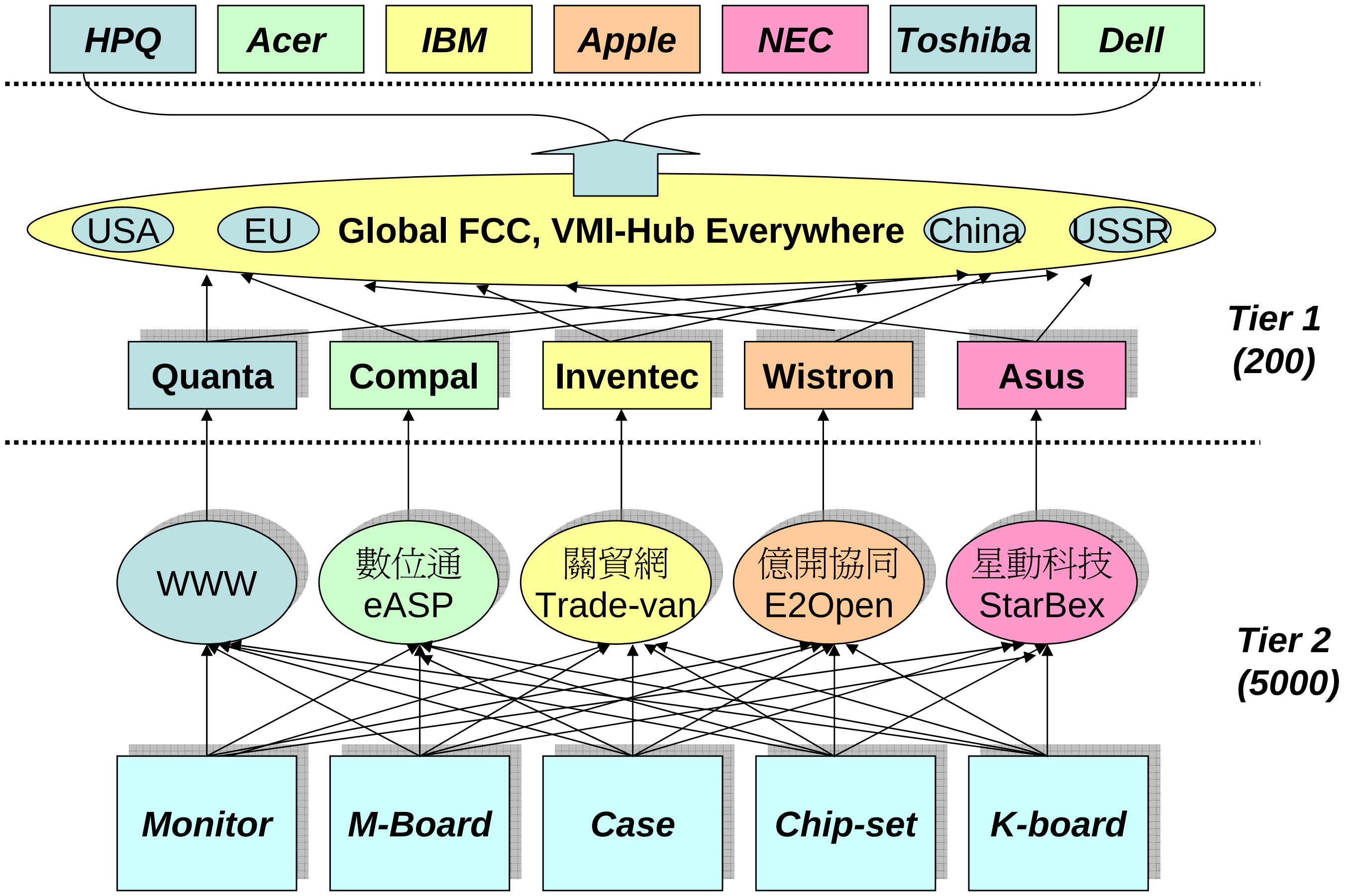
79%　**82%**　**84%**

2005　**2006**　**2007**

■ *Taiwan’s Core Competence*

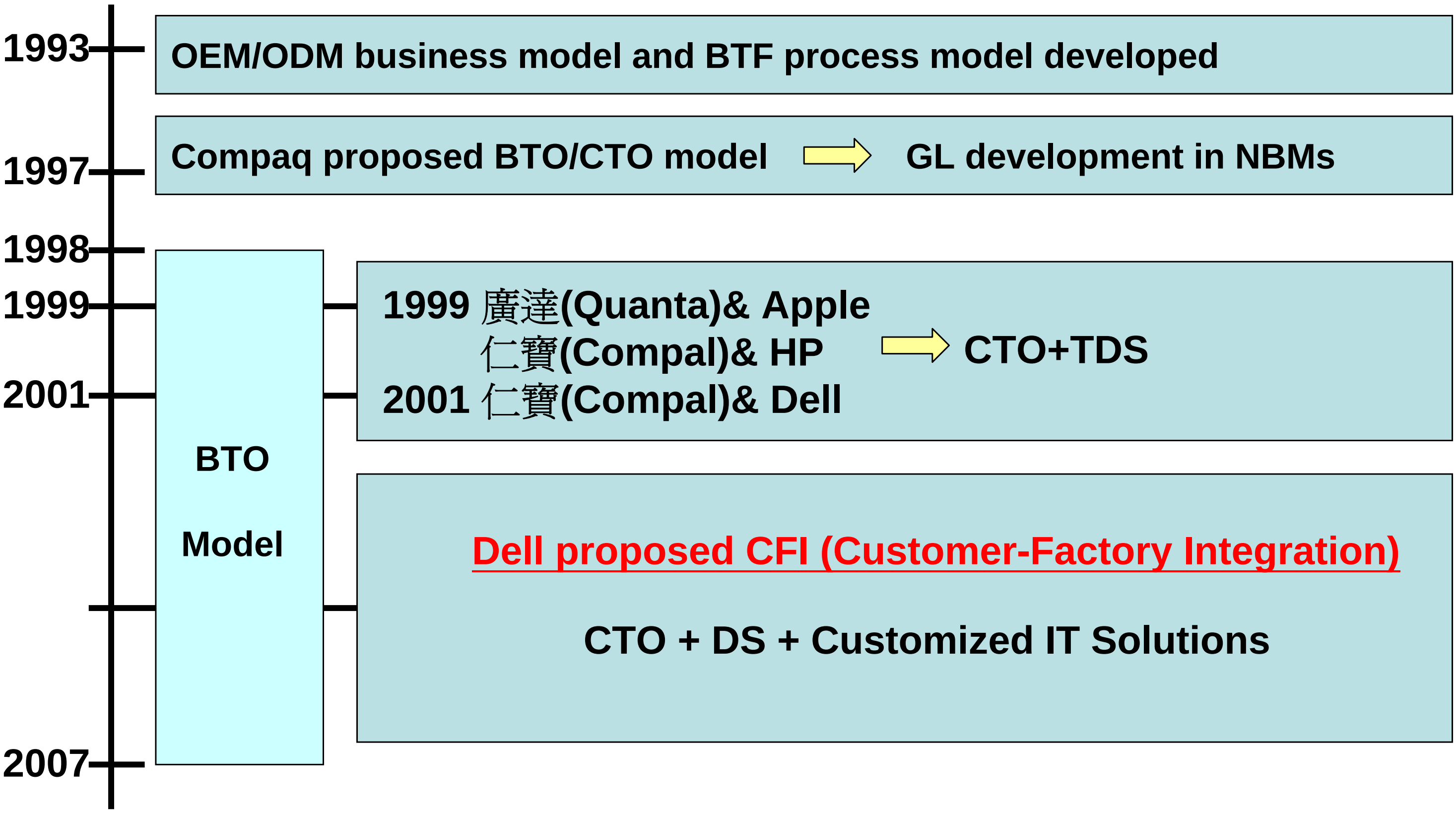
- ➢ Experienced Hi-Tech expertise operation managers with knowledge & skills can perform globally
- ➢ Flexibility from an expert-oriented supporting ability
- ➢ Cluster efforts form a reliable supply chain to link with an efficient global logistics operations
- ➢ Value-added process substitutes cost competition

■ Present Global Logistics Environment



資料來源: 廣達電腦

■ Progressive tracks in supply chain operations



OEM/ODM business model and BTF process model developed

Compaq proposed BTO/CTO model ⇨ GL development in NBMs

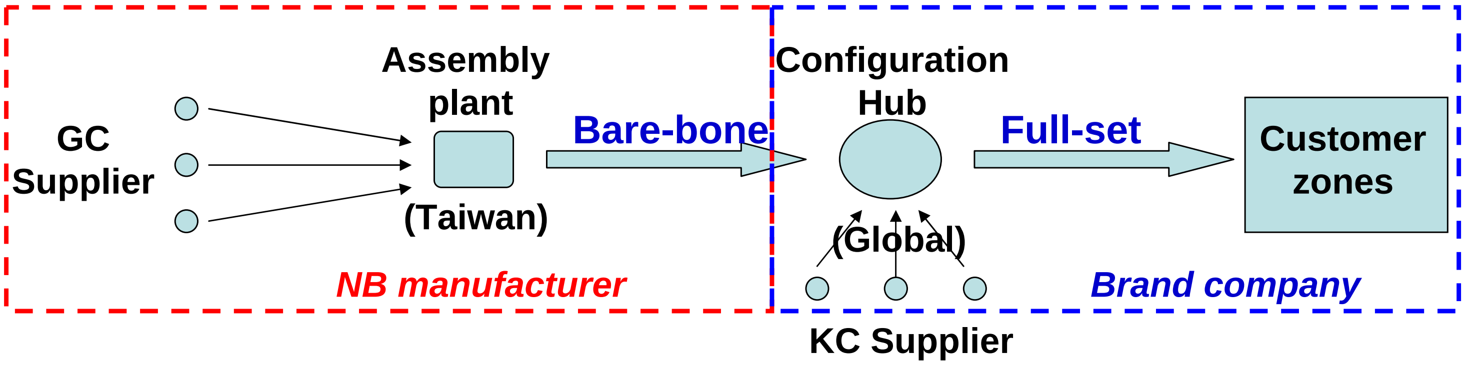
1999 廣達(Quanta)& Apple
仁寶(Compal)& HP ⇨ CTO+TDS
2001 仁寶(Compal)& Dell

<u>Dell proposed CFI (Customer-Factory Integration)</u>

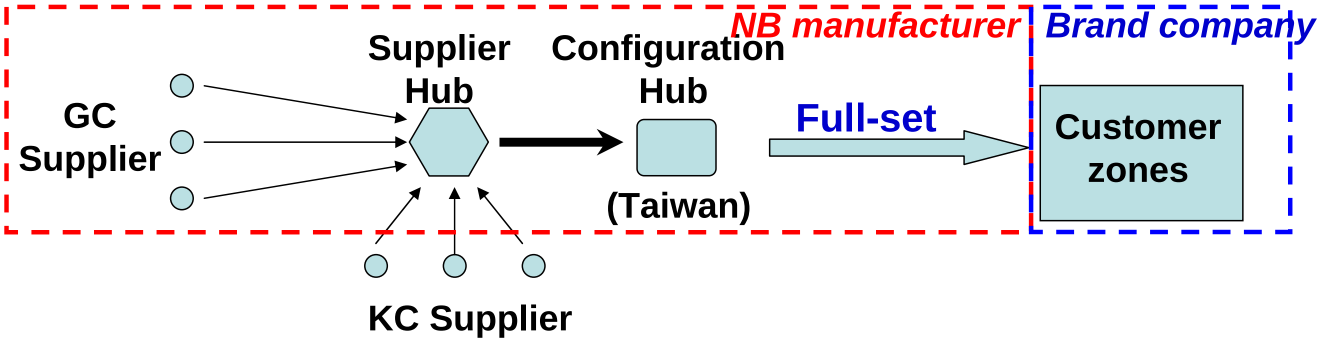
CTO + DS + Customized IT Solutions

supply Chain layout

BTO model (1998~)

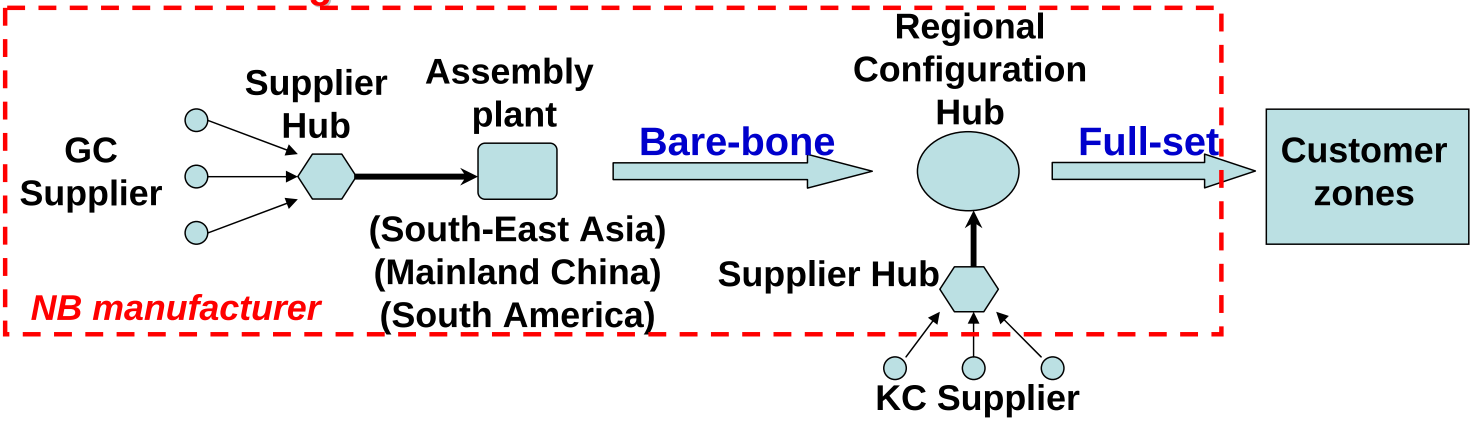

GC Supplier
Assembly plant
(Taiwan)
Bare-bone
Configuration Hub
(Global)
KC Supplier
Full-set
Customer zones
NB manufacturer
Brand company

CTO+TDS specific model

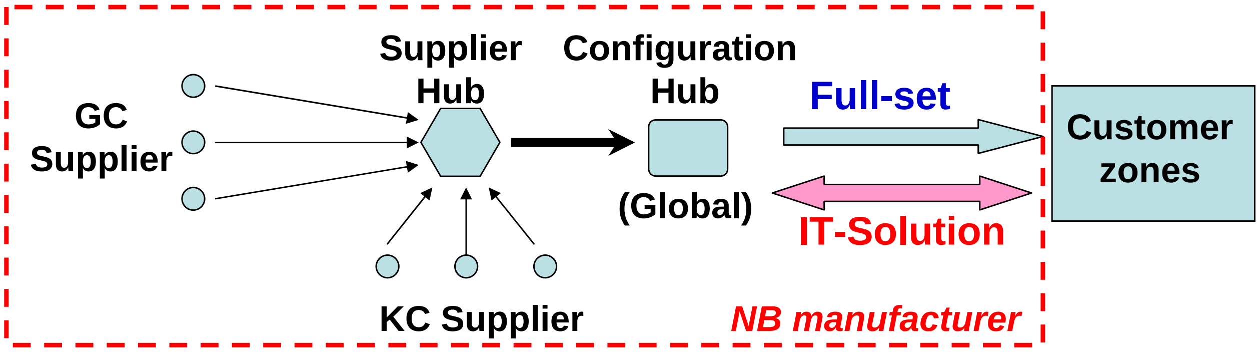

GC Supplier
Supplier Hub
KC Supplier
Configuration Hub
(Taiwan)
Full-set
Customer zones
NB manufacturer
Brand company

supply Chain layout

BTO/CTO general model


GC Supplier
Supplier Hub
Assembly plant
(South-East Asia)
(Mainland China)
(South America)
Bare-bone
Regional Configuration Hub
Supplier Hub
KC Supplier
Full-set
Customer zones
NB manufacturer

BTO/CTO+DS model

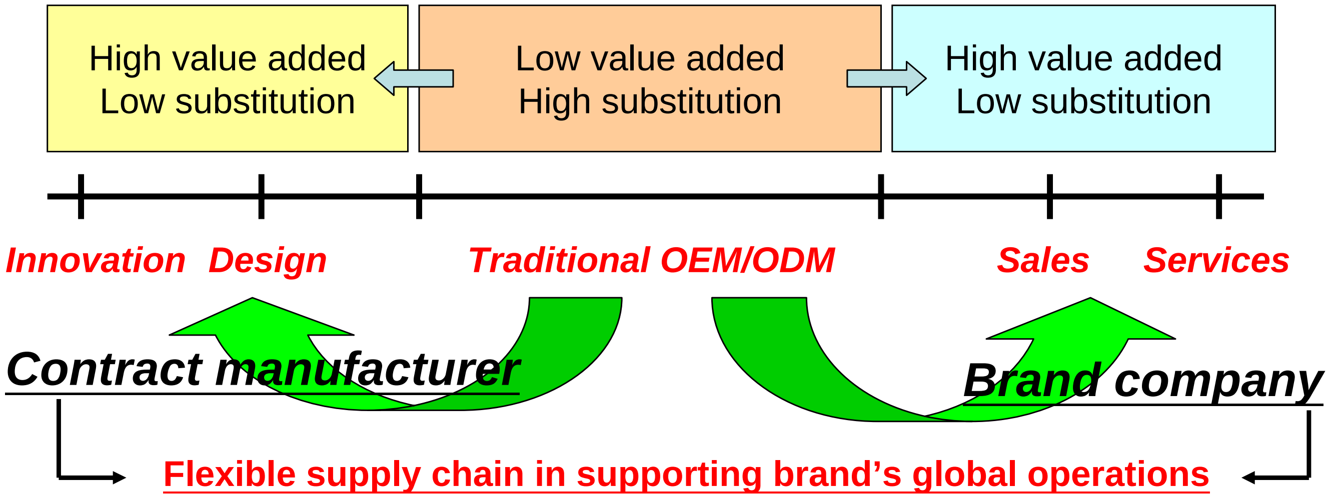

GC Supplier
Supplier Hub
KC Supplier
Configuration Hub
(Global)
Full-set
IT-Solution
Customer zones
NB manufacturer

Review Comments — Notebook- Computer Industry

- **The role of contract manufacturers**

Follower → Total solution provider

- **High value added based on seamless cooperation**



Flexible supply chain in supporting brand's global operations

---

Key Factors of Different Operational Model

■ *Literature Review*

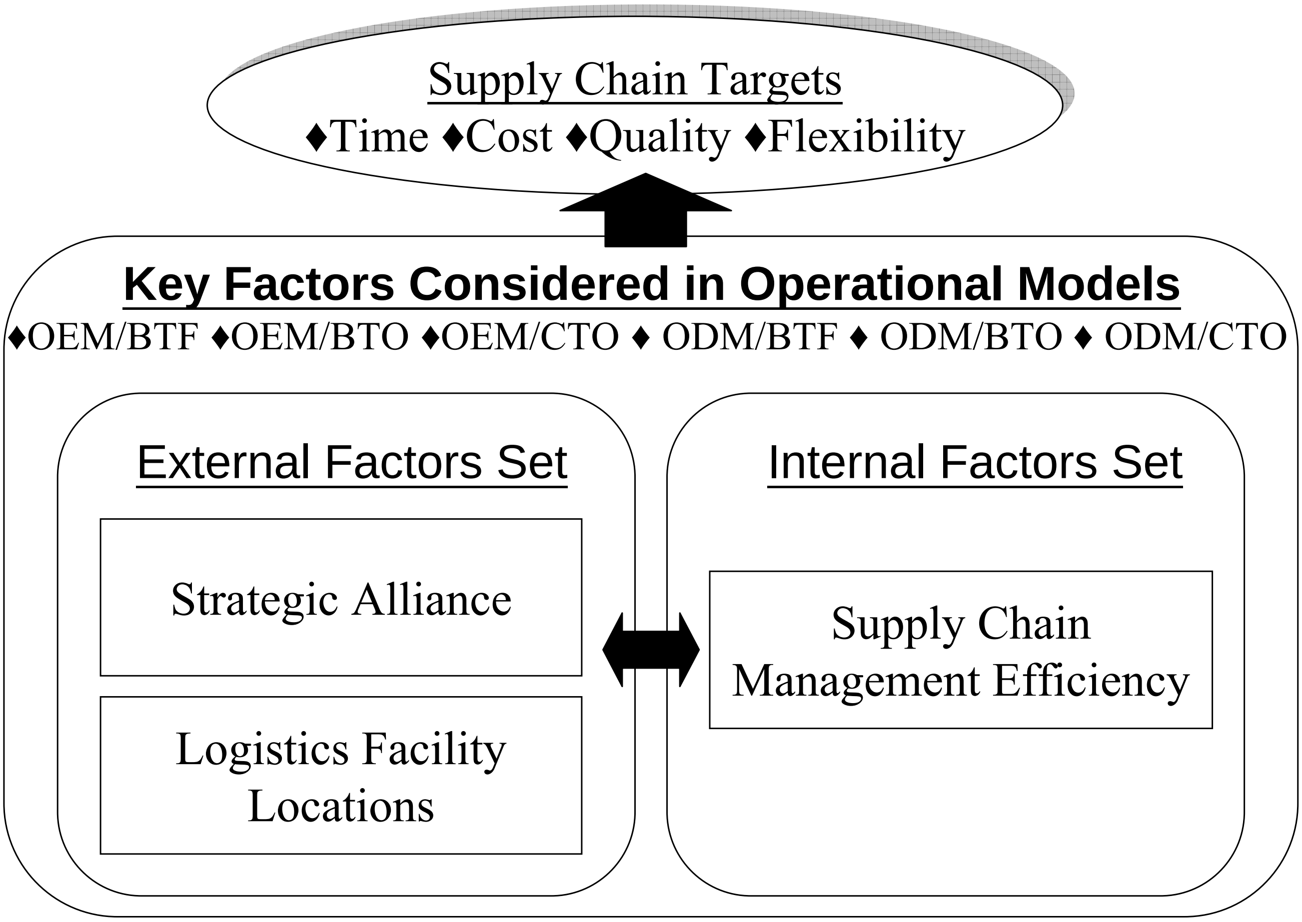
- ◆ 供應鏈競爭準則

時間、成本、品質、彈性 (Crowe 1991, Krajewski, 1999, Shin et al. 2000……)
創新、回應速度、服務 (Corbett 1992, Sweeney, 1993, Chen 1999….)

- ◆ 影響全球供應鏈因素

切入點	考量因素	相關文獻
全球佈局 區位選擇	勞工因素、市場因素、交通因素、土地因素、政府因素、聚集因素、金融因素、成本因素、服務因素、當地支援能力、外在環境與個人偏好	Hayyington (1983) Gold (1991) 李東杰 (1995) 戴琮哲 (2000) Sunil Chopra (2003)
國際製造 國際分工	接近因素（市場/顧客/供應商）、政府政策、法規因素、社會特質、稅制、取得資源因素(能源/資本/高技術勞力/低成本勞工)、資訊技術	Brush et. al. (1999) 戴琮哲 (2000) Courevitch et. al. (2000)
全球運籌 運籌策略	企業內部（產品範圍/產品型態）、績效管理、核心協調、行銷服務、外在環境（法律、匯率）、供應鏈作業(規劃、採購、製造、配送）、主要目標、存貨型式、全球佈點數	葉蕙 (1999) 張志華 (2000) 吳佳倫 (2001) 林呈衛 (2002)
策略聯盟	資源互補、組織文化、競爭地位	Sierra (1995) Devlin & Bleakly (1998)

■ *Analytical Framework*



Supply Chain Targets

♦Time ♦Cost ♦Quality ♦Flexibility

Key Factors Considered in Operational Models

♦OEM/BTF ♦OEM/BTO ♦OEM/CTO ♦ ODM/BTF ♦ ODM/BTO ♦ ODM/CTO

External Factors Set

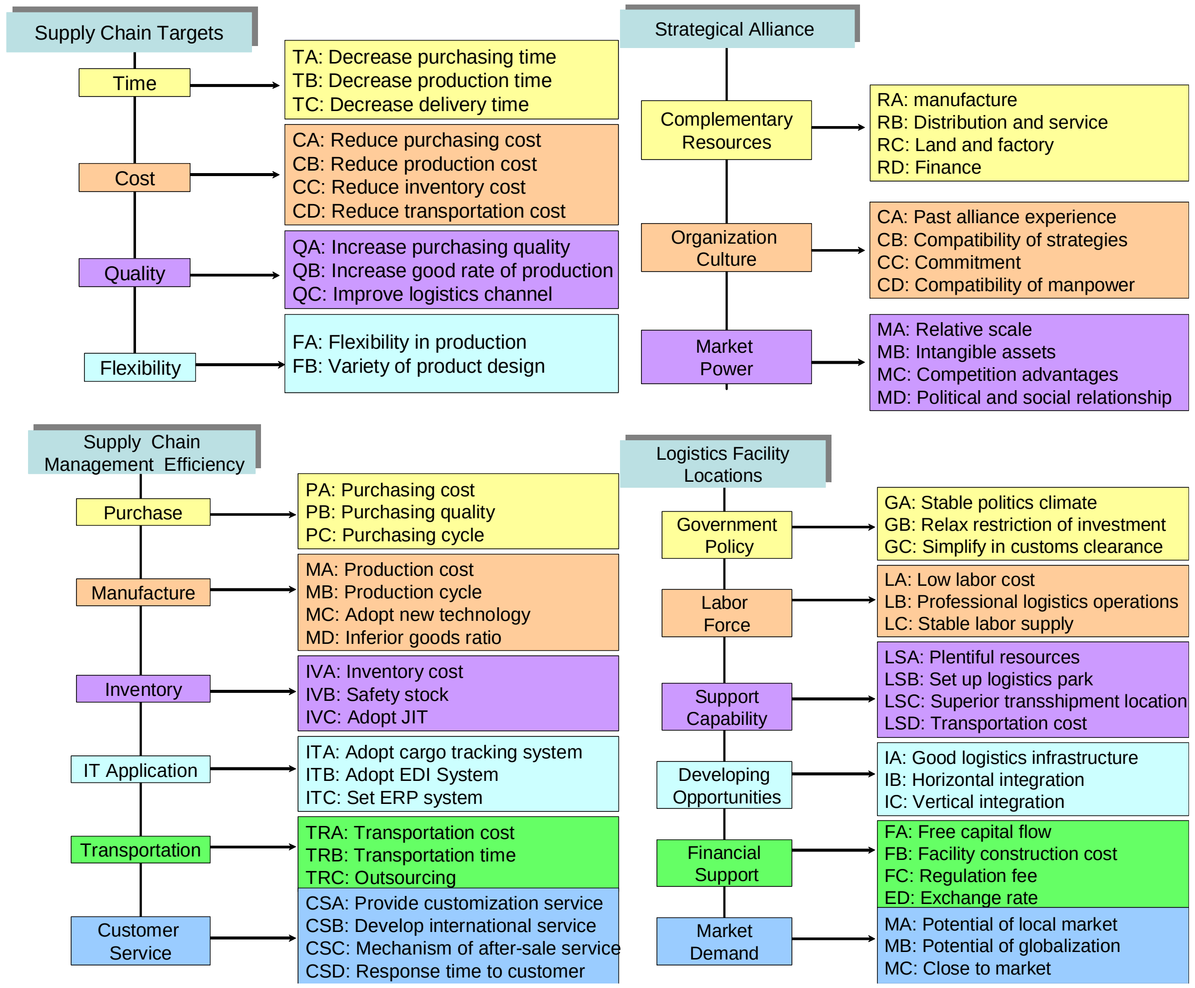
Strategic Alliance

Logistics Facility Locations

Internal Factors Set

Supply Chain Management Efficiency

■ Factor Sets in Different Dimensions



Supply Chain Targets

- Time
  - TA: Decrease purchasing time
  - TB: Decrease production time
  - TC: Decrease delivery time
- Cost
  - CA: Reduce purchasing cost
  - CB: Reduce production cost
  - CC: Reduce inventory cost
  - CD: Reduce transportation cost
- Quality
  - QA: Increase purchasing quality
  - QB: Increase good rate of production
  - QC: Improve logistics channel
- Flexibility
  - FA: Flexibility in production
  - FB: Variety of product design

Strategical Alliance

- Complementary Resources
  - RA: manufacture
  - RB: Distribution and service
  - RC: Land and factory
  - RD: Finance
- Organization Culture
  - CA: Past alliance experience
  - CB: Compatibility of strategies
  - CC: Commitment
  - CD: Compatibility of manpower
- Market Power
  - MA: Relative scale
  - MB: Intangible assets
  - MC: Competition advantages
  - MD: Political and social relationship

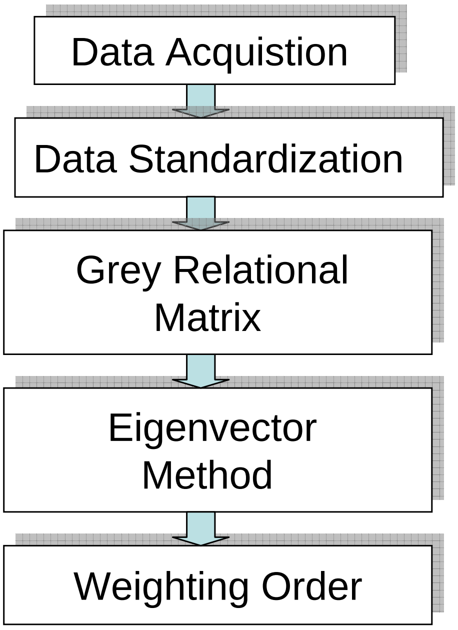
Supply Chain Management Efficiency

- Purchase
  - PA: Purchasing cost
  - PB: Purchasing quality
  - PC: Purchasing cycle
- Manufacture
  - MA: Production cost
  - MB: Production cycle
  - MC: Adopt new technology
  - MD: Inferior goods ratio
- Inventory
  - IVA: Inventory cost
  - IVB: Safety stock
  - IVC: Adopt JIT
- IT Application
  - ITA: Adopt cargo tracking system
  - ITB: Adopt EDI System
  - ITC: Set ERP system
- Transportation
  - TRA: Transportation cost
  - TRB: Transportation time
  - TRC: Outsourcing
- Customer Service
  - CSA: Provide customization service
  - CSB: Develop international service
  - CSC: Mechanism of after-sale service
  - CSD: Response time to customer

Logistics Facility Locations

- Government Policy
  - GA: Stable politics climate
  - GB: Relax restriction of investment
  - GC: Simplify in customs clearance
- Labor Force
  - LA: Low labor cost
  - LB: Professional logistics operations
  - LC: Stable labor supply
- Support Capability
  - LSA: Plentiful resources
  - LSB: Set up logistics park
  - LSC: Superior transshipment location
  - LSD: Transportation cost
- Developing Opportunities
  - IA: Good logistics infrastructure
  - IB: Horizontal integration
  - IC: Vertical integration
- Financial Support
  - FA: Free capital flow
  - FB: Facility construction cost
  - FC: Regulation fee
  - ED: Exchange rate
- Market Demand
  - MA: Potential of local market
  - MB: Potential of globalization
  - MC: Close to market

■ Key factors Selected and Methodology



Data Acquistion

Data Standardization

Grey Relational Matrix

Eigenvector Method

Weighting Order

$$x_i^*(k)=\frac{x_i(k)-\min[x_i(k)]}{\max[x_i(k)]-\min[x_i(k)]}$$

$$\gamma(x_0,x_i)=\frac{\max\limits_{\forall i}\max\limits_{\forall k}\left\| x_0(k)-x_i(k)\right\|-\bar{\Delta}_{oi}}{\max\limits_{\forall i}\max\limits_{\forall k}\left\| x_0(k)-x_i(k)\right\|-\min\limits_{\forall i}\min\limits_{\forall k}\left\| x_0(k)-x_i(k)\right\|}$$

$$\bar{\Delta}_{oi}=\frac{1}{n}\sum_{k-1}^{n}\left\|x_0(k)-x_i(k)\right\|$$

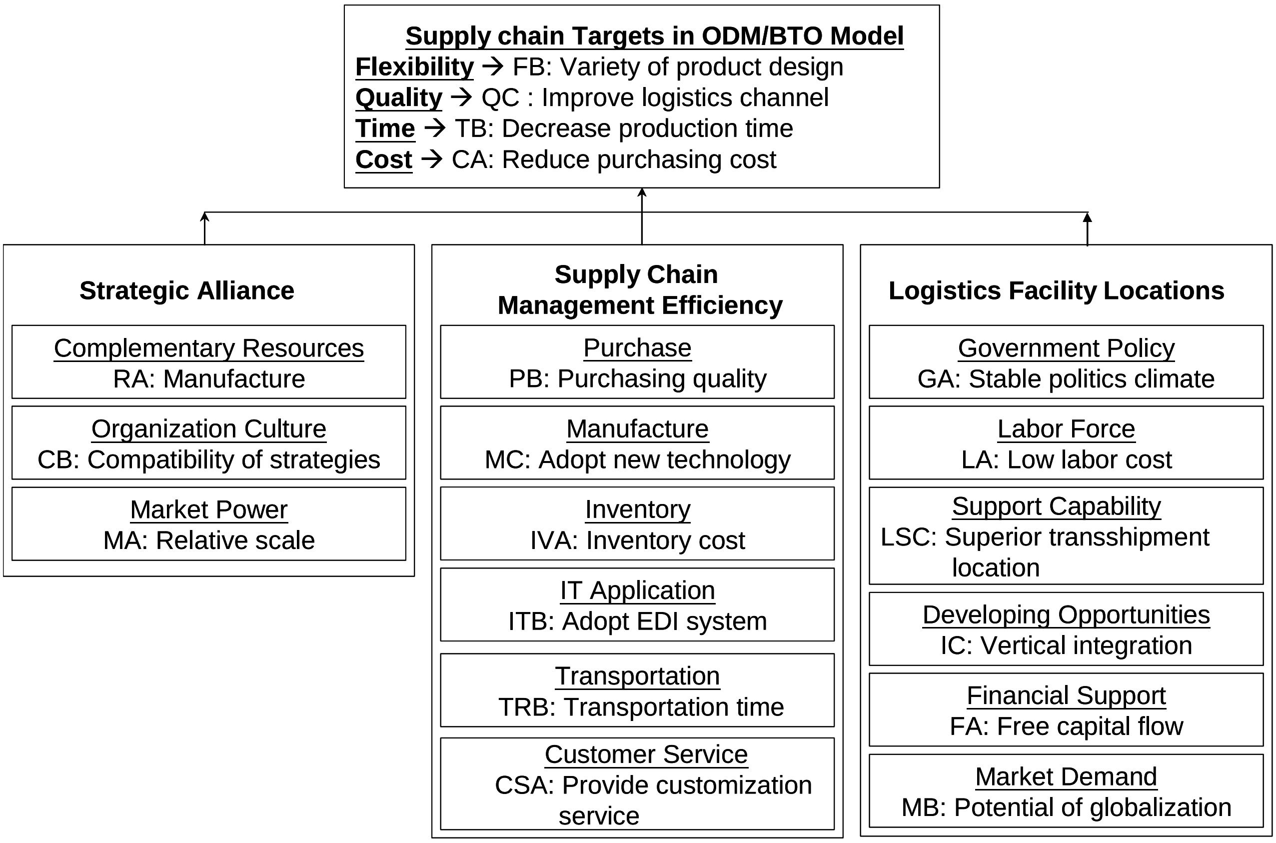
$R*X=\lambda*X$ → Weighting

(MATLAB)

→ Critical Attribute

	BTF	BTO	CTO
OEM	明基、華碩、志合、精英	英業達、大眾、華碩、明基、精英、倫飛、華宇、志合、藍天	神基、英業達、大眾、華碩、精英、倫飛、華宇、志合、藍天
ODM	仁寶、明基、華碩、志合、精英	倫飛、仁寶、廣達、大眾、志合、藍天、英業達、明基、華碩、精英	倫飛、仁寶、大眾、志合、神基、藍天、英業達、華碩、精英

Key factors Relational structure in ODM/BTO Model



Supply chain Targets in ODM/BTO Model
Flexibility → FB: Variety of product design
Quality → QC : Improve logistics channel
Time → TB: Decrease production time
Cost → CA: Reduce purchasing cost

Strategic Alliance
- Complementary Resources
  RA: Manufacture
- Organization Culture
  CB: Compatibility of strategies
- Market Power
  MA: Relative scale

Supply Chain Management Efficiency
- Purchase
  PB: Purchasing quality
- Manufacture
  MC: Adopt new technology
- Inventory
  IVA: Inventory cost
- IT Application
  ITB: Adopt EDI system
- Transportation
  TRB: Transportation time
- Customer Service
  CSA: Provide customization service

Logistics Facility Locations
- Government Policy
  GA: Stable politics climate
- Labor Force
  LA: Low labor cost
- Support Capability
  LSC: Superior transshipment location
- Developing Opportunities
  IC: Vertical integration
- Financial Support
  FA: Free capital flow
- Market Demand
  MB: Potential of globalization

Common / Different factors Considered in Different OEM Model

Classification		OEM		
		BTF	BTO	CTO
Common Key Factors	Supply Chain Management Efficiency	**Manufacture** – Inferior goods ratio **Inventory** – Inventory cost **IT Application** – Adopt EDI system **Transportation** – Transportation time		
	Strategic Alliance	**Complementary Resources** - Manufacture **Organization culture** - Commitment		
	Logistics Facility Locations	**Government Policy** - Stable politics climate **Labor Force** – Low labor cost **Support Capability** Superior transshipment location **Financial Support** – exchange rate		

Classification		OEM		
		BTF	BTO	CTO
Different Key Factors	Supply Chain Management Efficiency	**Purchase** Purchasing cost **Customer Service** Response time to customer	**Purchase** Purchasing quality **Customer Service** Provide customization service	**Purchase** Purchasing quality **Customer Service** Provide customization service
	Strategic Alliance	**Market Power** Competitive advantages	**Market Power** Competitive advantages	**Market Power** Relative Scale
	Logistics Facility Locations	**Developing Opportunities** Vertical integration **Market Demand** Potential of local market	**Developing Opportunities** Vertical integration **Market Demand** Potential of globalization	**Developing Opportunities** Good logistics infrastructure **Market Demand** Potential of globalization

Common / Different factors Considered in Different ODM Model

Classification		ODM		
		BTF	BTO	CTO
Common Key Factors	Supply Chain Management Efficiency	**Manufacture** – Adopt new technology **Inventory** – Inventory cost **IT Application** – Adopt EDI system **Transportation** – Transportation time		
	Strategic Alliance	**Complementary Resources** - Manufacture **Organization culture** - Commitment **Market Power** – Relative Scale		
	Logistics Facility Locations	**Government Policy** - Stable politics climate **Labor Force** – Low labor cost **Support Capability** Superior transshipment location		

Classification		ODM		
		BTF	BTO	CTO
Different Key Factors	Supply Chain Management Efficiency	**Purchase** Purchasing quality **Customer Service** Response time to customer	**Purchase** Purchasing quality **Customer Service** Provide customization service	**Purchase** Purchasing cycle **Customer Service** Response time to customer
	Strategic Alliance	--	--	--
	Logistics Facility Locations	**Developing Opportunities** Vertical integration **Financial Support** Exchange rate **Market Demand** Potential of local market	**Developing Opportunities** Vertical integration **Financial Support** Free capital flow **Market Demand** Potential of globalization	**Developing Opportunities** Good logistics infrastructure **Financial Support** Exchange rate **Market Demand** Potential of globalization

Conclusion Remarks

- OEM business model typically emphasize orders fulfillment and production quality control for quick response to multinational brand companies, and focus on improving manufacturing process to reduce the inferior goods rate, control inventory costs, establish an EDI system and reduce transportation time. In the aspect of logistics facilities locations, low labor cost, stable politics climate, and superior transshipment location are all influences on logistics. In the aspect of strategic alliance, commitments in coordinated operations and complementary resource in manufacture are emphasized.

- ODM manufacturers activate the process of product design, purchase, and manufacture according to the requirements of brand companies. Technological innovation, inventory cost control, EDI system application and reducing transportation time are important in supply chain management. ODM manufacturers thus support the supply chain of brand firms based on their ability and efficiency in innovative manufacturing. The main influences on supply chain layout are stable politics climate, low labor cost and superior transshipment location. The main determinants of strategic alliance formation include complementary manufacturing resources, commitment to coordinated operations, and relative scale between partners in terms of market power.

Conclusion Remarks

- BTF manufacturers are characterized by forecasting production. Order fulfillment is based on the comprehensive inventory of bare-bones. Therefore, minimizing the ratio of inferior goods is necessary to maintain acceptable supply quantity and quality. Meanwhile, it brings the risks associated with high inventory and manufacturing cost. Effective manufacturing process control is necessary to pay more attention to shortening lead times and reducing costs.

- Establishing a professional integration system is extremely important to BTO manufacturers. It makes them to react to the changeable market demand quickly. Based on consideration of cost and flexibility, delivery time must be shortened to a few days. Simultaneously, manufacturing strategies need to be adjusted from mass production to small batches to satisfy more frequent orders from brand companies. Consequently, efficiency and cost must be balanced to meet short-term global market demand. Additionally, the modular production mode is also necessary for BTO manufacturers to enhance supply chain operational efficiency. IT is indispensable in achieving seamless integration in monitoring stock levels and operational information.

Conclusion Remarks

- CTO manufacturers stress customization to end-customers. Most products have no fixed specifications, increasing the importance of production flexibility and commitment to clients. Limited quantity supply of a diverse range of products makes manufacturers inseparable from suppliers. Close communication and coordination is necessary to ensure smooth manufacturing process operation. The key to successful CTO model is well-organized strategic alliances, while vendor-managed inventory is necessary not only to avoid declining component prices, but also to increase efficiency through in-time reordering. Additionally, under pressure from uncertain orders and quick delivery requirements, it is essential for CTO manufacturers to establish a quick response logistics facility.

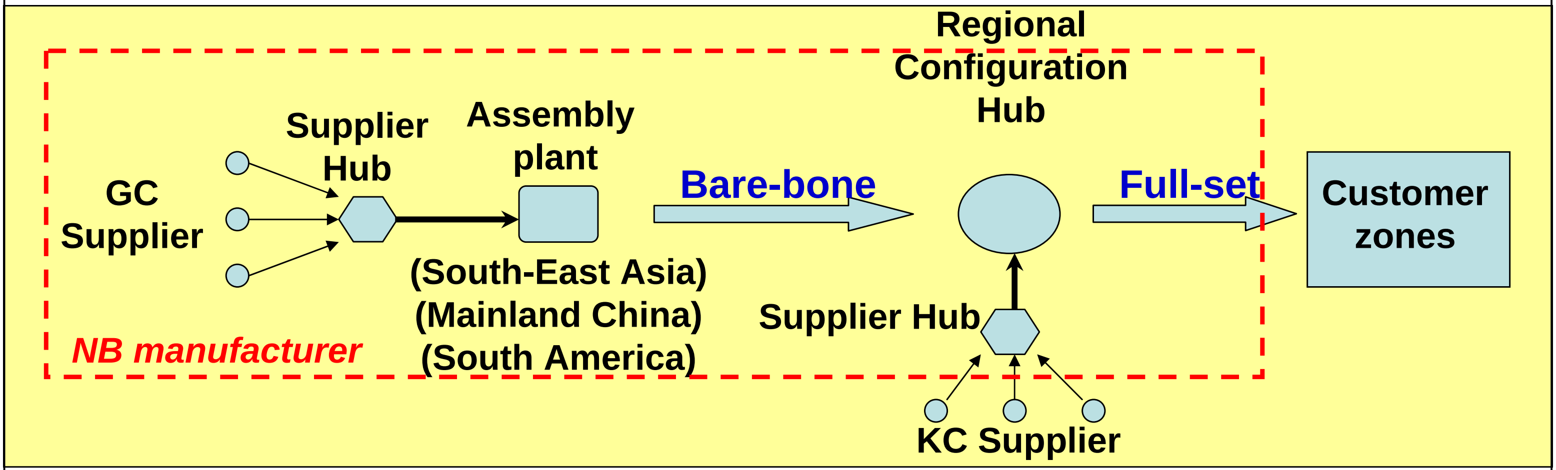
- This investigation is a pilot study that aims to understand the characteristics of Taiwanese notebook-computer manufacturers. The construction of reference models is helpful in describing and analyzing the global operations of such manufacturers from a macro perspective.

- Cost, Flexibility, customer service level (fill rate), lead-time are the core factors emphasized by contract manufacturers in quickly responding customers’ needs and supporting brands’ global operations. Such factors would be incorporated into supply chain design model.

Conceptual Framework in Supply Chain Design

Scope and Assumptions in Modeling

- Model structure was established according to BTO/CTO general model based on views of NB contract manufacturer.



- Supply Chain Flexibility was taken into consideration in planning stage for quick reaction to uncertainty from market requirements.
- NB manufacturer received orders from different brands. Logistics activities , such as component modules procurement, bare-bone assembly and full-set configuration could be arranged according to the BOM. Market demand is assumed to be deterministic.
- Cell operations are used in configuration hub. Therefore, Full-set configuration processing time is similar in different brands’ order types. The unit final assembly cost was assumed to be fixed.

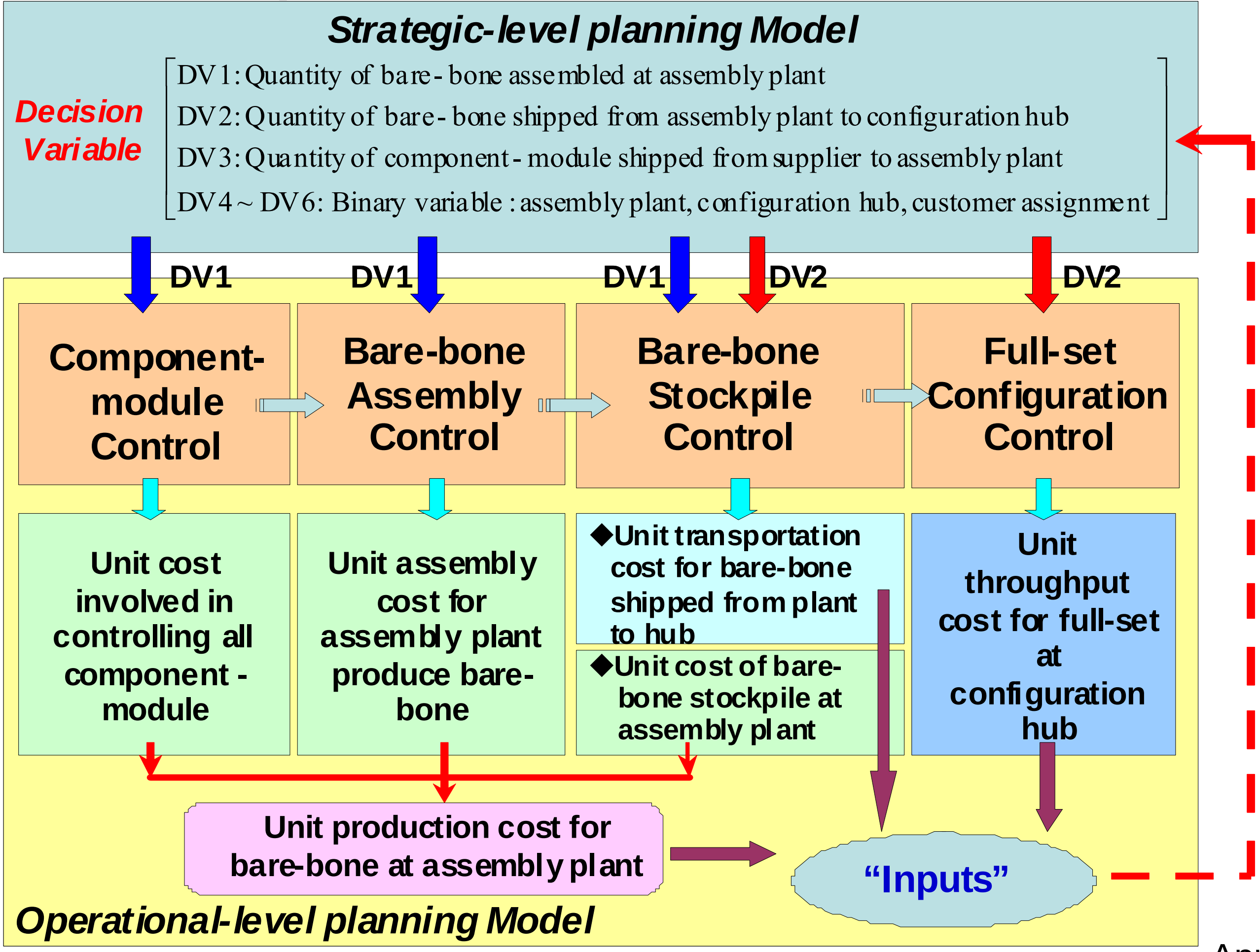
Scope and Assumptions in Modeling

- All the components were supplied in module items, The supply of GC-modules and KC-modules were based on VMI in supplier hub. Component module suppliers operated accompany NB manufacturer’s inventory control policy.

- Supply chain layout of assembly plant, configuration hub, and customer zone assignment were determined in the strategic-level planning model, outputs in this level would be as inputs in operational-level planning model for measuring the strategic impacts in operational performance.

- A process-oriented, analytical, and decomposed model was adopted in operational-level planning due to the limits on data collection. It consisted of “GC-module Control”, “Bare-bone Assembly Control”, “Bare-bone Stockpile Control”, and “Full-set Configuration Control” sub-models.

Overall Concepts in Model Structure



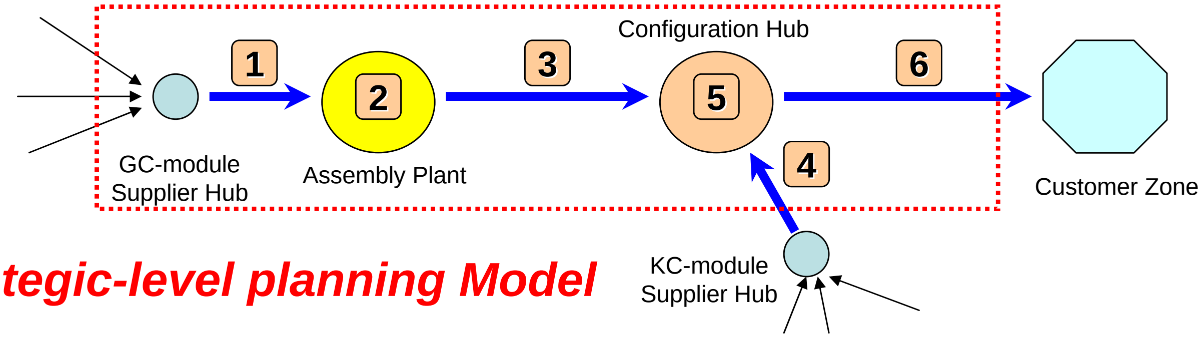
Strategic-level planning Model

Decision Variable

$$\begin{bmatrix} \text{DV1: Quantity of bare-bone assembled at assembly plant} \\ \text{DV2: Quantity of bare-bone shipped from assembly plant to configuration hub} \\ \text{DV3: Quantity of component-module shipped from supplier to assembly plant} \\ \text{DV4} \sim \text{DV6: Binary variable: assembly plant, configuration hub, customer assignment} \end{bmatrix}$$

Operational-level planning Model

Modeling and Applications in Supply Chain Design



Strategic-level planning Model

$$Z_1 = \underbrace{\sum_r\sum_v\sum_k (a_{rvk}+\lambda_{rvk})\boxed{A_{rvk}}}_{1} + \underbrace{\sum_k f_k \boxed{q_k} + \sum_i\sum_k \boxed{U_{ik}}\,\boxed{X_{ik}}}_{2} + \underbrace{\sum_i\sum_k\sum_m \boxed{c_{ikm}}\,\boxed{B_{ikm}}}_{3}$$

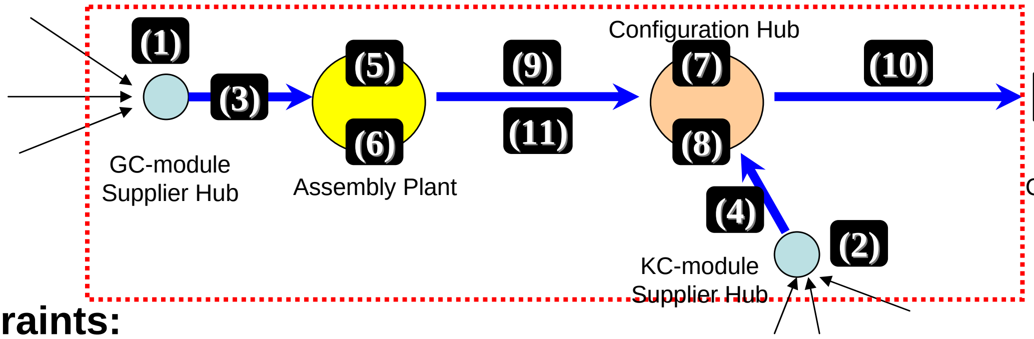
$$+ \underbrace{\sum_s\sum_m \left\{[a_{sm}+\lambda_{sm}]\left[e_{si}\left(\sum_k \boxed{B_{ikm}}\right)\right]\right\}}_{4}$$

$$+ \underbrace{\sum_m f_m \boxed{q_m} + \sum_j\sum_m \boxed{U_{jm}}\left(\sum_z D_{jz}\boxed{y_{mz}}\right)}_{5} + \underbrace{\sum_j\sum_m\sum_z d_{jmz}\left(D_{jz}\boxed{y_{mz}}\right)}_{6}$$

● $Z_2 = \sum_k\left(\boxed{q_k}\Phi_k - \sum_i \delta_{ik}\boxed{X_{ik}}\right)$

● $Z_3 = \sum_m\left(\boxed{q_m}\beta_m - \sum_j\sum_z \delta_{jm}D_{jz}\boxed{y_{mz}}\right)$

$$W = \left[\sum_k\left(q_k\Phi_k - \sum_i \delta_{ik}X_{ik}\right)\right]w_k + \left[\sum_m\left(q_m\beta_m - \sum_j\sum_z \delta_{jm}D_{jz}y_{mz}\right)\right]w_m$$



Constraints:

(1) $\sum_{k} A_{rvk} \le \Psi_{rv} \quad \forall(r,v)$

(2) $\sum_{m} \left[e_{si} \sum_{k} B_{ikm} \right] \le \Psi_{s} \quad \forall(s)$

(3) $\sum_{i} \tau_{ri} X_{ik} \le \sum_{v} A_{rvk} \quad \forall(r,k)$

(4) $\sum_{j} \tau_{sj} D_{jz} y_{mz} \le e_{si} \sum_{k} B_{ikm} \quad \forall(s,m)$

(5) $\sum_{i} \delta_{ik} X_{ik} \le \Phi_{k} q_{k} \quad \forall(k)$

(6) $\zeta_{ik} q_{k} \le X_{ik} \le \xi_{ik} q_{k} \quad \forall(i,k)$

(7) $\sum_{j} \sum_{z} \delta_{jm} D_{jm} y_{mz} \le \beta_{m} q_{m} \quad \forall(m)$

(8) $\alpha_{jm} q_{m} \le \sum_{z} D_{jz} y_{mz} \le \gamma_{jm} q_{m} \quad \forall(j,m)$

(9) $X_{ik} = \sum_{m} B_{ikm} \quad \forall(i,k)$

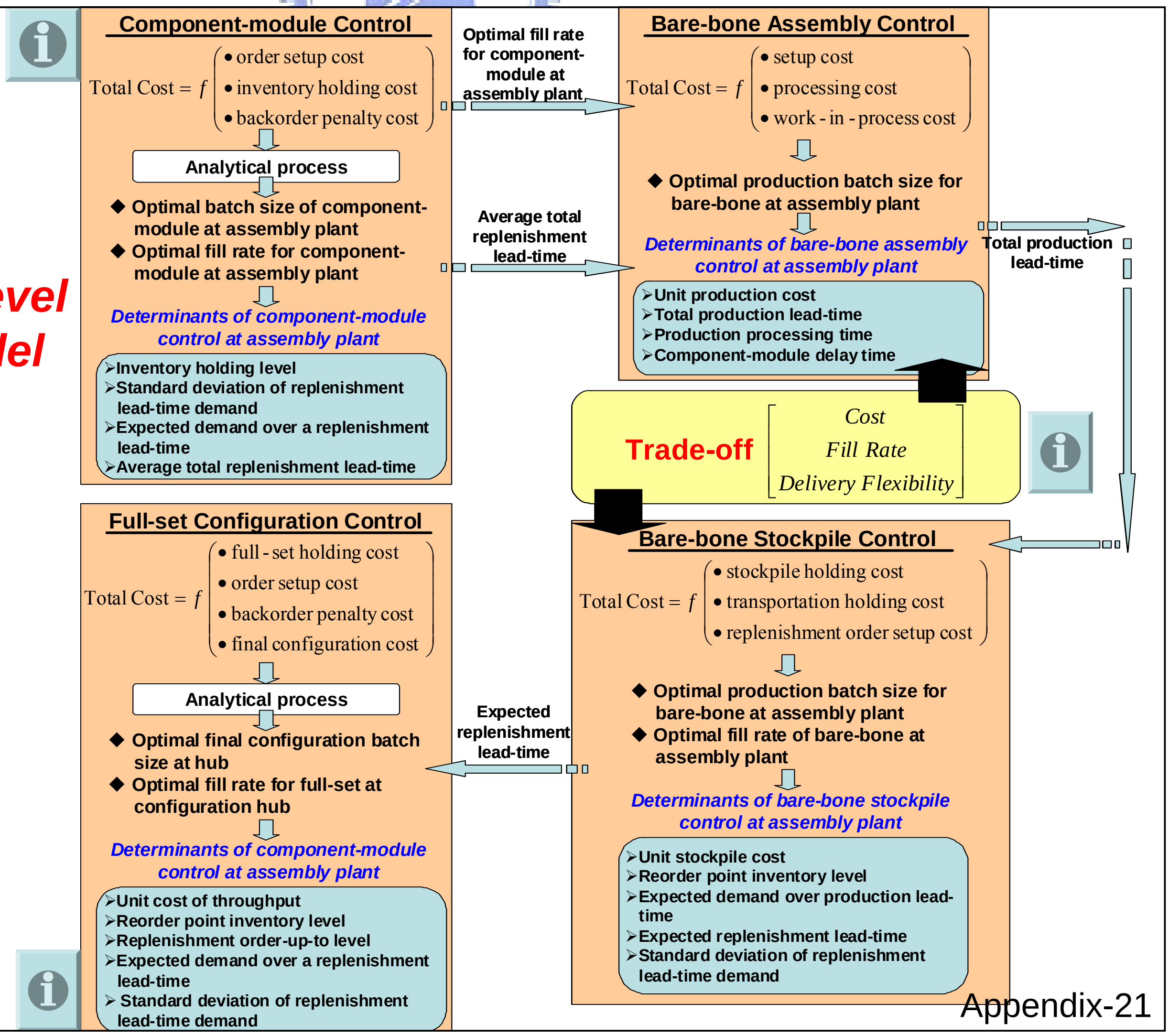
(10) $\sum_{k} \sum_{m} B_{ikm} = \sum_{j} R_{ij} \left(\sum_{m} \sum_{z} D_{jz} y_{mz} \right) \quad \forall(i)$

(11) $\sum_{k} B_{ikm} = \sum_{z} s_{ij} D_{jz} y_{mz} \quad \forall(i,m)$

(12) $\sum_{m} y_{mz} = 1 \quad \forall(z)$

$$(13)\ A_{rvk},\, X_{ik},\, B_{ikm} \ge 0\,; \quad q_{k},\, q_{m},\, y_{mz} = 0\,,1$$

Operational-level planning Model



Component-module Control

Total Cost = f
- order setup cost
- inventory holding cost
- backorder penalty cost

Analytical process

◆ Optimal batch size of component-module at assembly plant

◆ Optimal fill rate for component-module at assembly plant

Determinants of component-module control at assembly plant

- Inventory holding level
- Standard deviation of replenishment lead-time demand
- Expected demand over a replenishment lead-time
- Average total replenishment lead-time

Optimal fill rate for component-module at assembly plant

Average total replenishment lead-time

Bare-bone Assembly Control

Total Cost = f
- setup cost
- processing cost
- work-in-process cost

◆ Optimal production batch size for bare-bone at assembly plant

Determinants of bare-bone assembly control at assembly plant

- Unit production cost
- Total production lead-time
- Production processing time
- Component-module delay time

Total production lead-time

Trade-off

Cost
Fill Rate
Delivery Flexibility

Full-set Configuration Control

Total Cost = f
- full-set holding cost
- order setup cost
- backorder penalty cost
- final configuration cost

Analytical process

◆ Optimal final configuration batch size at hub

◆ Optimal fill rate for full-set at configuration hub

Determinants of component-module control at assembly plant

- Unit cost of throughput
- Reorder point inventory level
- Replenishment order-up-to level
- Expected demand over a replenishment lead-time
- Standard deviation of replenishment lead-time demand

Expected replenishment lead-time

Bare-bone Stockpile Control

Total Cost = f
- stockpile holding cost
- transportation holding cost
- replenishment order setup cost

◆ Optimal production batch size for bare-bone at assembly plant

◆ Optimal fill rate of bare-bone at assembly plant

Determinants of bare-bone stockpile control at assembly plant

- Unit stockpile cost
- Reorder point inventory level
- Expected demand over production lead-time
- Expected replenishment lead-time
- Standard deviation of replenishment lead-time demand

Operational-level Planning : GC-module Control Sub-model

$$TC_{rk}^{G}=q_k\left[\underline{\left(\sum_{i\in F_{rk}}\frac{\tau_{ri}X_{ik}}{Q_{rk}}\right)\theta_{rk}}+\underline{H_{rk}I_{rk}}+\underline{\pi_{rk}\sigma_{rk}}\right]\Rightarrow$$

(Silver & Peterson,1995)
(Sabri & Beamon, 2000)

Setup Cost + Holding Cost + Backorder penalty cost

$$I_{rk}=\frac{Q_{rk}}{2}+n_{rk}\sigma_{rk}\ ,\quad n_{rk}\approx\left(\frac{1}{2}\sqrt{\frac{\pi}{2}}\right)\ln\left(\frac{p_{rk}}{1-p_{rk}}\right)$$

$$s_{rk}=L_{rk}+n_{rk}\sigma_{rk}$$

$$L_{rk}=\left[\sum_{i\in F_{rk}}\tau_{ri}X_{ik}\right]\Theta_{rk}$$

$$\Theta_{rk}=\frac{\sum_{v}\left[u_{rvk}+\rho_{rv}(1-p_{rv})\right]}{v}$$

$$\mathrm{var}(\Theta_{rk})=\mathrm{var}\left(\frac{\sum_{v}u_{rvk}}{v}\right)+\mathrm{var}\left(\frac{\sum_{v}\rho_{rv}(1-p_{rv})}{v}\right)$$

$$\mathrm{var}(L_{rk})=\left[\sum_{i}\tau_{ri}X_{ik}\right]^2\mathrm{var}(\Theta_{rk}),\quad \sigma_{rk}=\sqrt{\mathrm{var}(L_{rk})}$$

Optimal order batch size

$$Q_{rk}^{*}=\frac{\partial TC_{rk}^{G}}{\partial Q_{rk}}=\sqrt{\frac{2\theta_{rk}\sum_{i}\tau_{ri}X_{ik}}{H_{rk}}}$$

Optimal fill rate

$$P_{rk}^{*}=\frac{\partial TC_{rk}^{G}}{\partial p_{rk}}=1-\frac{H_{rk}}{\pi_{rk}}$$

$$u_{rk}=\frac{TC_{rk}^{G}}{\sum_{i}\tau_{ri}X_{ik}}$$

$$\boxed{u_{ik}^{G}=\sum_{r}\tau_{ri}u_{rk}}$$

Operational-level Planning :

Bare-bone Assembly Control

$$TC_{ik}^{P}=q_k\left[\underline{\theta_{ik}\left(\frac{X_{ik}}{Q_{ik}}\right)}+\underline{\Gamma_{ik}X_{ik}}+\underline{\Omega_{ik}X_{ik}t_{ik}}\right]$$

$$=f(Q_{ik})$$

Setup Cost + Processing Cost +
Work-in-process Cost

$$t_{ik}=g_{ik}+h_{ik}+l_{ik}+\Theta_{ik}\qquad\xrightarrow{t_{ik}}$$

$$h_{ik}=\frac{Q_{ik}}{r_{ik}}\ ,\quad \Theta_{ik}=\underline{\underset{r\in Y_i}{Max}\left[\Theta_{rk}\left(1-p_{rk}^{*}\right)\right]}$$

$$\boxed{u_{ik}^{p}=\frac{TC_{ik}^{P}}{X_{ik}}}$$

Bare-bone Stockpile Control

$$TC_{ik}^{S}=q_k\left\{\underline{H_{ik}\left(\frac{Q_{ik}}{2}+n_{ik}\sigma_{ik}\right)}+\underline{\sum_{m}x_{ikm}B_{ikm}\left[N_{ikm}P_{ik}+E_{ikm}(1-p_{ik})\right]}\right.$$

$$\left.\underline{+e_{ik}\frac{X_{ik}}{Q_{ik}}(1-p_{ik})}\right\}=f(Q_{ik},p_{ik})$$

Stockpile Holding Cost + Transportation holding Cost
+ Replenishment Order Setup Cost

$$s_{ik}=L_{ik}+n_{ik}\sigma_{ik}$$

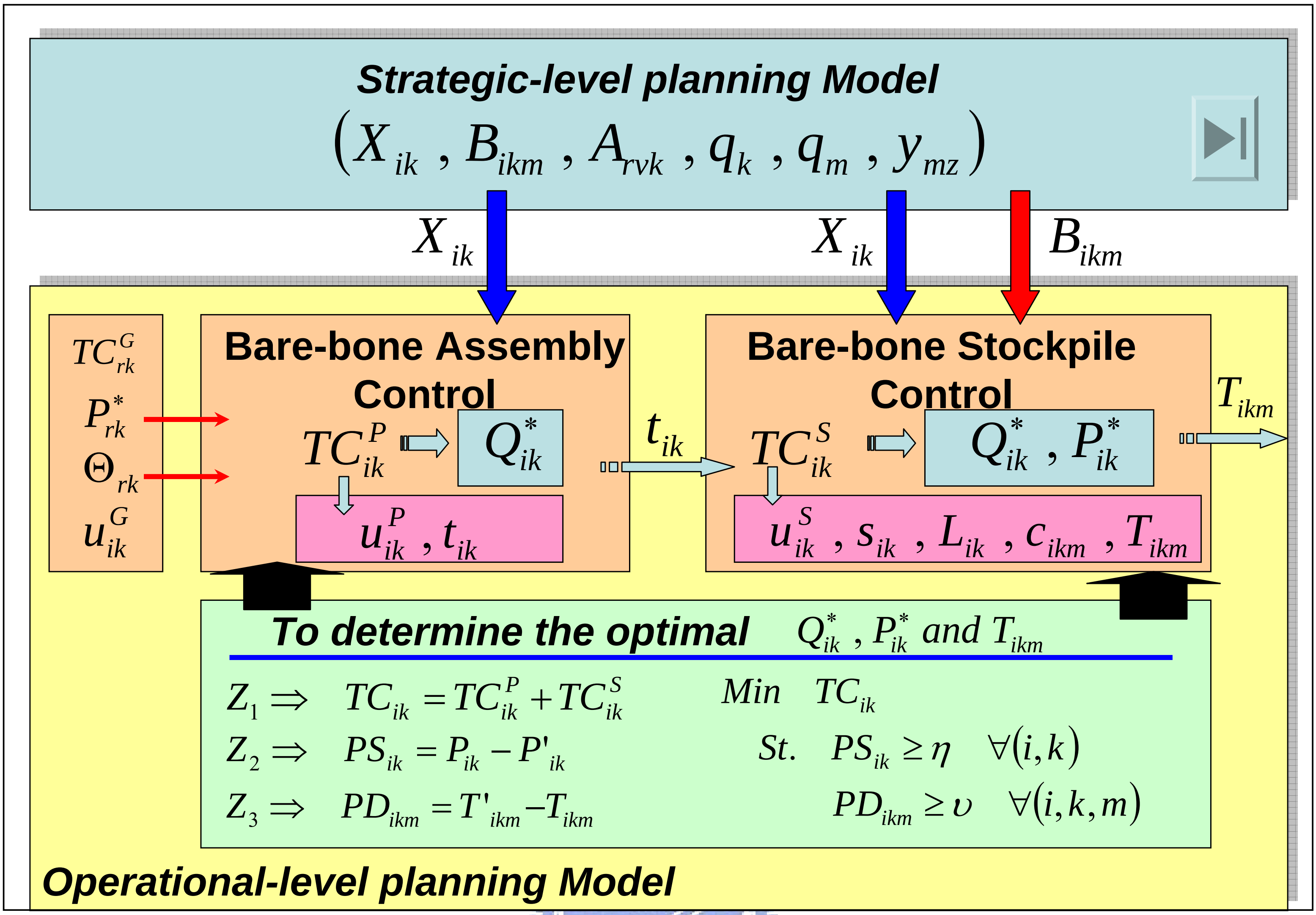
$$=X_{ik}t_{ik}+\frac{1}{2}\sqrt{\frac{2}{\pi}}\ln\left(\frac{P_{ik}}{1-p_{ik}}\right)\sqrt{\mathrm{var}(L_{ik})}$$

$$\mathrm{var}(L_{ik})=(X_{ik})^2\,\mathrm{var}(t_{ik})$$

$$T_{ikm}=N_{ikm}P_{ik}+(t_{ik}+E_{ikm})(1-p_{ik})$$

$$c_{ikm}=x_{ikm}\left[N_{ikm}P_{ik}+E_{ikm}(1-P_{ik})\right]$$

$$\boxed{u_{ik}^{S}=\frac{TC_{ik}^{S}}{X_{ik}}}$$



Strategic-level planning Model

$(X_{ik}, B_{ikm}, A_{rvk}, q_k, q_m, y_{mz})$

X_{ik} X_{ik} B_{ikm}

TC^G_{rk}

P^*_{rk}

Θ_{rk}

u^G_{ik}

Bare-bone Assembly Control

TC^P_{ik} ⇒ Q^*_{ik}

u^P_{ik}, t_{ik}

t_{ik}

Bare-bone Stockpile Control

TC^S_{ik} ⇒ Q^*_{ik}, P^*_{ik}

$u^S_{ik}, s_{ik}, L_{ik}, c_{ikm}, T_{ikm}$

T_{ikm}

To determine the optimal Q^*_{ik}, P^*_{ik} and T_{ikm}

$$Z_1 \Rightarrow \quad TC_{ik} = TC^P_{ik} + TC^S_{ik} \qquad Min \quad TC_{ik}$$

$$Z_2 \Rightarrow \quad PS_{ik} = P_{ik} - P'_{ik} \qquad St. \quad PS_{ik} \geq \eta \quad \forall(i,k)$$

$$Z_3 \Rightarrow \quad PD_{ikm} = T'_{ikm} - T_{ikm} \qquad PD_{ikm} \geq \upsilon \quad \forall(i,k,m)$$

Operational-level planning Model

Operational-level Planning : Full-set Configuration Control Sub-model

$$TC^F_{jm} = q_m \left[\underline{H_{jm}\left(\frac{Q_{jm}}{2} + n_{jm}\sigma_{jm}\right)} + \underline{\theta_{jm}\frac{\sum_z D_{jz}y_{mz}}{Q_{jm}}} + \underline{\pi_{jm}\sigma_{jm}} + \underline{I_{jm}\left(\sum_s \Omega_{sj}B_{jkm}\right)} \right]$$

Full-set Holding Cost + Order Setup Cost + Backorder Penalty Cost + Final Configuration Operation Cost

$$B_{jkm} = \frac{\sum_i R_{ij}B_{ikm}}{\sum_i R_{ij}} \qquad t_{jm} = \frac{\sum_k q_k T_{jkm}}{\sum_k q_k}, \qquad T_{jkm} = \frac{\sum_i R_{ij}T_{ikm}}{\sum_i R_{ij}}$$

$$L_{jm} = t_{jm}\sum_z D_{jz}y_{mz}$$

$$\mathrm{var}(L_{jm}) = \left(\sum_z D_{jz}y_{mz}\right)^2 \mathrm{var}(t_{jm})$$

$$\sigma_{jm} = \sqrt{\mathrm{var}(L_{jm})}$$

$$s_{jm} = L_{jm} + n_{jm}\sigma_{jm} = L_{jm} + \frac{1}{2}\sqrt{\frac{2}{\pi}\ln\left(\frac{p_{jm}}{1-p_{jm}}\right)}\sqrt{\mathrm{var}(L_{jm})}$$

$$S_{jm} = s_{jm} + Q_{jm}$$

Optimal Full-set Configuring Batch Size

$$Q^*_{jm} = \frac{\partial TC^F_{jm}}{\partial Q_{jm}} = \sqrt{\frac{2\theta_{jm}\left(\sum_z D_{jz}y_{mz}\right)}{H_{jm}}}$$

Optimal Fill Rate

$$P^*_{jm} = \frac{\partial TC^F_{jm}}{\partial p_{jm}} = 1 - \frac{H_{jm}}{\pi_{jm}}$$

$$\boxed{U_{jm} = \frac{TC^F_{jm}}{\sum_k B_{jkm}}}$$

Solving Methodology for Multi-objective problem

◆ ε **Constraint method is selected**

- No specific conditions are required
- Transform the problem into single-objective
- Specify the bounds on the objectives in a sequential manner
- The magnitude of ε reflects the relative importance of various objective to DMs

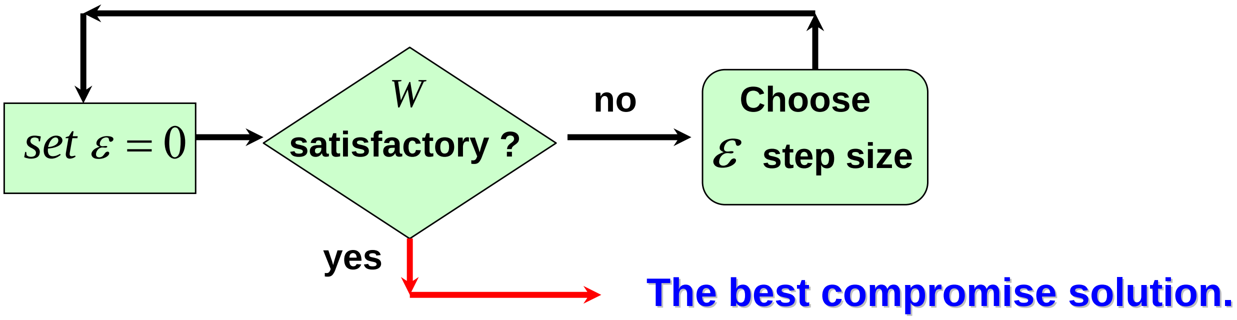
Strategic-level planning model

$$\begin{aligned} &Min\ Z_1 \\ &St.\quad W \geq \varepsilon \\ &\qquad \cdots\cdots\cdots \end{aligned}$$

$$Z_2 = \sum_k \left(q_k \Phi_k - \sum_i \delta_{ik} X_{ik} \right)$$

$$Z_3 = \sum_m \left(q_m \beta_m - \sum_j \sum_z \delta_{jm} D_{jz} y_{mz} \right)$$

$$W = \left[\sum_k \left(q_k \Phi_k - \sum_i \delta_{ik} X_{ik} \right) \right] w_k + \left[\sum_m \left(q_m \beta_m - \sum_j \sum_z \delta_{jm} D_{jz} y_{mz} \right) \right] w_m$$



$set\ \varepsilon = 0$

W **satisfactory ?**

no

Choose ε step size

yes

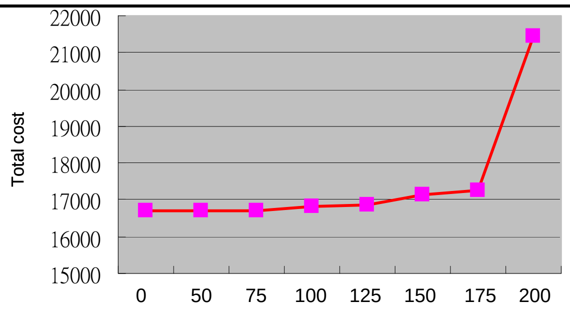
The best compromise solution.

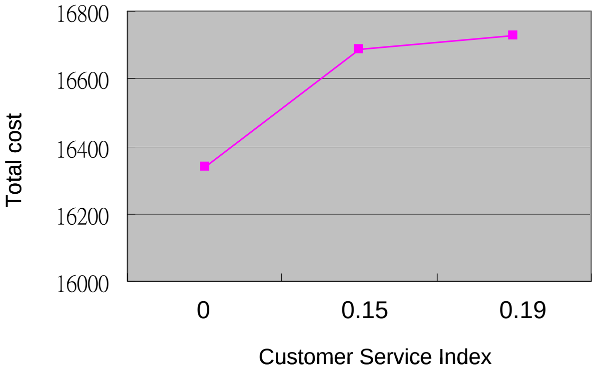
Case Study

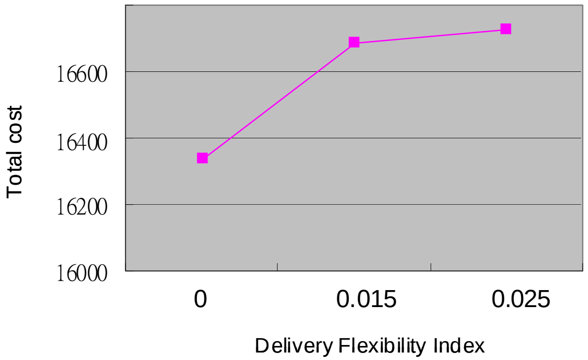
Scenario	ε	$w_k,\ w_m$	η, υ	***Performance index*** (Z, W, P_{ik}, T_{ikm})	***SC configuration*** (q_k, q_m, y_{mz})
1	0	0.5, 0.5	0, 0	(16337,35,0.8,0.04)	$[0,0,1],[0,1,1,0],\begin{bmatrix}0,0,0,0,0\\1,0,1,0,1\\0,1,0,1,0\\0,0,0,0,0\end{bmatrix}$
2	0	0.5, 0.5	0.15, 0.015	(16685,35,0.95,0.025)	$[0,0,1],[0,1,1,0],\begin{bmatrix}0,0,0,0,0\\1,0,0,1,1\\0,1,1,0,0\\0,0,0,0,0\end{bmatrix}$
3	100	0.5, 0.5	0, 0	(16575,135,0.8,0.04)	$[0,0,1],[1,1,1,0],\begin{bmatrix}0,1,0,0,0\\1,0,1,0,1\\0,0,0,1,0\\0,0,0,0,0\end{bmatrix}$
4	100	0.5, 0.5	0.15, 0.015	(16823,135,0.95,0.025)	$[0,0,1],[1,1,1,0],\begin{bmatrix}0,1,0,0,0\\1,0,0,1,1\\0,0,1,1,0\\0,0,0,0,0\end{bmatrix}$
5	100	0.9, 0.1	0, 0	(19649,127,0.8,0.04)	$[0,1,1],[0,1,1,0],\begin{bmatrix}0,0,0,0,0\\1,0,0,1,1\\0,1,1,0,0\\0,0,0,0,0\end{bmatrix}$

■ Numerical Example Summary Results (Sensitivity Analysis)

	Scenario #				
	1	2	3	4	5
# Assembly Plants	1	1	1	1	2
# Configuration Hubs	2	2	3	3	2
Volume Flexibility	35	35	135	135	127
Average Customer Service	0.93	0.983	0.93	0.983	0.93
Average Delivery Flexibility	0	0.015	0	0.015	0
Total Cost	16,337	16,685	16,575	16,823	19,649







Conclusions and Suggestions

Conclusions

- This study has applied grey relation analysis to select key factors for different global supply chain operational models adopted by Taiwanese notebook manufacturers. The hidden knowledge of the cooperative relationship between manufacturers and multinational brand companies can then be systematically described.

- The developed model (which consists of the conceptual framework, mathematical formulation, and solution algorithm) gives valuable insights into the modeling and analysis of complex SC configurations, and allows specific problems to be solved through coordinated decision-maker interaction.

- The key innovation lies in the integration of strategic and operational levels, and the associated linkages of decisions and performance measures. The model developed herein aids in the design of efficient, effective and flexible supply chains, and in the evaluation of competing SC networks for notebook-computer manufacturers.

Suggestions

- Collecting and using the real operation parameters to calibrate the cost function of each control sub-model. It will be very useful for comprehensive supply chain performance measurement.

- A comprehensive identification of SC flexibility could be further incorporated in supply chain design for notebook-computer industry.

Operational level	Strategic level	Network level
■Machine	■Volume	■Robustness
■Automation	■Delivery	■Relationship
■Labor	■Production	■Re-configuration
■Routing	■New design	■Logistics
■……….	■Expansion	■……….
	■……….	

- Facing the future challenges, contract manufacturers need to work together in global operations. What is the next step?

Integration in global facilities layout & establishment of supplier management platform

~ The END ~

Thanks for your listening

VITA

一、基本資料

中文姓名：陳其華
出生日期：57年01月30日
連絡住址：115台北市南港區成福路121巷62弄4號

二、學歷

國立交通大學	交通運輸研究所	博士
國立交通大學	交通運輸研究所	碩士
私立逢甲大學	交通工程與管理學系	學士

三、經歷

交通部運輸研究所所長室　研究員兼機要秘書(94.6~迄今)
交通部運輸研究所運輸經營管理組　研究員(92.6~94.5)
交通部運輸研究所運輸經營管理組　副研究員(90.7~92.5)
交通部運輸研究所運輸經營管理組　助理研究員(88.6~90.6)
台北市政府交通局局長室 機要秘書(87.10~88.5)
台北市政府交通局第一科　技士(87.1~88.5)
台北市政府交通局第二科　約聘研究員(85.7~86.12)
昭凌工程顧問股份有限公司　交通工程師(84.7~85.6)

四、資格與獎勵

專門職業及技術人員高等考試交通工程技師考試及格(81年)
公務人員高等考試交通技術職系交通工程科考試及格(86年)
交通部運輸研究所九十年度績優員工(90年)
交通部九十三年度模範公務人員(93年)
英國皇家物流與運輸協會ILT物流營運經理人職業證照(93年)
薦任公務人員晉升簡任官等訓練合格(97年)

五、論文著述

A. 國際期刊論文

Cheng-Min Feng, and Chi-Hwa Chern, “Key Factors Used by Manufacturers to Analyse Supply-Chain Operational Models: An Empirical Study of Notebook-Computer Industry”, International Journal of Management, Vol. 25, No. 4, 2008. (已獲得刊登邀請)

Cheng-Min Feng, and Chi-Hwa Chern, “The Development of A Supply Chain Design Model for The Notebook-Computer Industry”, International Journal of Management, Vol. 26, No. 2, 2009. (已獲得刊登邀請)

Cheng-Min Feng, and Chi-Hwa Chern, “Strategical-level Planning in Supply Chain Design for Notebook-Computer Industry”, International Journal of Logistics and SCM Systems, Vol. 2, No.1, 2009. (已獲得刊登邀請)

Cheng-Min Feng, and Chi-Hwa Chern, “Incorporating Strategic and Operational Planning in Supply Chain Design for Notebook-Computer Industry”. (已投稿 International Journal of Logistics Management，審查中)

B. 國內期刊論文

林繼國、陳其華，「示範性砂石車運輸管理系統之建置」，土木技術月刊，第 33 期，民國 89 年。

林繼國、陳其華，「台灣地區公路貨運產業發展之現況與展望」，全球運籌學刊，民國 91 年。

陳其華，「荷蘭國際物流發展經驗-以物流能力提昇其在國際上之競爭力」，物流新世紀 2003 特輯，第 229-247 頁，中華民國物流協會，民國 92 年。

C. 研討會論文

林繼國、陳其華，「台灣地區公路汽車貨運業種分類之研究」，中華民國運輸學會第十七屆學術論文研討會，民國 91 年。

陳其華、王穆衡、黃德治，「全球發展趨勢下的我國國家貨運發展政策」，運籌技術應用研討與展示會，第 48-64 頁，民國 93 年。

Cheng-Min Feng and Chi-Hwa Chern,"Exploring The Factors Affecting The Supply Chain Operational Model For Notebook-Computer Companies", Proceedings of Eastern Asia Society for Transportation Studies, Vol.2007, pp.132-145, 2007.