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Design And Development Of An Intelligent Agent-Based Supply Chain Simulation System

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Abstract

An intelligent agent-based supply chain simulation model, in which each enterprise/consumer is represented by an agent, is designed. There are six layers in this supply chain simulation model: raw material providers, component manufacturers, product assemblers, product holders, retailers, and final customers. Each entity in the supply chain represented by an agent has five components: interface, task distribution, business processing activities, knowledge management and decision support, and information storage. A detailed agent structure is designed and various functions of an agent including communication among agents are described. Issues in supply chain integration, information sharing among supply chain partners, demand forecasting, supply chain risk management, and automated communication and negotiation, could be simulated and studied by using the proposed system.

Based on the proposed supply chain simulation model, a generic six-layer prototype mobile phone supply chain simulation system is designed, developed and implemented. The system allows a user to setup and adjust a large number of parameters, including (1) simulation period, loan and saving interest rates; (2) customers' behavior and market demand; (3) each retailer's initial cash, loan, market share, inventories, Order Amount Policy and Order Point Strategy; (4) each product holder's initial cash, loan, market share, inventories, Order Amount Policy, Order Point Strategy and inventory strategy; (5) each assembler's and component agent's initial cash, loan, inventories, Order Amount Policy, Order Point Strategy, production strategy, and production capacities; and (6) each material provider's initial cash, loan, inventory, production strategy, and production capacities. Extensive simulation studies are carried out to examine and compare many supply chain management strategies and agent behaviors. This system can be used to test which strategy is most suitable in certain environments. The generic supply chain simulation system developed can be used in a number of ways, including: as an analysis tool for an entity in a supply chain from the entity's perspective; as a tool for studying supply chain coordination and integration from the perspective of an entire supply chain, or portion of it; as a tool to design supply chains by answering "what-if" questions.

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Nomenclature

C_{CM}^{CB}	the number of possible customer behavior values
C_{CM}^{DC}	the number of possible demand by customer values
C_{HO}^{OA}	the number of possible order point policies of Housing
C_{HO}^{OP}	the number of possible order point policies of Housing
C_{HO}^{PC}	the number of possible production capacities of Housing
C_{HO}^{PS}	the number of possible production strategies of Housing
C_{LD}^{OA}	the number of possible order amount policies of London
C_{LD}^{OP}	the number of possible order point policies of London
C_{LD}^{PC}	the number of possible production capacities of London
C_{LD}^{PS}	the number of possible production strategies of London
C_{LG}^{OA}	the number of possible order amount policies of Logers
C_{LG}^{OP}	the number of possible order point policies of Logers
C_{MH}^{OA}	the number of possible order amount policies of Markham
C_{MH}^{OP}	the number of possible order point policies of Markham
C_{MH}^{PC}	the number of possible production capacities of Markham
C_{MH}^{PS}	the number of possible production strategies of Markham
C_{MO}^{OA}	the number of possible order amount policies of Mokia
C_{MO}^{OP}	the number of possible order point policies of Mokia
C_{MO}^{SS}	the number of possible inventory strategies of Mokia
C_{MT}^{PC}	the number of possible production capacities of Metal
C_{MT}^{PS}	the number of possible production strategies of Metal
C_{NO}^{OA}	the number of possible order amount policies of Notorola
C_{NO}^{OP}	the number of possible order point policies of Notorola
C_{NO}^{SS}	the number of possible inventory strategies of Notorola
C_{PL}^{OA}	the number of possible order amount policies of Pell
C_{PL}^{OP}	the number of possible order point policies of Pell
C_{PB}^{OA}	the number of possible order point policies of PCBA
C_{PB}^{OP}	the number of possible order point policies of PCBA

C_{PB}^{PC}	the number of possible production capacities of PCBA
C_{PB}^{PS}	the number of possible production strategies of PCBA
C_{SI}^{PC}	the number of possible production capacities of Silicon
C_{SI}^{PS}	the number of possible production strategies of Silicon
CB	customer behavior when a product sold out
DC	demand by customers
HM Amount	the order amount in an *HM contract*
HM Contract	the total contract from Housing to Metal
HS Amount	the order amount in a *HS contract*
HS Contract	the total contract from Housing to Silicon
i	an product or component in agent *j*
j	an agent
LHM Amount	the order amount in a *LHM contract*
LHM Contract	the total contracts from London to Housing for Morkia Housing
LHN Amount	the order amount in a *LHN contract*
LHN Contract	the total contracts from London to Housing for Notorola Housing
LM Amount	the order amount in an *LM contract*
LM Contract	the total contracts from Logers to Mokia
LM Demand	market demand in Logers for Mokia phones
LM Sale	the sales amount of Logers for Mokia phones
LM Shortage	the shortage of Mokia phones in Logers
LN Amount	the order amount in an *LN contract*
LN Contract	the total contracts from Logers to Notorola
LN Demand	market demand in Logers for Notorola phones
LN Sales	the sales amount of Logers for Notorola phones
LN Shortage	the shortage of Notorola phones in Logers
LPM Amount	the order amount in a *LPM contract*
LPM Contract	the total contracts from London to PCBA for Morkia House

LPN Amount	the order amount in a *LPN contract*
LPN Contract	the total contracts from London to PCBA for Notorola Housing
MHM Amount	the order amount in an *MHM contract*
MHM Contract	the total contracts from Markham to Housing for Morkia Housing
MHN Amount	the order amount in an *MHN contract*
MHN Contract	the total contracts from Markham to Housing for Notorola Housing
ML Amount	the order amount in an *ML contract*
ML Contract	the total contracts from Mokia to London
MM Amount	the order amount in an *MM contract*
MM Contract	the total contracts from Mokia to Markham
MPM Amount	the order amount in an *MPM contract*
MPM Contract	the total contracts from Markham to PCBA for Morkia House
MPN Amount	the order amount in an *MPN contract*
MPN Contract	the total contracts from Markham to PCBA for Notorola House
MTO	make-to-order inventory strategy
MTS	make-to-stock inventory strategy
n(j)	total number of products and/or components in agent *j*
N1	number of raw material agents
N2	number of component agents
N3	number of assembly agents
N4	number of product holder agents
N5	number of retailer agents
N6	number of customer agents
NL Amount	the order amount in an *NL contract*
NL Contract	the total contracts from Notorola to London
NM Amount	the order amount in an *NM contract*
NM Contract	the total contracts from Notorola to Markham
OA	order amount policy

OP	order point strategy
OTO	Order-to-Order inventory strategy
PC	production capacity for manufacturing agents
PCM Amount	the order amount in a *PCM contract*
PCM Contract	the total contract from PCBA to Metal
PCS Amount	the order amount in a *PCS contract*
PCS Contract	the total contract from PCBA to Silicon
PM Amount	the order amount in a *PM contract*
PM Contract	the total contracts from Pell to Mokia
PM Demand	market demand in Pell for Mokia phones
PM Sale the	sales amount of Pell for Mokia phones
PM Shortage	the shortage of Mokia phones in Pell
PN Amount	the order amount in a *PN contract*
PN Contract	the total contracts from Pell to Notorola
PN Demand	market demand in Pell for Notorola phones
PN Sale	the sales amount of Pell for Notorola phones
PN Shortage	the shortage of Notorola phones in Pell
$profit_1$	the profit from an offer
$profit_0$	the profit from the negotiation strategy as defined by the *Strategy Selector* in the *Negotiation Support Module* or by the user
PS	production strategy for assembler and component agents
RFQ	request-for-quotation
SS	inventory strategy for product holder agents
STO	Stock-to-Order inventory strategy

Chapter 1 Introduction

Any kind of product that people consume cannot be manufactured and sold to customers by only one company. The product must complete many steps and pass through several companies. For example, any model of Nokia mobile phones needs approximately 350 components to make one device (Nokia, 2005). Many steps are required to make a mobile phone (Peterson, 2006; Reinhardt, 2006). First, mineral substances are obtained from mines and then are smelted to extract raw materials in raw material processing factories. Basic elements (such as resistors, capacitors, highly-integrated circuits, memory chips, plastic, metal and alloy) are produced by basic element manufacturers from raw materials. Components (such as liquid-crystal displays, keypads, plastic cases, printed circuit boards, batteries, buzzers, and antennas) are made in component manufacturing facilities using basic elements and raw materials. A mobile phone is then assembled and tested by an assembler. In order for a mobile phone to arrive at an end user, it is sold to a mobile telecommunication service provider, then it is delivered to a mobile phone retailer store, where the end user can buy it. Therefore, a mobile phone supply chain consists of the mining industry, raw material factories, basic elements and component manufacturers, the assembler, the mobile telecommunication service provider, the mobile phone retailer, and the end user. A supply chain is a set of related enterprises and consumers forming a network which produces and consumes a type of product. Enterprises may include raw material providers, vendors, manufacturers, warehouses, distributors, and retailers. In a supply chain, there are three typical flows: material in a forward direction, information bi-directionally, and currency in a backward direction. Some of the activities in a supply chain include: quotation, order (purchase), production, storage, delivery, sales, negotiation, and customer service.

Supply chain management is the science of designing and developing a set of technologies to make a supply chain work efficiently. The main stages of a supply chain include purchasing, manufacturing, distribution, and selling. Every entity in a supply chain is eager to minimize costs and maximize profits. This can result in conflicting purchase, production and sales strategies between partners. The objective of maximizing the whole supply chain value is more difficult because of the marketing uncertainty and information opacity. Since middle of the last century, many techniques and methodologies have been developed to make the supply chains more smooth and efficient. For example, enterprise resource planning (ERP) systems (such as SAP, Oracle-JD Edwards EnterpriseOne, Oracle-PeopleSoft Enterprise, and Microsoft Dynamics NAV) have been developed and applied to provide comprehensive and easily accessed data, and to implement supply chain functions within a business (Microsoft, 2007; Oracle, 2007a, 2007b; SAP, 2007). Vendor-managed-inventory (VMI) techniques have been developed to increase manufacturer's profits by satisfying customer demand with lower inventory, and decreasing retailers cost. To reduce inventory and to eliminate sources of manufacturing waste, the just-in-time (JIT) strategy, lean manufacturing, assemble-to-order (ATO), and make-to-order (MTO) policies have been developed. Other supply chain management technologies and tools have been developed including: manufacturing planning and control (MPC); customer relationship planning (CRP); material requirements planning (MRP); distribution requirement planning (DRP); enterprise application integration (EAI); business activity management (BAM) and; flexible manufacturing systems (FMS) (Vollmann et al., 2004).

The rapid growth of the Internet and of computer communication techniques has provided many opportunities for the improvement of processes and behaviors in supply chain management. Supply chain integration, which unites a business' internal processes with some external processes relating to its partners, is one of the important improvements. By using this technique, the business can eliminate redundancies, decrease errors, enhance efficiencies, reduce costs, and speed up product time to market (Wisner et al., 2005). The e-Supply chain, an Internet-based supply chain management technique, has the characteristics of high speed, low cost, fluent communication and collaboration among partners (Luo et al., 2001; Sadeh et al., 2003; Singh et al., 2005). The e-marketplace provides an easy and costless way for supply chain partners to exchange products (Brunn et al., 2002; Rudberg et al., 2002; Di Noia et al., 2004; Murtaza et al., 2004). The Internet also provides an efficient channel for supply chain partners to share information. Communication and negotiation between partners is the most important of all of those activities.

1.1 Supply Chain Characteristics

A supply chain is a dynamic, uncertain, stochastic, and complex network which is characterized by cooperation, collaboration and competition. It is highly reliant on information technology (IT). First, a supply chain faces many uncertainties and difficulties, such as the development of new products, and unpredictable events (factory fires or explosions, typhoons, and earthquakes). Second, the relationships among partners in a supply chain network are not only characterized by cooperation and collaboration, but also by competition. To reduce costs, every enterprise wants to obtain products and services from a partner at lower prices, while the partner's goal is to sell those products and services for maximum profit. Ultimately, a company's supply chain performance is highly dependent on the quality of the information system(s) applied. A good supply chain management software, such as SAP, PeopleSoft, or JD-Edward, allows the company to quickly make decision by immediately obtaining needed information.

Although supply chain management has been studied for many years, researchers will continue to search for ways to make improvement. In this research, when designing and developing an intelligent agent-based supply chain simulation system, many supply chain management methodologies, including supply chain integration, information sharing, demand forecasting, supply chain risk management, inventory management, supply chain intelligence, automated communication and negotiation, multi-agent technologies, customer/supplier relationship management, and multi-objective decision making, are considered.

1.2 Research Objectives

The overall objective of this research is to design and develop an intelligent agent-based supply chain simulation system. In this system, a company will be represented by an agent, and the agent structure will be designed according to the author's proposed supply chain focused enterprise architecture. Based on this system, some supply chain management related technologies can be tested and studied. The sub-objectives of this research include:

1. To design a supply chain focused enterprise architecture. The architecture considers all aspects of an enterprise, from external factors to internal factors; from soft factors to hard factors; from uncontrollable factors to manageable factors; and from equipment factors to knowledge factors.
2. To design an intelligent agent-based supply chain simulation model. The agent structure relies on the proposed enterprise architecture. The model describes the ability for communication and negotiation between agents, to utilize knowledge, to forecast customer demand, and to test supply chain management technologies.
3. To design, develop, implement, and test a prototype mobile phone supply chain simulation system. The system has six layers – customers, retailers, product holders, assemblers, component manufacturers, and raw materials. A large number of factors and parameters affecting the performance of a supply chain are considered.
4. To carry out extensive studies to examine many supply chain management strategies and agent behaviors, and to determine which strategy is most suitable in certain environments.

1.3 Organization of the Dissertation

The remainder of this dissertation is organized as follows. Chapter 2 surveys some current research directions and methodologies in supply chain management. Chapter 3 provides a description of the supply chain focused enterprise architecture model which the author designed. Chapter 4 discusses the intelligent agent-based supply chain simulation system model proposed by the author. The main structure of agents, communication and negotiation between agents, and the system processing mechanism are discussed. In Chapter 5, the author's design of a prototype mobile phone supply chain network is used to demonstrate how this simulation system works. Chapter 6 illustrates the implementation of a mobile phone supply chain simulation system. Chapter 7 and Chapter 8 contain testing and applications of the simulation system. In Chapter 9, conclusions and future work are discussed.

Chapter 2 Literature Review on Supply Chain Management

Supply chain management and logistics have been popular research topics for a long time. Some of the current research issues are:

- Supply chain integration (Van Der Vaart and Van Donk, 2004),
- Information sharing (Lee et al., 2004; Chen and Lee, 2009),
- Demand forecasting (Mentzer and Moon, 2005),
- Inventory management (Mishra and Raghunathan, 2004),
- Price discrimination (Chen et al., 2005; Anderson and Dana, 2009),
- E-marketplace (Laudon and Traver, 2004),
- Supply chain risk management (Jüttner et al., 2003),
- Automated negotiation and communication (Yuan and Turel, 2004),
- Knowledge management (Halley et al., 2010; Jin and Rong, 2011),
- Multi-objective decision making (Macal and North, 2002, 2005; Gupta and Sivakumar, 2005),
- Multi-agent technique (Nissen, 2001).

Although focused on different aspects including: making the entire supply chain more reliable, saving processing time, reducing supply chain failure risk, and increasing profits and decreasing costs, these methodologies and techniques have the same overall objective: to make a supply chain more efficient and effective.

2.1 Supply Chain Integration

Although there is no common definition of supply chain integration, its objective is to eliminate the barriers between business partners in order to make the supply chain more efficient (Naylor et al., 1999; Van Der Vaart and Van Donk, 2004). The challenge is how to coordinate partners in a supply chain in order to improve its performance in areas, such as reducing cost, increasing service level, and decreasing the bullwhip effect (Simchi-Levi et al., 2004). The ideal integration situation for a supply chain is that all the information about the supply chain should be shared among all the partners. This includes all the partners' inventory, production planning, demand forecasting, and real time orders. In reality, complete supply chain integration is an ideal but unattainable situation. It is difficult to implement because of distrustful relationships and asymmetry of information values (Simatupang and Sridharan, 2001). Current supply chain integration is focusing on sharing partial information, and has already brought significant value for many businesses. This is especially true for third party logistics companies and manufacturing supply chains using just-in-time (JIT), lean and agile strategies (Van Der Vaart and Van Donk, 2004).

Frohlich and Westbrook (2001) used arcs to represent the integration degree of a business supply chain. If a business only wants to share little information with its partners, it has a narrow arc of integration; if it wants to share more information, it has a broad arc. After examining 322 global manufacturing companies they classified them into five categories of integration arc degree depending on their supplier and customer integration strategies. Frohlich and Westbrook concluded that the broader the arc a business has, the more performance improved. Harrigan (1985) depicted supply chain integration from four integration dimensions: stage, breadth, degree and form. Stages of integration are the number of steps in a supply chain that the business wants to participate in, from initial ultra-raw materials to interaction with final consumers. Breadth of integration is the number of activities that the business performs at a stage. Degree of integration is the proportion of the total output of a product or service that the business holds. Form of integration indicates the ownership of an integrated unit.

Briscoe et al. (2004) demonstrated an integration technology that has emerged in the semiconductor industry. The function of managing components' quality in manufacturing is moved to the upstream first-tier and second-tier suppliers, using the

Standardized Supplier Quality Assessment (SSQA) criteria and the Small Business Operating System (SBOS). Other methods for helping supply chain integration include: vendor managed inventories (VMI); quick response; collaborative planning, forecasting and replenishment (CPFR); and multi-level supply control (MLSC). Siau and Tian (2004) presented a conceptual structure of supply chain integration using new technologies including: Wireless and Mobile Techniques, extensible markup language (XML), simple object access protocol (SOAP), common object request broker architecture (CORBA), distributed component object model (DCOM), Enterprise JavaBeans, .NET, and Semantic WEB. These technologies are based on both Internet and e-Business. Kemppainen and Vepsalainen (2003) analyze and predict trends in industrial supply chains and networks from the early 1990s to the early 2010s. Data was collected through 25 interviews with managers in six supply chains in electronics, mechanical and paper industries. In the early 1990's, companies often collected information from customers but did not share it with upstream partners (suppliers). Currently, most companies focus on integration with their first-tier suppliers and customers while some build up collaborative relationships extending to second-tier or even third-tier suppliers and customers. Business processes are the focus of integration. By the early 2010's, it is predicted that about half of businesses will focus on coordinating supply chains and networks, and supply chain integration will be focused on inter-enterprise processes. They confirmed that supply chain collaboration and information sharing are the keys to successful supply chain integration.

Hvolby and Trienekens (2010) reviewed various business integration models, such as supply chain operations reference-model (SCOR); collaborative planning, forecasting, and replenishment (CPFR); ISA-S95 (a standard of enterprise and manufacturing integration developed by the Instrumentation, Systems and Automation Society Consensus Committee); and specifications developed by open applications group (OAG). Although in the beginning the SCOR model only focused on planning, sourcing, making, and delivering, it has now added more processes including return, performance evaluation (delivery reliability, responsiveness, flexibility, costs and asset management efficiency), order fulfillment, and supplier relationships. CPFR focuses on planning, forecasting, and replenishment which can improve supply chain overall efficiency. ISA-S95 emphasizes business planning and logistics, manufacturing operations management, manufacturing process systems, and sensing production process. OAG concentrates on business information sharing through an extensive group of XML schemas. While ISA-S95 is good for design models and terminology, OAG is adept at describing implementation elements. With collaboration, OAG and ISA-S95 work well on the development of integration standards for process, discrete, and mixed-mode manufacturers.

2.2 Information Sharing

In a supply chain network, each participant has a lot of data and knowledge itself as well as its partners. This includes production planning, sales planning, procurement planning, inventory, productivity, forecasted demand, its suppliers and buyers, production/service capacity, production lead time, order lead time, delivery lead time, and historical sales data. Some of this knowledge is private while some is public. Many studies have confirmed: the greater the information sharing, the more efficient the supply chain.

A typical phenomenon in supply chain demand information asymmetry, also called demand variability or distortion, is the “bullwhip effect” (Lee et al., 1997). Because of lead times for some or all participants, and real time demand in downstream partners unable to be captured by upstream ones, demand information is amplified at every stage in a supply chain. Consequently, the inventory cost to the upstream side is raised. Lee et al. (2000) analyzed why and how the inventory cost is reduced with real time demand information sharing in a two level (manufacturing and retailing) supply chain. They also discussed techniques and methodologies developed by other companies and researchers to reduce the bullwhip effect from four aspects: demand signal processing, order batching, price fluctuations, and shortage gaming (Lee et al., 2004).

Simatupang and Sridharan (2001) illustrated the main benefits of information sharing in supply chains which include: helping participants achieve contractual clarity, allowing participants to respond quickly to market uncertainties, facilitating supply chain coordination, and reducing opportunistic behaviors. They designed a framework to illustrate the relationship between information sharing and decision making and explained how information is shared in this framework. In most situations information sharing will not bring equivalent benefit to each partner. As a result the lower benefitting participants occasionally prefer to provide distorted information. Methods to implement a win-win strategy, such as use of service levels, volume discounts, and wholesale price policies (Iyer and Bergen, 1997) as well as the employment of transfer pricing, consignment, and additional backlog penalty methods are discussed (Lee and Whang, 1999). The term supply chain collaboration, or collaborative supply chain (Simatupang and Sridharan, 2002; Barratt, 2004; Simatupang et al., 2004), is an application of information sharing in supply chains.

Gaur et al. (2005) studied the influence of demand information sharing in a two-stage supply chain model for three situations: (i) the manufacturer infers demand information from the retailer's orders; (ii) the retailer shares the demand information with the manufacturer; and (iii) the manufacturer uses the most recent orders in its production planning. They found that the manufacturer's safety-stock is reduced 16% in first two situations, but increased in the third.

Unlike most research, which assumes the retailer does not use order smoothing and the supplier has full knowledge of the retailer's demand model and order policy, Chen and Lee (2009) adopted a general retailer demand model combined with an order smoothing policy. They found that although the supplier does not know the retailer's demand model or order policy, information sharing could benefit both supplier and retailer.

Based on a reverse supply chain of the automobile industry, Olorunniwo and Li (2010) investigated information sharing and collaboration techniques and the supply chain performance of 600 companies. They found that information sharing increases collaboration among supply chain partners and directly improve supply chain performance. Conversely, they also found that collaboration between partners increases information sharing and enhances supply chain performance. They further pointed out that collaboration is the foundation of information sharing.

2.3 Demand Forecasting

Supply and demand forecasting is one of the most important elements for a successful supply chain. With forecasting information, decision makers can determine which selling/buying method(s) should be adopted, and can produce efficient production plans.

Forecasting is not a new topic and there are currently many forecasting approaches. DeLurgio (1998) classified forecasting methods into five categories:

(1) Time series methods including: simple regression, moving averages, exponential smoothing, decomposition, census method, univariate autoregressive integrated moving average (ARIMA), and Fourier series;

(2) Causal/multivariate methods including: multiple regression, multivariate ARIMA, and cyclical;

(3) Qualitative/technological methods such as: panel consensus, sales force composite, DELPHI, historical analogy, and relevance trees;

(4) Artificial intelligence methods including: expert systems, artificial neural networks, and genetic algorithms; and

(5) Combination methods.

In business marketing disciplines, demand forecasting often uses qualitative approaches (jury of executive opinion, sales force composite, survey of buyer intentions, and DELPHI), or quantitative methods (time-series techniques: moving average, trend fitting, exponential smoothing, adaptive control, and ARIMA) or, causal techniques (regression, econometrics, leading indicators, diffusion index, Input-Output analysis, and life-cycle analysis) (Bingham et al., 2005; Mentzer and Moon, 2005). Knowledge-based decision support systems and other artificial intelligence-based techniques are not very common in supply and demand forecasting due to their difficulty and complexity in implementation. DeLurgio (1998) stated that forecasting results which come from good models of expert systems, artificial neural networks and genetic algorithms are more reliable because of demand uncertainties.

Based on a simultaneous equations model (SEM) relating cost of sales, inventory and gross margin for retailers, Kesavan et al. (2010) presented a simultaneous equations forecast model. The model has many variables including: selling, general and administrative expenses, store growth, capital investment per store, index of consumer sentiment, accounts-payable-to-inventory ratio, and lagged values of cost of sales, inventory, and margin. To test the performance of the model, they used annual and quarterly data of many U.S. retailers listed on NYSE, AMEX, or NASDAQ for the 1993 to 2007 fiscal years. Compared with other time series forecasting models, this model is more accurate, because it has either a lower mean absolute percentage error or a lower median absolute percentage error.

Taylor and Xiao (2009) built a news-vendor supply chain model. The newspaper market has the following characteristics: demand uncertainty, short product life cycle, and retailers taken the price. In the model, the manufacturer adopted two promotion strategies for retailers: a rebate contract and a return contract. Using this model, they compared the whole supply chain performance between retailers using superior forecasting technology and retailers no forecasting. They found that both manufacturers and retailers benefit from the retailer's forecasting when using either return or rebate contracts. In addition, return contract is the optimal strategy among all contracts. The conclusion is suitable for computer, electronics, fashion, and toy industries.

2.4 Inventory Management

Inventory management affects supply chain efficiency. Inventory exists at many locations in a supply chain: raw material provider, factory, vendor, warehouse/distributor, and retailer. Current research on inventory management focuses on: (1) inventory strategies between vendor and retailers; and (2) inventory strategies for manufacturers.

The strategy of vendor-managed inventory (VMI), in which retailers' stock is controlled by the vendors or manufacturers, has been adopted by many retailers (Lee et al., 2000; Mishra and Raghunathan, 2004; Sari, 2007). After analyzing performance under retailer-managed inventory (RMI) and VMI strategies, Mishra and Raghunathan (2004) pointed out that VMI strategies intensified the competition between different manufacturers with similar products, and result in more profits for retailers. Benefits for retailers include reduced costs by transferring inventory costs to manufacturers, and less chance to lose sales because sufficient stock is provided by manufacturers. The main benefit for a manufacturer is that it will not lose customers. Sales can be increased by selling to competitors' customers when competing brands are out of stock. Moinzadeh (2002) analyzed the inventory performance of a multi-echelon inventory system with information exchange. In that system, Moinzadeh (2002) considered a single product with one supplier and multiple identical retailers using a Q and R policy (a retailer's order for Q units will be placed when its inventory position reaches R). Moinzadeh (2002) found that the supplier and retailers can significantly decrease inventory levels if the system shares inventory (or order) information at the retailers' side for intermediate Q values.

Haksever and Moussourakis (2005) presented a mixed-integer programming model to optimize multiple products' inventories under multiple constraints in manufacturing and service industries. Constraints included order numbers for each product, amount of each order, intervals between any two adjacent orders, and cycle time of each product. This model can deal with a large number of linear constraints and products, and can be solved using personal computers. Bollapragada et al. (2004) discussed the inventory management and supply performance problem in assembly systems with random supply capacities and demands. They presented a supply chain model with uncertain supply capacity, and discussed its impact on the steady-state inventory level. They further proposed a quick decomposition method to get near-optimal base-stock levels for components. This resulted in the possibility of reducing safety stock cost by one third. They pointed out that the cost reduction from improving supply performance was evident in the following situations: (1) demand variability is high; (2) the number of components is high; (3) the target service level is high; and (4) the end product is more expensive.

Shang et al. (2009) presented coordination mechanisms in decentralized serial inventory systems for batch ordering. For a multiple stage series inventory system, they analyzed three scenarios representing different information integration: echelon, local, and quasilocal. Each stage ordered an integer multiple of a base order quantity (or batch size) with fixed cost, linear holding and backorder cost. In the echelon scenario, in which each stage knows every other stage's inventory and cost information, they developed a coordination mechanism to achieve the true minimum long-run average cost. In the local scenario, in which each stage knows only its own inventory and cost, they developed a coordination mechanism to induce the stages to choose the best local-stock policy. In the quasilocal scenario, in which each stage knows its own inventory, cost and demand, they presented a similar coordination mechanism to achieve the optimal system-wide cost.

2.5 Price Discrimination

Expected prices of a product are different for different customers according to their purchasing power and spending strategies. By using a price discrimination method, a retailer can increase its profits. Varying prices in different stores (depending on competition), rebate promotion, and varying prices with different packaging are typical price discrimination examples.

Chen et al. (2005) analyzed the seller's profit after rebates. They pointed out: (1) the rebate promotion method is better suited to consumers with moderate incomes, but it does not benefit sellers who sell the goods to the very high or very low income consumers; (2) the rebate promotion method is better suited to new products, complex products, and occasionally purchased products, while it is not suitable for low involvement and simple products; (3) the greatest benefit of the rebate method is that some consumers do not redeem the rebates; (4) the redemption cost should be not too high or too low. They also compared the benefits from the rebate method with another price discrimination method – the coupon approach, and explained that the rebate method is more profitable for sellers than the coupon approach. Anderson and Dana (2009) pointed out that only few situations are suitable to adopting price discrimination strategies.

Another method of price discrimination is personalized pricing (PP), in which different customers are charged different prices by a firm according to the customer's willingness to pay. Choudhary et al. (2005) discussed the relationship between personalized pricing and quality differentiation, and the profit influence for firms that may or may not adopt PP tactics in various situations. They concluded the following: (1) for two firms in competition, if the low-quality firm applies a PP strategy, it should use a non-monotonic pricing schedule; (2) when a high-quality firm applies a PP strategy, other firms will enhance their product quality to compete with it; and (3) when the firm using PP has low quality, other firms will decrease their product quality to reduce their prices. Firms using PP acquire their profits by attracting more customers, while the benefit to the customer is the lower price or higher quality product.

By utilizing a stylized analytical model to identify and understand key trade-offs driving the decision to use a Name-Your-Own-Price (NYOP) retailing channel, Wang et al. (2009) discovered some phenomena and drew conclusions. When there is unsold capacity in a travel industry, the service provider cannot maintain high prices if he adopts a NYOP strategy. The service provider will only get profit if the available capacity is not too large relative to the expected number of business travelers and their willingness to pay. Before the extent of travel demand is known, it is better to set the wholesale price in the NYOP channel. If the service provider can determine optimal capacity, when the cost of this capacity is small, the single channel (NYOP) is a good choice. But when the cost of capacity is large, the dual channels of NYOP and contract are recommended. In addition, if the service provider adopts vertical integration, higher profits will be obtained.

2.6 E-marketplace

Electronic marketplace (e-marketplace) is a Web-based marketplace where buyers and sellers exchange information about their supply and demand to achieve business transactions. Laudon and Traver (2004) categorized e-marketplaces into four classes according to supply characteristics and partners' relationships: E-Distributor, E-Procurement, Exchange, and Consortia. After analyzing opportunities and challenges in e-marketplaces, Murtaza et al. (2004) pointed out that integration is one of the biggest challenges for a company joining an e-marketplace since most e-marketplaces cannot be integrated with back-end systems. An e-marketplace has two advantages over traditional marketplaces: market intelligence and supply chain integration (Bloch and Catfolis, 2001). Market intelligence does not mean that a buyer finds out the lowest price and a supplier finds out the highest price, but it implies that a buyer discovers the best supplier and the supplier discovers the best customers. Supply chain integration not only provides a better perspective for buyers and suppliers, but it also increases the processing transparency for them.

Brunn et al. (2002) presented an e-marketplace framework – Temple Framework, which has three parts: The Objective, The Challenge, and The Setup. The Setup is the foundation for an e-marketplace's success, and it has five elements: focus (to determine who will participate and what products should be included), governance (to decide who will manage the e-marketplace, and determine the bias or neutral strategy), functionality, technology, and partnerships. The Objective is to succeed as an e-marketplace, and The Challenge is to reach the objective which includes building liquidity and capturing value. From the buyer, seller, and information system manager's views, Yuen (2010) presented some points to construct an e-marketplace framework in supply chain management.

Poundarikapuram and Veeramani (2004) developed a distributed decision-making model by using an integer L-shaped method to solve supply chain and private e-marketplace problems. Compared with the clumsy (due to computational complexity), centralized decision-making model, this model reduced the problem size by letting each player solve its own sub-problem with local information. They also developed some iterative algorithms to solve these problems, and results showed that this model is more efficient and feasible than the centralized model. Fang and Wang (2005, 2006) designed an online combinatorial auction system. Comparing with single item auctions, this system allows auction of a combination of desired items.

Grey et al. (2005) analyzed the advantages and disadvantages of e-marketplaces and traditional relationship-based contracting methods in B2B transactions. Benefits for supply chain partners from relationship-based contracts include decreasing transaction and agency costs, improving information sharing for production coordination, customized pricing, and price stickiness. The potential profits for e-marketplace participants include improving resource allocation efficiency, enhancing both information collection and aggregation level, and improving risk management ability. They proposed some methods that drive a relationship-based supply chain to conduct B2B transactions, such as developing market liquidity, retaining the value associated with long-term supply chain relationships, and creating a win-win environment for participants.

Overby and Jap (2009) observed two channels (e-marketplace and physical) in the used vehicle industry for two and half years. They found that buyers have to face a trade-off between low transaction cost and uncertain quality. They further found that vehicles with low uncertainty related to their quality rarely appeared in the e-marketplace. Conversely, vehicles with high uncertainty related to their quality often appeared in the e-marketplace.

2.7 Supply Chain Risk Management

After summarizing supply risk descriptions given by other researchers, Zsidisin (2003) presented a definition:

> "Supply risk is defined as the probability of an incident associated with inbound supply from individual supplier failures or the supply market occurring, in which its outcomes result in the inability of the purchasing firm to meet customer demand or cause threats to customer life and safety." (p.222)

Uncertainty in demand and supply is a risk for a supply chain. Jüttner et al. (2003) classified the sources of supply chain risk into three categories: environmental risk sources, network-related risk sources, and organizational risk sources. Environmental risk sources are accidental events that come from external events, such as fire, terrorist attack, hurricane, and earthquake. Network-related risk sources include lack of ownership, chaos and inertia. Organizational risk sources are events that happen within supply chain partnerships such as machine failure, labor strike, and system failure. Jüttner et al. (2003) pointed out some factors that increase the risk level: a focus on efficiency more than effectiveness; supply chain globalization; focused manufacturing and centralized distribution; outsourcing trend; and reduction in the supplier base. Following the standpoint of Miller (1992), they gave some strategies to mitigate supply chain risk: avoidance, control, co-operation, and flexibility.

Christopher and Lee (2004) pointed out that visibility and control are two main methods to reduce supply chain risk, in which information sharing among supply chain members is the key to increasing visibility. They further gave some approaches to mitigate supply chain risks: increasing information accuracy, visibility and accessibility; informing business partners when breaking control conditions occur; and providing corrective action. Grey et al. (2005) also presented some methodologies to manage supply chain risks, such as using spot markets or dynamic pricing and revenue management to manage demand risk, and using spot and derivative markets to manage price risk. Giunipero and Eltantawy (2004) pointed out four factors that affect the level of investment in supply chain risk management: product technology level, requirement for security level, the degree of supplier's importance, and buyers' prior experience level. They presented four theories: (1) high technology markets need to pay more attention to risk management than low technology markets; (2) suppliers whose items require high security need to pay more attention to risk management than those whose items that require low security; (3) suppliers that provide large volume, value and/or critical goods need to pay more attention to risk management than those that provide a small number of and/or less important items; (4) less experienced suppliers need to pay more attention to risk management than experienced suppliers.

Harland et al. (2003) surveyed risks in supply networks, and further presented a supply network risk tool for helping to identify, evaluate and manage risk in a supply network. The tool included six actions: map supply network, identify risk and its current location, assess risk, manage risk, form collaborative supply network risk strategy, and implement supply network risk strategy. By using this tool iteratively in four cases, they showed that the visibility of risk has increased.

Chen and Yano (2010) studied a manufacturer-retailer supply chain for a seasonal product with weather sensitive demand. They presented a weather rebate contract model. The model can achieve supply chain coordination and can provide Pareto improvement without increasing wholesale price, and it does not need inventory or markdown audit. The model is not only easy to implement, but is also very flexible. It allows broad functional forms and parameter values.

2.8 Automated Communication and Negotiation

Communication and negotiation are indispensable in a supply chain, and they happen everywhere. For example, when a business buys or sells products, it has to inquire or negotiate with its trade partners about the price and delivery time. When a customer receives a defective product or the product is not as anticipated, the customer has to negotiate with its supplier about the method (e.g., return, exchange, or repair) for fixing the problem and the required processing time. Traditional communication and negotiation are conducted face-to-face, or by telephone, fax, or mail. The development of Internet technologies provides us with a digital channel – electronic negotiation (e-Negotiation), in which negotiation relies on electronic media to transmit information (Kersten, 2003). Media include e-mail, forum, blackboard, chat-room, and software agents. Recently, e-Negotiation research has mainly focused on automated negotiation or agent-based negotiation, in which negotiation is conducted automatically by a computer software system (agent).

Jennings et al. (2001) described an outline and a generic framework of automated negotiations, including negotiation protocols, negotiation objectives, and agents' decision models. They also discussed how to design a particular negotiation strategy, based on game theory which maximizes the agent's own profit. Yuan and Turel (2004) summarized existing e-Negotiation services, which included process support, decision support, contract management, and training. In addition, they presented an e-Negotiation business service model, which had the following components: market demand, service type, customer value, cost structure, revenue source, issues of using services, and sustainability. Bichler et al. (2003) discussed negotiation media and systems (tools, agents and platforms) from the viewpoint of computer science and information systems, and negotiation procedures and models (strategies, tactics and techniques) from the standpoint of economics, management, law, and social sciences. They also presented some characteristics of auctions and negotiations and their interrelation.

Fang and Wong (2010) presented a hybrid case-based reasoning automatic negotiation model. Unlike many other agent-based negotiation models, in which negotiation process was limited to the stage when agents interact to exchange bargaining offers, their model is applied to the phases of pre-negotiation and post-negotiation. For a new negotiation problem, the model will search for a similar previous negotiation case then adjust the negotiation parameters to get a possible conclusion. The user may also adjust those parameters to meet the conditions. If the conclusion is desired, it will be added to the negotiation case library for future usage.

2.9 Multi-Objective Decision Making

In a supply chain, decision makers often confront situations, in which they have to choose one solution from a number of possible solutions (Hines, 2004). For example, consider a situation where a company needs to purchase a type of component. Many sellers produce this type of component, but they offer different prices, qualities, and delivery times, and have different reputations. The buying company wants a lower price, higher quality, and a lower probability of delivery delay or failure. The best solution may not be the one that offers the lowest price, depending on the trade-off among the buyer's objectives. In this example, the decision maker may also face a strategic dilemma: which method should be used – auction or long-term contract, because each method has its own advantages and disadvantages. When a company develops a new product or upgrades a current product, it encounters issues of how to balance cost, quality and reputation. These situations involve multi-objective decision making.

Methodologies have been developed to solve multi-objective decision problems. The most popular method is the multi-objective utility analysis approach, which transfers multiple objectives to one overall objective function (Kirkwood, 1997; Sabri and Beamon, 2000; Gupta and Sivakumar, 2005). In this method, any objective is represented by a utility function, and the overall objective function is the sum of these utility functions multiplied by their weights. Luo et al. (2001) proposed a fuzzy logic-based optimization model to solve multi-objective problems in a global and Internet-based manufacturing supply chain. Their model dealt with three types of problems on given e-business information networks and material flow networks: (1) choose proper material flow networks for a product's supply chain; (2) choose the best combination of partners for a supply chain; and (3) optimize material flow networks and e-business information networks simultaneously. Some variables in a supply chain cannot be evaluated by a crisp value. For example, information sharing or acquiring ability may be based on a linguistic statement of "unclear, little, normal, most, or complete", and reliability of a system is based on a statement of "excellent, good, fair, or poor". These variables are easily represented by fuzzy sets, and using fuzzy optimization models is a convenient method for solving these problems. Another example is a genetic algorithm presented by Joines et al. (2002) for optimizing a supply chain simulation model. First, the system generates a few solutions as initial population. Then the system ranks them according to their fitness (overall objective value). After generating some new population randomly from randomly selected parents, the system ranks the population again, and it eliminates the last solutions to keep the population size unchanged. Carrying out these steps a number of times (often many thousands of times), the optimal solution in the last sample population is selected as the final solution.

Sasikumar and Noorul Haq (2010) analyzed reverse supply chain from the manufacturer's standpoint. There are three available models that a manufacturer may rely on – self support, joint venture, and outsourcing. Each model has advantages and disadvantages. They developed a multi-criteria decision making model by using an analytic hierarchy process method. Through some case studies, they pointed out that in most of cases, outsourcing is the best choice.

2.10 Multi-agent Technologies in Supply Chain Management

An agent is a software system which can decide automatically what it needs to do in order to satisfy its design objectives (Wooldridge, 2000; Macal and North, 2002, 2005; Hamichi et al., 2010). It has the following characteristics: autonomy, social ability, reactivity, temporal continuity, adaptability, mobility, and collaboration (Bradshaw, 1997; Ferber, 1999; Flores-Mendez, 1999; ASAP, 2000; Wooldridge, 2000). Therefore, a multi-agent system is very suitable to describe decentralized, distributed environments, especially for a supply chain. Some applications of multi-agent systems in supply chain management can be found in the literature.

Nissen (2001) presented an agent-based supply chain integration model in which a user agent is used to conduct procurement activities, a supply agent to represent a seller's activities, and a contract agent to carry out transaction activities. Business processing integration was stressed by Nissen (2001). Frey et al. (2003) presented a multi-agent system to integrate planning, scheduling, tracking and tracing activities among partners in a supply chain. Sadeh et al. (2003) developed an agent-based decision support environment for supply chain partners called MASCOT to help them to make heterogeneous planning, scheduling and sourcing decisions. Bodendorf and Zimmermann (2005) built up a multi-agent system called PAMAS to identify and correct disruptions and malfunctions in operational supply-chain processes. Cloutier et al. (2001) presented a multi-agent system framework to simulate network organizations and production operations for a real manufacturing supply chain. The system focuses on coordination based on contracts and conventions. Most of these multi-agent systems concentrate on supply chain planning and scheduling through partners' coordination.

By using genetic algorithm (GA), Kazemi et al. (2009) solved the production-distribution planning problem to support global optimization. But based on different crossover strategies, the model may get different solutions. To treat each genetic algorithm as an agent, they developed a multi- agent system to find the optimal one from those solutions. The result shows that the multi-agent technology works well for finding the optimal solution.

2.11 Other Topics in Supply Chain Management

Beyond the above research directions, there are some other topics, such as supply chain network design (Amiri, 2006; Klibi et al., 2010; Nagurney, 2010; Georgiadis et al., 2011; Pishvaee et al., 2011), reverse-logistics also called reverse supply chain (Lieckens and Vandaele, 2007; Min and Ko, 2008; Pishvaee et al., 2010; Sasikumar and Noorul Haq, 2010), supply chain coordination (Hill and Scudder, 2010; Jaber et al., 2010; Krishnan and Winter, 2010; Wang et al., 2010; Bhatnagar et al., 2011), radio frequency identification (RFID) (Kim et al., 2010; Sarac et al., 2010; Sari, 2010), and resource allocation (Melo et al., 2009; Mafakheri et al., 2011; Zhang et al., 2011). Research on those topics is also very important and useful for improving a company's overall performance. Those issues are not covered in this research.

In this dissertation, many supply chain management methodologies will be considered in designing and developing an intelligent agent-based supply chain simulation system. These methodologies include supply chain integration, supply chain coordination, supply chain network design, multi-objective decision making, multi-agent technique, automated communication and negotiation, demand forecasting, and inventory management. The system not only can be utilized to simulate and study various supply chain management strategies and behaviors and to examine supply chain performance from an individual supply chain entity's perspective, but also can be used to examine supply chain performance for the perspective of an entire supply chain, or portion of it.

Chapter 3 Design of a Supply Chain Focused Enterprise Architecture

An enterprise, which is a business organization, includes employees, facilities, assets and business processing activities in order to produce certain products and/or to provide service to customers. Because the main objective of a for-profit enterprise is to make profits through business processing activities, analyzing and evaluating the performance of an enterprise is an important task. This is a complicated task, because many elements affect the performance of an enterprise, such as: employees' ability and loyalty, managers' skills and ability, business processing efficiency, quality of products and/or services, customers' preferences, and the external economic environment. To analyze an enterprise, researchers often utilize enterprise architectures. Enterprise architecture is a framework detailing an enterprise's organizational structure, business processes, assets, and management activities (Minoli, 2008). The main objective of building an enterprise architecture is to better understand an enterprise's structure, business processes, and business activities and strategies, in order to identify opportunities to improve the performance and competitiveness of the enterprise.

3.1 Background of Enterprise Architecture

Since enterprise architecture is the main approach to analyze/reengineer an existing enterprise, or to design and build a new enterprise, a variety of enterprise architectures have been presented. Zachman Enterprise Architecture, a commonly used framework, utilizes a two-dimension grid to represent an enterprise (Zachman,1987, 2009; Minoli, 2008): one dimension applies ***What, How, Where, Who***, ***When,*** and ***Why*** ("6**Ws**") to demonstrate enterprise scenarios, and the other dimension captures all critical models through six views – **scope, business, system, technology, component,** and **operations**.

From the "6**Ws**" dimension, ***What*** denotes the entities and data in each point of view; ***H****ow* represents the functions and processes from each point of view; ***Where*** furnishes the locations and network relationships within the enterprise; ***Who*** shows people and the organization structure of the enterprise in each view; ***When*** gives the time that an event or activity would happen; and ***Why*** describes the reason or motivation of an enterprise's goal, plan, strategy and operation. From the six views, the **scope** view considers the strategy issues that relate to the nature and purpose of the enterprise, and it is the planner's view; the **business** view is the observation and expectation of the enterprise which come from the owner's standpoint; the **system** view is the perception of designers and architects for the enterprise model; the **technology** view is from a builder's viewpoint to depict the constraints of technology, languages, tools, and materials; the **component** view stands for a subcontractor's view point which only focuses on the individual module related to the subcontractor; and the **operation** view illustrates how the system works and operates.

Another commonly used framework, the open group architecture framework (TOGAF), describes enterprise architecture from four aspects: Business Architecture, Application Architecture, Data Architecture, and Technical Architecture (The Open Group, 2007; Minoli, 2008). The Business Architecture thinks about the business strategy, organization, governance, and key business processes, which contribute to achieving the goals of the enterprise. The Application Architecture displays the expected individual application systems and the relationships among them. The Data Architecture demonstrates the organization structure of enterprise data storage either in logical view or in physical view, and how to access the data. The Technology Architecture illustrates the necessary software and hardware to implement the applications. To help create and develop enterprise architecture, TOGAF presents an architecture development method (ADM), which is its most important contribution. While Zachman Enterprise Architecture Framework is suitable for building an enterprise architecture concept, TOGAF ADM can be used to develop and create enterprise architecture.

The field of computer integrated manufacturing (CIM) is a pioneer in enterprise processing integration, which uses computer technologies to integrate manufacturing processes (Brandimarte, and Cantamessa, 1995; Doumeingts et al., 1995; Johnson et al., 2007). Open system architecture for CIM (CIMOSA), a process-based enterprise architecture for controlling and monitoring enterprise operations based on CIM technology, is comprised of an enterprise modeling framework and integrating infrastructure (Kosanke, 1995; Zelm et al., 1995; Bernus, 2001; Chen et al., 2008). There are two steps to building a CIMOSA enterprise modeling framework: a partial modeling module and a generic modeling module. While a partial modeling process constructs business requirements and conducts design and implementation of a particular enterprise operation model (called CIMOSA business modeling process), generic modeling integrates all partial models into one by means of the concept of building blocks through the CIMOSA integrating infrastructure. All models are demonstrated through at least four different modeling views – Function, Information, Resource, and Organization. Based on CIM, some enhanced enterprise architectures have been designed, such as the generic enterprise reference architecture and methodology (GERAM) (Bernus and Nemes, 1996; Bernus, 2001), reference model of open distributed processing (RM-ODP) (Naumenko and Wegmann, 2007; Wegmann et al., 2007), and Purdue enterprise reference architecture (PERA) (Williams, 1994). The issue of supply chain integration has also been considered in enterprise architecture by some researchers. Davenport and Brooks (2004) discussed supply chain related issues of enterprise systems, including information integration, cost reduction, customer service, processing efficiency, and infrastructural and strategic capabilities. Based on a generic supply chain from the textile industry, Chandra and Kumar (2001) proposed a cooperative supply chain (CSC) system and discussed the issues of structure, analysis, control, and optimization of such a system.

Most of those frameworks and models mentioned above focus on the business organization, business functions, and information technology issues. They have been used to carry out business analysis and to improve the performance of enterprises. However, they rarely consider managerial knowledge acquisition and application which is an important factor for the development of an enterprise. In the next section, a supply chain simulation focused enterprise architecture is presented.

3.2 Conceptual Model of an Enterprise

An enterprise may be a manufacturer, a trader, a service provider, or a large company which has many business units. Its role to other enterprises or individuals may be as: supplier, consumer, competitor and/or partner. To build an enterprise, an entrepreneur must consider the following factors: customers, market, industry, opportunities, competitors, regulators, and investors (Minoli, 2008). Establishing and managing an enterprise requires consideration of the external environment and relationships, and the internal organizational structures and business processes. All business entities and activities as well as external environmental issues can be classified into two categories: hard components and soft components. A hard component is an entity that can be seen and measured, such as organizational structure and employees, workshops, equipment and facilities, products and materials, cash flow, investments, and computer and application software. A soft component is about skill, ability, or environment, which is difficult to measure and include: managerial skills and competency, enterprise culture, enterprise technical advantages, external environment, supply chain management ability, and business processing capability. Enterprise culture is made up of beliefs and values held by an enterprise. All employees should work under the influence of their enterprise's culture. Figure 3.1 shows a conceptual model of an enterprise.

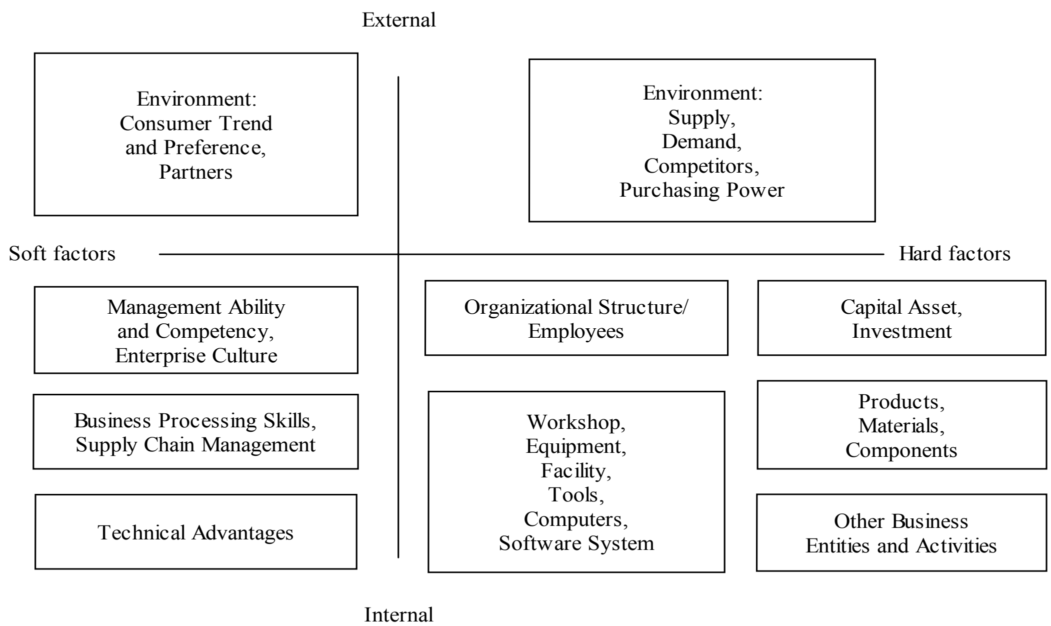


Figure 3.1 Conceptual model of an enterprise

Through activities such as hiring new employees, purchasing new facilities or service, the components that belong to the *Internal* and *Hard factors* quadrant in Figure 3.1 can be directly improved or altered. Through initiatives such as training, learning, adjusting and modifying business strategies, processing technologies, and employees' managerial and professional knowledge, the components located in the *Internal* and *Soft factors* quadrant can be improved and strengthened. The enterprise could influence the components in the *External* and *Soft factors* quadrant through cultivating, advertisement and promotion. However, the components in the *External* and *Hard factors* quadrant are difficult for enterprise to influence. By examining the characteristics of each component, owners and managers can recognize effective and efficient methods and strategies to consolidate and expand the enterprise.

Furthermore, the components in Figure 3.1 can be categorized into four segments according to functionalities (Business Processing Activities; Organization Structure; Workplace and Properties; and Strategy and Technology) through four different views (business processing, organization, facilities, and management) as shown in Figure 3.2.

This structure is defined as the organizational model of an enterprise, which is the foundation of forming the proposed new enterprise architecture as shown in Figure 3.3.

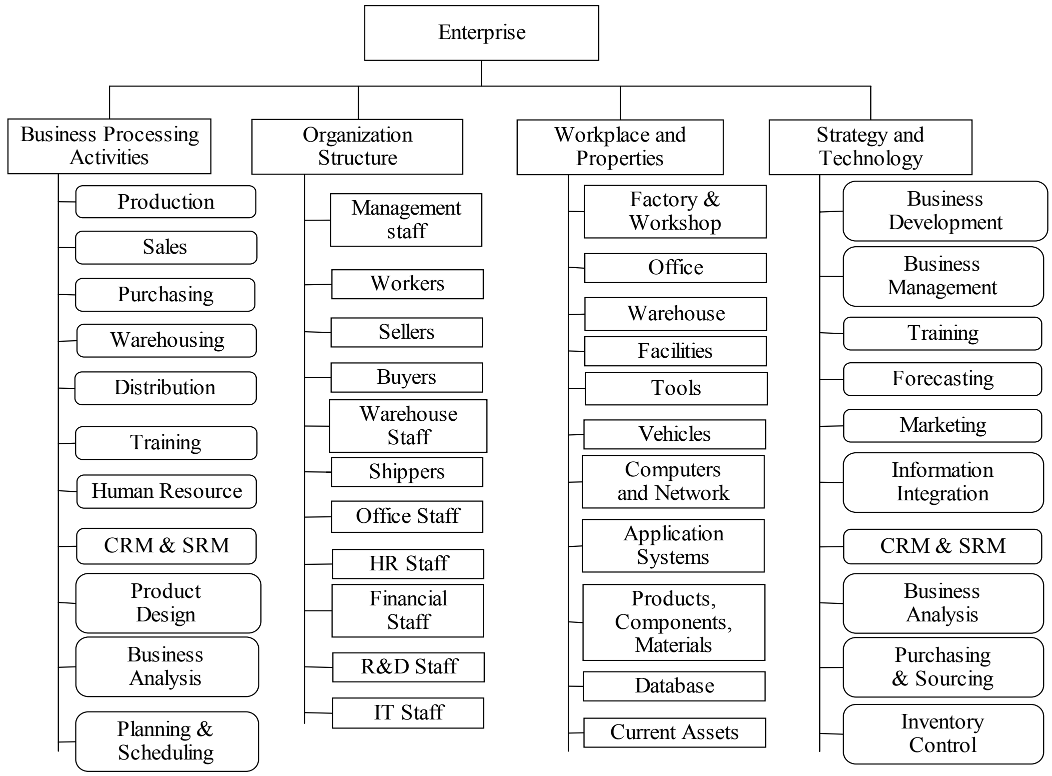


Figure 3.2 Organizational model of an enterprise

3.3 Proposed Enterprise Architecture Model

As shown in Figure 3.3, the Organization Structure in the proposed architecture is comprised of the entrepreneur and all employees. Workplace and Properties may include factories, workshops, offices, warehouses, production and processing facilities, tools, transportation vehicles, computers and networks, computer operation systems and office software systems, business processing application systems, products, semi-finished products, components, materials, and current assets. Business Processing Activities may include production, sales, purchasing, warehousing, distribution, shipping, employee training, human resources functions, customer relationship management (CRM), supplier relationship management (SRM), product design, product advertising and promotion, business analysis and intelligence, and business planning and scheduling. Business Strategy and Technology covers business management and processing policies and methodologies, which deal with business development, business management, employee training mechanisms, forecasting techniques, marketing strategies, information integration techniques, CRM and SRM strategies, business analysis and intelligence techniques, purchasing and sourcing strategies, and inventory control policies.

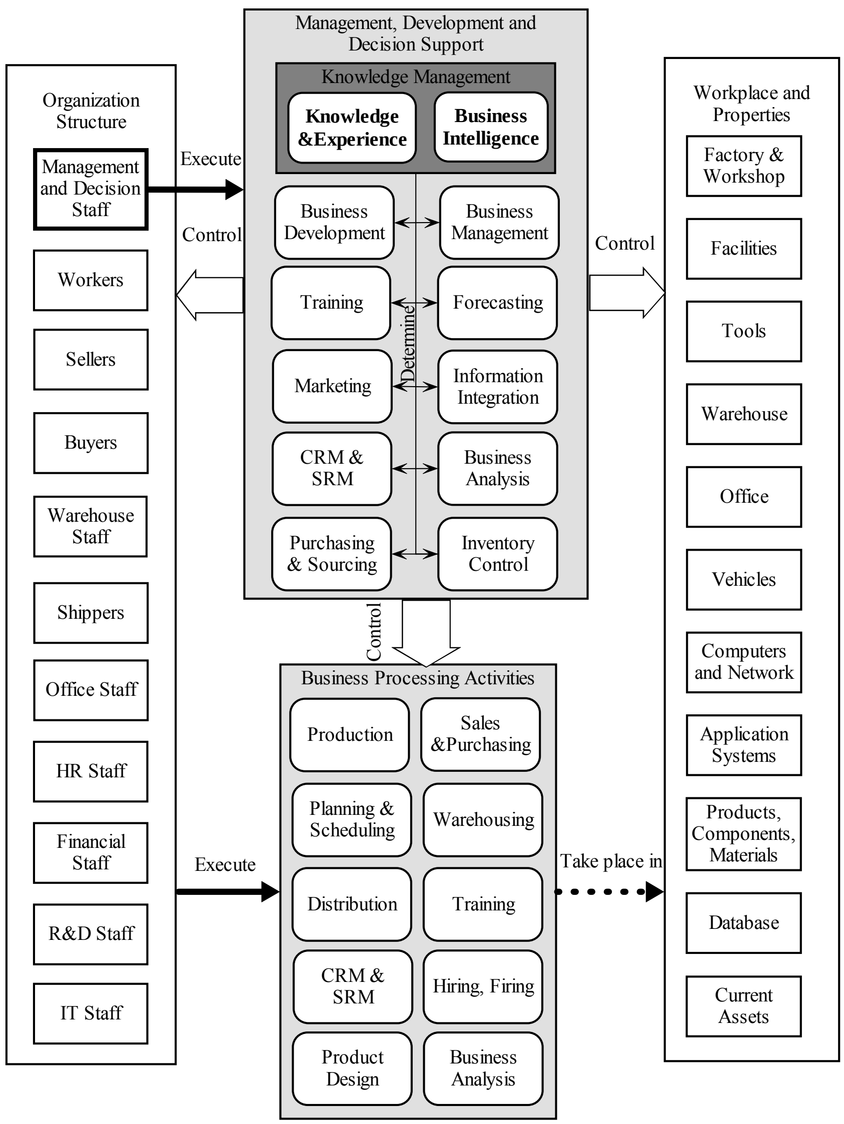


Figure 3.3 Enterprise architecture

Each employee has to create or add value or profit for the enterprise, and profit can be increased through employee training or using better facilities or techniques. As the workplace and properties are the medium for generating value, suitable locations as well as appropriate and high quality facilities would generate more profit. Similarly, since business processing activities are the main activities and concrete operations to create value or increase profit, effective processing procedures and technologies will increase value significantly. Moreover, management skills and technologies are the foundation of enterprise development and survivability, and they will enhance an enterprise's competitiveness through actions, such as:

- Making the organization, facilities and business processing activities more efficient and effective,
- Enhancing staff quality and enterprise culture, and
- Strengthening cohesiveness of the enterprise.

Management ability depends on knowledge, which comes from experience, education, training and learning, and business intelligence analysis. Enterprise culture influences almost all aspects of the enterprise.

The proposed enterprise architecture can be utilized to develop a new enterprise, and reengineer or analyze an existing enterprise. Through analyzing each element of the enterprise, the entrepreneur and managers can identify the strengths and weaknesses of the enterprise. The proposed model emphasizes the application of managerial knowledge and experience, which is an important factor in business operation. Based on this architecture, an intelligent supply chain simulation system to analyze and simulate management strategies and business processing activities has been designed and developed (Wang and Fang, 2007). This will be detailed in the next Chapter. The system can be used for managers to test and evaluate decision strategies for improving business processing activities.

Chapter 4 Design of an Intelligent Agent-based Supply Chain Simulation Model

Each business in a supply chain has its own characteristics and processing strategies. Both Dell and IBM are computer manufacturing giants, with different marketing strategies (Simchi-Levi et al., 2004). As a traditional business, IBM has adopted the following processing sequence: designing products, purchasing components, manufacturing products, distributing to warehouses, selling and shipping to retailers, and selling to final customers. In contrast, Dell's processing sequence is as follows: designing products, selling customized products through its website, confirming orders, manufacturing products, and shipping products to customers through third-party logistics (3PL). By providing ordering information to its suppliers and distributors, Dell makes its' supply chain more efficient.

To better understand an entity's position and roles in a product supply chain, Tien (2011) pointed out that a supply chain network actually is a value chain, and it is comprised of two chains – supply chain and demand chain. The chains' structures are varied, depending on the Customer Order Penetration Point (COPP). The COPP is the point where customer orders are received in a value chain. This classification is very helpful for studying manufacturing and service customization.

Since the supply chain is a dynamic, stochastic, and complex network, researchers have utilized simulation techniques to study new methodologies in supply chain management. Beer Game and TAC-SCM (trading agent competition for supply chain management) are two widely known supply chain simulation models. Beer Game (Sterman, 1989; Chen and Samroengraja, 2000; David, 2002) is a four-layer simulation system: a factory, a distribution centre, a warehouse, and a retail store. Materials flow in a forward direction (from the factory to the distribution center, to the warehouse, and to the retail store), while information, in the form of replenishment orders, flows in the reverse direction. This system has been utilized to study partners' relationships, forecasting techniques, lead times, capacities, inventories and planning problems. TAC-SCM is an agent-based simulation system, in which there are six personal computer assembly agents who compete for customer orders and purchase various computer components from eight suppliers (Arunachalam et al., 2003, 2004; Arunachalam and Sadeh, 2005). Agents design strategies to determine:

(1) which request-for-quotations (RFQs) will be responded to and with what price;

(2) which combinations of supplier offers should be accepted;

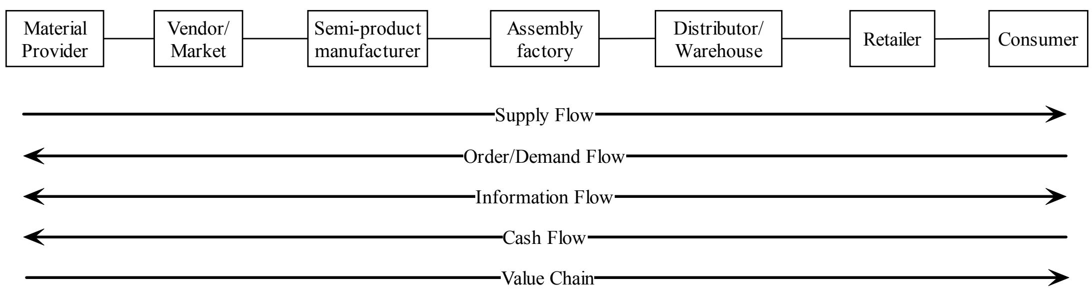
(3) how to plan production; and

(4) which finished computers should be shipped to which customers.

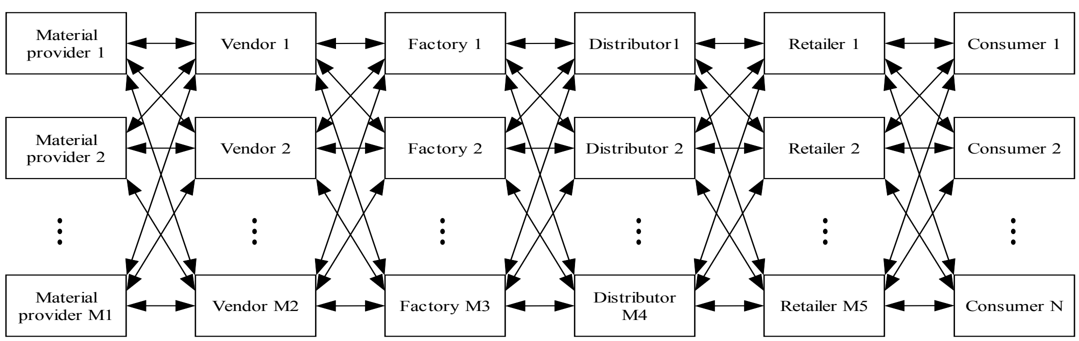
In this chapter, after illustrating the supply chain problem, an intelligent agent-based supply chain simulation model will be designed. Technologies and methodologies to make a supply chain more efficient, such as pricing methodology in negotiation, supply and demand forecasting methodologies, knowledge-based decision support techniques, automated communication and negotiation, and information sharing, could be studied and adopted in future research (Fang and Wang, 2007).

4.1 Model Description

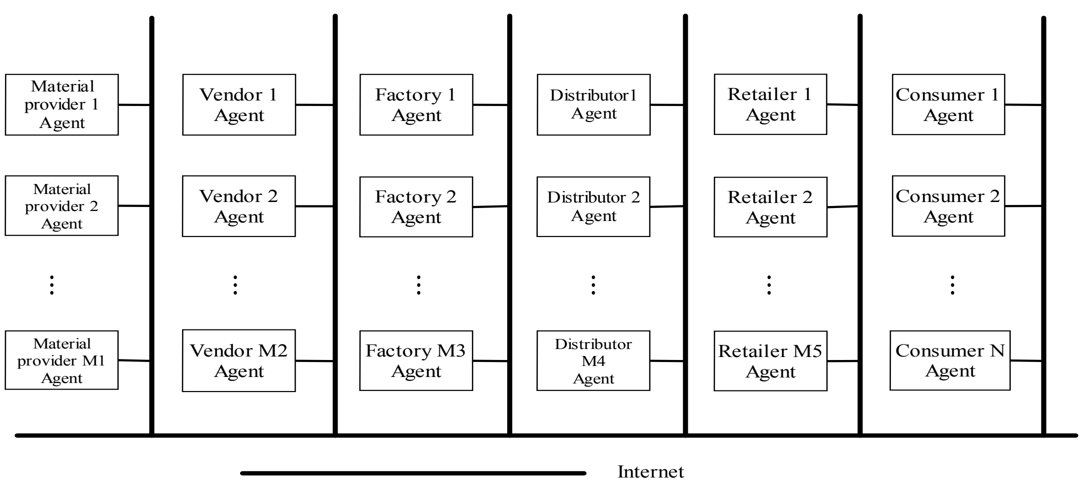
As shown in Figure 4.1(a), a supply chain includes many enterprises or businesses, including raw material providers, vendors, manufacturers, distributors, warehouses, retailers, and final consumers. Each business or enterprise has to be an individual entity in one or more supply chains. It can act either as a buyer or as a seller, or both. For example, raw material providers are sellers, final consumers are buyers, and the others (vendors, factories, etc.) are buyers as well as sellers. Every entity not only strives for maximum revenue, but also seeks steady and continuous development. In a traditional supply chain, as shown in Figure 4.1(b), the communication between supply chain partners relies on telephone, fax, mail, face-to-face communication, EDI, email, etc. A supply chain participant usually connects only to its first tier suppliers and buyers. Connections to second tier suppliers (the suppliers' suppliers) or buyers (the buyers' buyers) are difficult, to say nothing of connecting to participants at further tiers in the supply chain.



(a) Supply chain participants and flows



(b) Traditional supply chain network model



(c) Proposed supply chain network model

Figure 4.1 Supply chain flows and network model

In the new supply chain model proposed in this research, as shown in Figure 4.1(c), the main communication media are the Internet and businesses' websites; traditional communication methods may also be used. Based on this model, each enterprise is represented by an agent, and each company can communicate with any other company, regardless of how far removed in the supply chain.

The most important activity for a company is to buy supply goods and to sell products. As a product provider, a company may have many methods for selling its' goods including: auction, request-for-quotation (RFQ) plus negotiation, long-term contract, and fixed price plus promotion. A buyer in a supply chain has options for buying its required goods such as: reversed auction, RFQ plus negotiation, long-term contract, and direct purchase from the market. The first thing buyers/sellers must do is to seek sellers/buyers. Although they may have some trade partners' information stored in their database, they would still like to approach more potential partners. They may pay for advertisements to acquaint consumers with the products they supply as well as with the buying or/and selling methods they utilize. Alternatively, they may search for buyers/sellers on the Internet, and send RFQ messages to them or invite them to participate in a scheduled auction. The company may also send the same message to trade partners stored in its database. If the auction method is adopted, the winner is the one who places the best bid based on price. If the RFQ approach is utilized a few buyers/sellers may be selected as candidates based on their credit/reputation and on feedback from other buyers/sellers. Negotiation with each buyer/seller would determine who receives the contract. The company always faces the risk that the contractor may not fulfill the contract for some reason. Advertisement and promotion strategy is very important when the fixed price method of selling is used.

To determine which method(s) should be employed, companies utilize the current and forecast information on supply and demand. A company often uses some or all of these sale/procurement methods simultaneously in order to allow the business to grow steadily and continuously while also maintaining competency. Businesses in a supply chain will pursue their own maximum profit with as robust development as possible. In order to make the supply chain more effective, a business may disclose some confidential information to its trade partners.

4.2 The Intelligent Agent-based Supply Chain Simulation Model

In this section, an intelligent agent-based supply chain simulation model is designed. Each enterprise or supply chain entity is represented by an agent, and there are six layers in this model: raw material provider, component manufacturer, product assembly, product holder, retailer, and customer. The simulation system model is shown in Figure 4.2. There are *N1* raw material agents, *N2* component agents, *N3* assembly agents, *N4* product holder agents, *N5* retailer agents, and *N6* customer agents. Raw material agents provide materials; component agents manufacture semi-finished products; assembly agents assemble products; product holder agents design products and sell them to retailer agents; and retailer agents purchase products from product holders and sell them to customer agents.

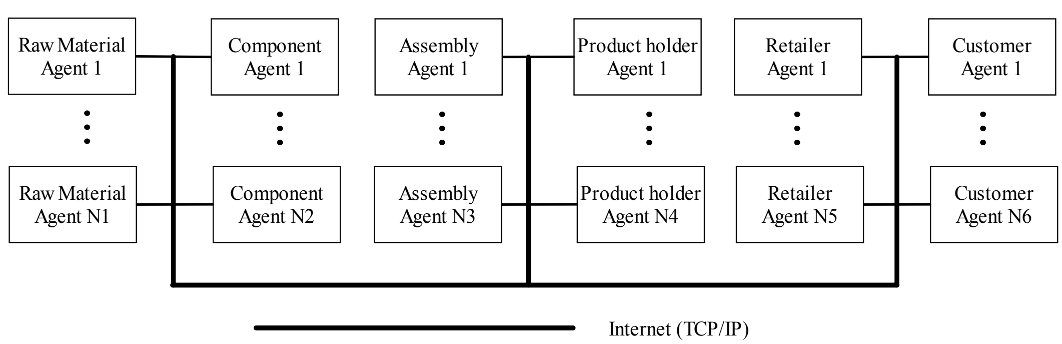


Figure 4.2 Simulation system model

Except for the raw material and customer agents, all other agents have both suppliers and buyers. To demonstrate the behavior of an agent, a partial supply chain network model with three layers is shown in Figure 4.3. In this model, the central layer is called the host layer, and its agents are labeled host agents. The front layer is called the input layer, and its agents are labeled input agents. The back layer is labeled the output layer, and its agents are called output agents. Input agents provide materials, components, or products to host agents. Host agents produce or stock products, and sell them to output agents. A host agent could be a raw material provider, a component manufacturer, an assembler, a product holder, a retailer, or a customer. If the host agent is a raw material provider, the model shown in Figure 4.3 is shrunk to two layers – only the host layer and output layer exist, and there is no input layer. A similar situation occurs when host agents are customers –the input agents would be retailers or product holders and no output agent layer would exist.

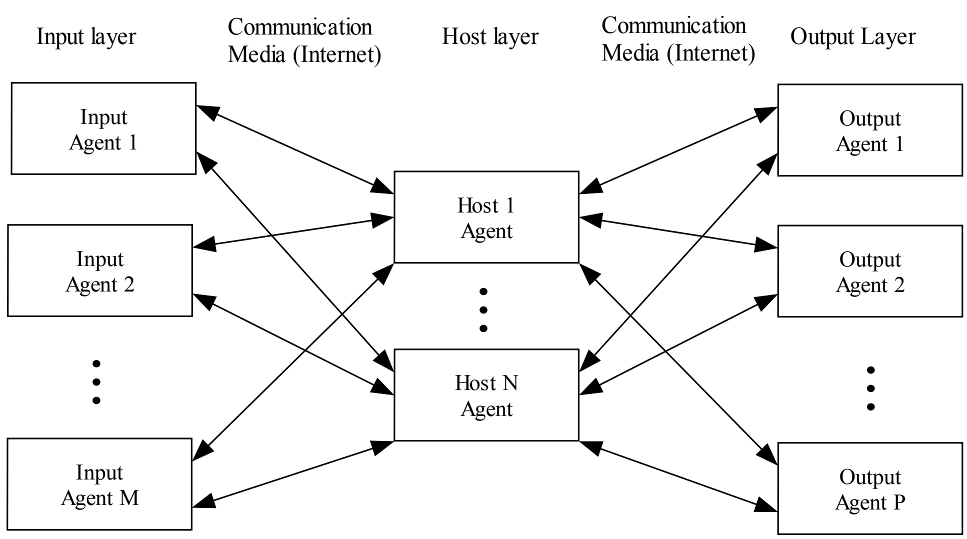


Figure 4.3 A partial supply chain model

If host agents are product holders, the input agents may be assemblers, component manufacturers, or material providers, and the output agents may be retailers, or final customers. In general, host agents buy products from input agents, process them, and sell them to output agents. The host agent can automatically communicate and negotiate with its input and output agents. In addition, every agent will have a rule-based knowledge base. Each agent will have the ability to forecast demand, make decisions using multiple objectives and determine production planning.

In this model, output agents will generate orders according to certain policies, and input agents will supply goods in terms of the appointed schedules. The host agent can choose either the make-to-order (MTO) or make-to-stock (MTS) strategy. When the make-to-order strategy is utilized, the simulation starts at the output agent's side and proceeds in the following sequence:

(a) An output agent generates an order according to a specific policy and it sends an RFQ message to each of the host agents;

(b) Each of the host agents sends an RFQ message of its own, which is different from the output agent's RFQ, to each of its input agents;

(c) Each input agent can reply to the RFQ with a price and delivery time;

(d) The host agent generates a response to the output agent's RFQ;

(e) If necessary, the output agent negotiates with the host agents automatically;

(f) The output agent determines which of the final responses from the host agents is the winner;

(g) The winning host agent purchases materials or semi-finished products from the input agent(s); and

(h) The winning host agent delivers the finished product(s) to the output agent.

The host agent may have some inventory. If the host agent has sufficient inventory to meet a particular order, steps (b) (c), and (g) of the process are skipped.

On the other hand, when the make-to-stock strategy is used, the simulation starts at the input agent's side, and proceeds according to the following sequence:

(a) The input agents prepare the supplies according to a certain schedule;

(b) Host agents purchase goods from the input agents;

(c) Host agents make products or stock goods;

(d) An output agent buys goods from host agents according to a specific policy. When demand arises, the output agent sends an RFQ message to each of the host agents;

(e) The host agents respond with an offer to the output agent;

(f) The output agent negotiates with the responding host agents automatically;

(g) The output agent determines the winner from the final offers of host agents; and

(h) The winning host agent delivers the products to the output agent.

When the inventory level of a host agent reaches its upper limit, the host agent stops production until its inventory is decreased to its lower limit.

Production-related activities in an enterprise include purchasing of components and materials, developing the inventory strategy and manufacturing plan, marketing of products, communicating and negotiating with its partners for information exchange and RFQ messages, fulfilling and delivering orders, and managing supplier and customer relationships. Since an enterprise is represented by an agent, the agent's structure should contain most of these activities. The proposed agent structure is shown in Figure 4.4. All agents have the following common components: Interface, Task Distributor, Fulfillment Engine, Forecast Engine, Search Engine, Communication and Negotiation Engine, Sales/Procurement Engine, SRM/CRM (Supplier Relationship Management/Customer Relationship Management) Engine, Decision Support Engine, Database, Algorithm Base, and Knowledge Base.

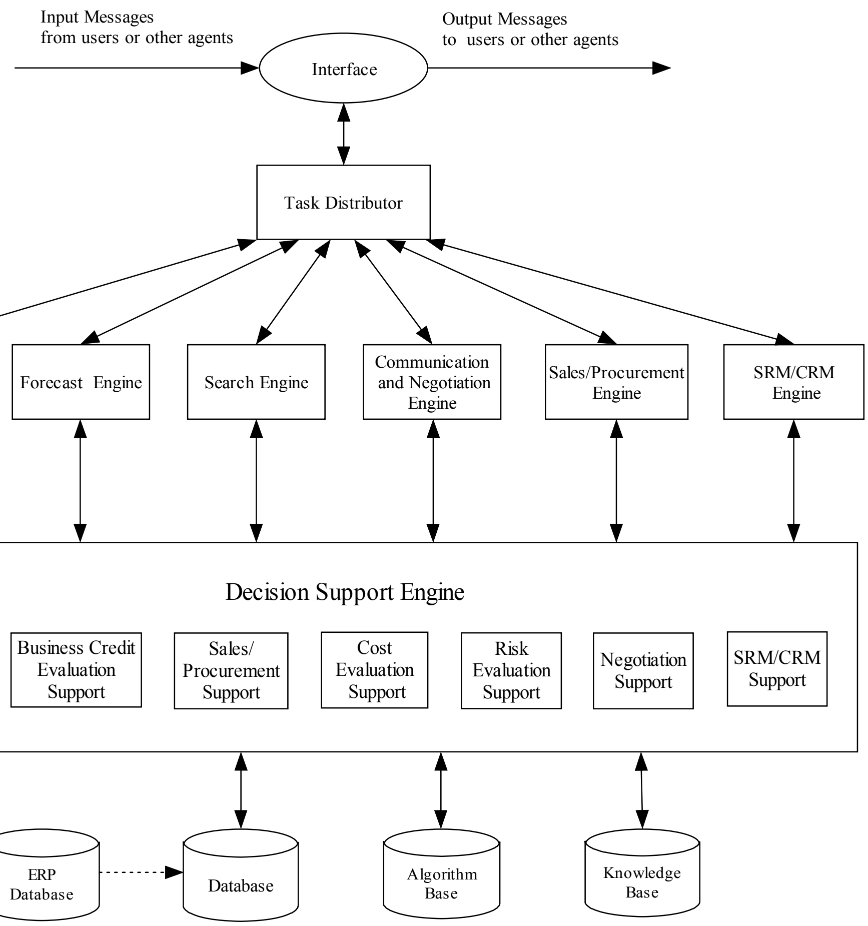


Figure 4.4 A typical agent structure

The Interface is used to send and receive messages to and from other agents, and to show the results to user(s). The function of the Task Distributor is to save and to assign jobs to relevant engines depending on the message it receives. When a message cannot be understood by the Task Distributor, it is delivered to the Communication and Negotiation Engine. By means of the Communication Protocol module, the Translator translates the incomprehensible message to a standard message that can be understood by the agent. If the message is an offer that needs to be negotiated, the agent will generate a new counter-offer to its partner, through the Negotiation module. If the message is not an offer, the agent will just generate a reply (confirming) message depending on the task. This message will be forwarded to the Interface via the Task Distributor, and then sent to the appropriate agent.

The Forecast Engine is used to forecast product demand. The Forecast Support module in the Decision Support Engine will determine which of the many available forecasting methods is most suitable. Forecasting is based on the historical data available in the Database. The Search Engine, which could be one of the commercial search engines such as Google or Yahoo, is used to find possible partners worldwide through the Internet. The businesses identified will be evaluated using the Business Credit Evaluation Support module in the Decision Support Engine. Businesses that pass the evaluation will be added to the Database to become potential partners. The Sales Engine conducts the product selling process. Many sales methods are available including: auction, negotiation, long-term contract, and fixed price, and the Sales Support module in the Decision Support Engine helps in identifying which method(s) should be adopted. The Procurement Engine deals with purchasing activities according to the method(s) identified using the Procurement Support module in the Decision Support Engine. In addition to the aforementioned support modules, the Decision Support Engine also has two other modules: the Cost Evaluation Support module and the Risk Evaluation Support module. The Cost Evaluation module estimates the cost and profit of an activity. The Risk Evaluation module calculates the probability that the contract cannot be fulfilled and the expected loss when if this was to occur.

The Fulfillment Engine deals with the receiving and shipping of components and products as well as the payment process. The SRM/CRM Engine is in charge of collaboration with supply chain partners (suppliers and customers). The collaboration includes technical support and sharing of information including: product lists, sales promotions, and production plans. The Database stores all relevant data and information, including information generated by the agent. It can obtain information (data) from the ERP (enterprise resource planning) Database which stores data generated by an ERP system, such as SAP, PeopleSoft/J.D. Orisoft, Microsoft Dynamics. The Knowledge Base contains rule-based and experiential knowledge and it can be updated by the Decision Support Engine. The Algorithm Base stores the algorithms used by the agent. Examples of algorithms are forecasting, business credit evaluation, and cost and risk evaluation algorithms.

4.3 Communication and Negotiation between Agents

Communication is the key for a successful supply chain. Efficient and effective communication between partners brings clear comprehension, allowing them to make fast and effective decisions.

Communication activities among agents are shown in Figures 4.5 and 4.6. The messages may come from external agents or users, or internal engines of this agent. External messages include RFQ, shipping, delivery confirmation, and negotiation feedback messages. Internal messages include outgoing RFQ and auction announcement messages (from the Sales/Procurement Engine), as well as outbound shipping, inbound receiving confirmation, and reminder messages (from the Fulfillment Engine).

When a message from another agent arrives, the Interface transfers it to the Task Distributor. The message is saved into the Database, and is transferred to the Message Translator. If the message does not have the standard format, it is translated into the standard format automatically, using the Communication Protocol. If it cannot be translated automatically, it is sent to the Manual Translator in order for a human to translate it. The translated message is then saved into the Database, and sent to the Message Analyzer.

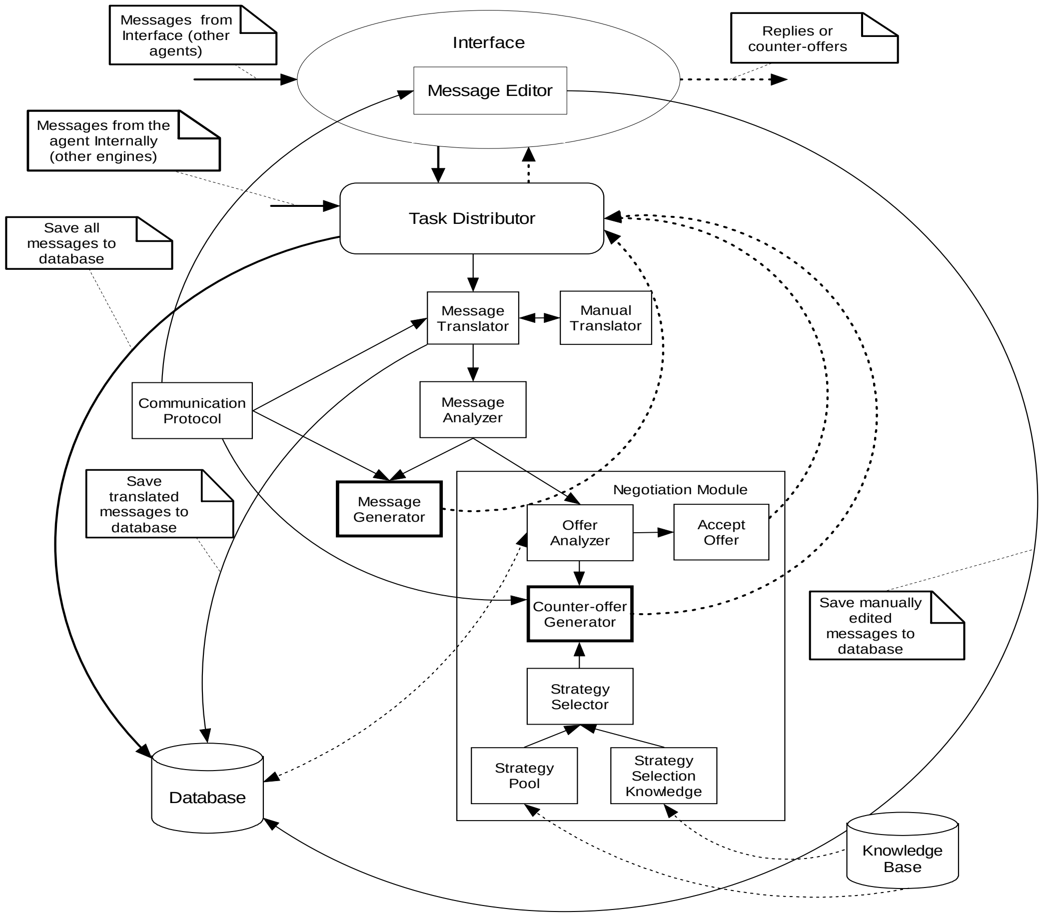


Figure 4.5 Communication and negotiation between agents

Shipping and delivery confirmation messages received from an external agent or user are not processed any further by the Message Analyzer. RFQ or negotiation feedback messages are sent from the Message Analyzer to the Negotiation Module. In response to an RFQ message, the Counter-offer Generator generates an offer, and sends it to the Task Distributor. The offer is saved in the Database, and sent out through the Interface. In response to a negotiation feedback message, the Offer Analyzer determines whether to accept this offer or to generate a counter-offer through the Counter-offer Generator. The resulting decision is sent to the Task Distributor, saved in the Database and sent out through the Interface.

When a message from an engine of this agent arrives, the Task Distributor saves it to the Database and sends it to the website or intended agent through the Interface.

The user has the option to review outbound messages. If reviewing outbound messages is selected, all messages are reviewed through the Interface, and can be edited by the user using the Message Editor.

Communication protocols and negotiation strategies are the key factors for successful automated communication and negotiations. A communication protocol is the set of rules and standards that communication participants must obey for interactive communication. Without a protocol, no communication and negotiation can be conducted by agents automatically since they cannot understand each other's messages. Negotiation strategies are the tactics established to generate an offer or a counter-offer. Some examples of negotiation strategies are time-dependent (Boulware, Linear, and Conceder), resource-dependent, or behavior-dependent tactics (Matos et al., 1998).

In this model, automated communication and negotiation will be conducted by the following components: *Communication Protocol, Message Translator, Manual Translator, Message Analyzer, Message Generator*, and *Negotiation Module* as shown in Figure 4.6. The *Communication Protocol* is stored in the *Algorithm Base* which is shared with other engines. The *Negotiation Module* is shared with the *Sales/Procurement Engine*, and consists of the following parts: *Offer Analyzer, Strategy Pool, Strategy Selection Knowledge Base*, *Strategy Selector*, and *Counter-Offer Generator*. The *Strategy Pool* and the *Strategy Selection Knowledge Base* are stored in the *Knowledge Base,* and the *Strategy Selector* is located in the *Negotiation Support Module* in the *Decision Support Engine*.

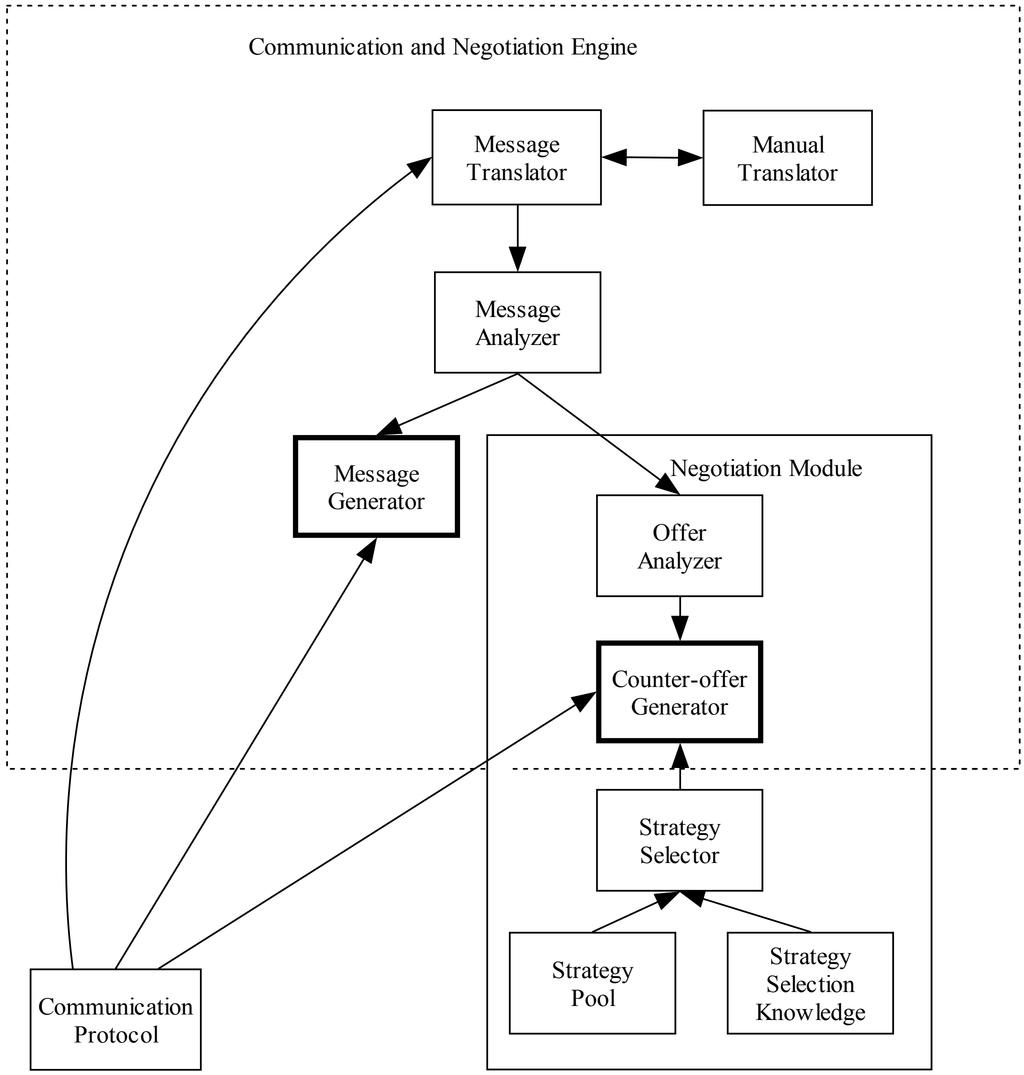


Figure 4.6 Structure of communication and negotiation engine

The *Communication Protocol* is designed using the following structure:

<Message_Start>

<Message_ID>: Message_ID

<Message_To>: Business_ID

<Message_From>: Business_ID

<Message_Time>: Time

<Message_Type>: Negotiation or RFQ or Confirmation or Receipt Or Shipping or Others

<Message_Body>

<Message_End>

When <*Message_type*> is Negotiation, the <*Message_Body*> structure is:

<Message_Body_Start>

<Message_Volume>: Volume_ID

<Message_Number>: Previous Serial_ID +1

<Products>: Product_ID1(amount1), Product_ID2(amount2),…

<Desired_Prices>: Product_ID1(price1), Product_ID2(price2),…

<Delivery_Time>: Product_ID1(Time1), Product_ID2(Time2),…

<Note>: Text message

<Message_Body_End>

When <*Message_type*> is RFQ (Request for quotation), the <*Message_Body*> structure is:

<Message_Body_Start>

<Message_Volume>: New Volume_ID

<Message_Number>: 1

<Products>: Product_ID1(amount1), Product_ID2(amount2),…

<Delivery_Time>: Product_ID1(Time1), Product_ID2(Time2),…

<Note>: Text message

<Message_Body_End>

When <*Message_type*> is Confirmation, the <*Message_Body*>structure is:

<Message_Body_Start>

<Message_Volume>: Volume_ID

<Previous_Message_Number>: Previous Message_Number

<Message_Number>: Previous Message_Number +1

<Confirmation_Type>: Agreement or Rejection

<Products>: Product_ID1(amount1), Product_ID2(amount2),…

< Prices>: Product_ID1(price1), Product_ID2(price2),…

<Delivery_Time>: Product_ID1(Time1), Product_ID2(Time2),…

<Note>: Text message

<Message_Body_End>

When *<Message_type>* is Receipt, the *<Message_Body>* structure is:

<Message_Body_Start>

<Message_Volume>: Volume_ID

<Previous_Message_Number>: Previous Message_Number

<Message_Number>: Previous Message_Number +1

<Receiving_Time>: Receiving Time

<Products>: Product_ID1(amount1), Product_ID2(amount2),…

<Note>: Text message

<Message_Body_End>

When *<Message_type>* is Shipping, the *<Message_Body>* structure is:

<Message_Body_Start>

<Message_Volume>: Volume_ID

<Previous_Message_Number>: Previous Message_Number

<Message_Number>: Previous Message_Number +1

<Shipping_Time>: Shipping Time

<Products>: Product_ID1(amount1), Product_ID2(amount2),…

<Note>: Text message

<Message_Body_End>

When *<Message_type>* is Others, the *<Message_Body>* structure is:

<Message_Body_Start>

<Message_Volume>: New Volume_ID

<Message_Number>: 1

<Note>: Text message

<Message_Body_End>

where,

- *Message_Start* and *Message_End* are utilized to identify the message body;
- *Message_ID* is a unique identification code used to distinguish messages;
- *Volume_ID* in *Message_Volume* is a uniform identification code for a group of messages that are generated in negotiating a contract;
- *Serial_ID* in *Message_Number* is the serial number of the massage in the group of messages associated with the same contract;
- *Business_ID* in *Message_From* is the business identification to record where the message comes from;
- *Business_ID* in *Message_To* is the business identification of the agent itself;
- *Time* in *Message_Time* records the sent time of the message;
- *Message_Type,* can be *Negotiation, RFQ, Confirmation, Receipt, Shipping*, or *Others*, and identifies the purpose of the message;
- *Products* identifies the products to be sold or purchased and the quantity of each;
- *Desired_Prices* identifies the price the buyer or seller is asking for each product;
- *Delivery_Time* identifies the preferred delivery time for each product.

All communication messages will be built using this structure. If a received message does not have this structure, for example, coming from an e-mail written by a human, the agent will translate it to the above format. It can be translated automatically using the *Message Translator* or by a human being – the *Manual Translator*. For a negotiation message, the *Offer Analyzer* will check the time constraint for delivery; calculate the profit $profit_1$ from this offer, and the profit $profit_0$ from the negotiation strategy as defined by the *Strategy Selector* in the *Negotiation Support Module* or by the user. If time allows, and if $profit_1$ is no less than $profit_0$, the agent accepts the offer. Otherwise, the agent will terminate the negotiation, or generate a counter-offer according to the negotiation strategy it selects. The negotiation will end when one agent quits or accepts the last offer.

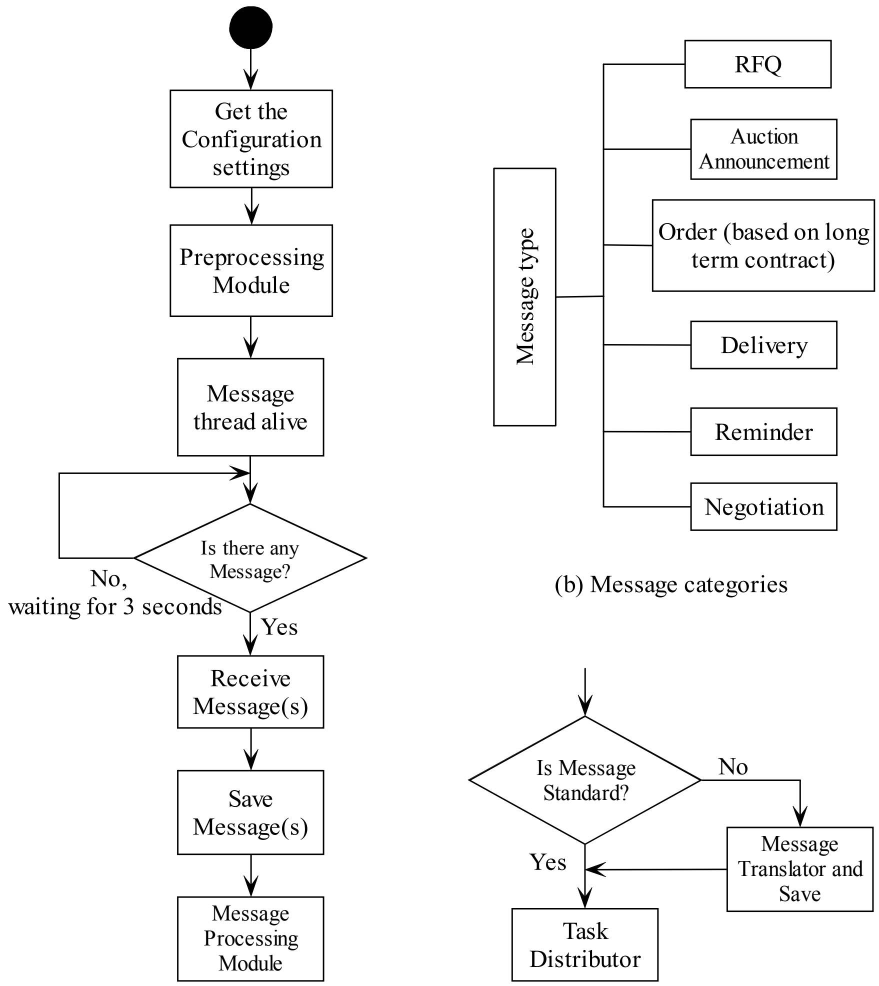
4.4 System Processing

The simulation model can be operated in two modes: manual or automatic. Each business is represented by an agent. An agent may be implemented to consist of a website, an application program, a database, a knowledge base, and an algorithm base. The website is the interface to the agent, and is utilized to initialize and configure a simulation run, to execute a manual simulation, to check the progress and results of a simulation run by users, and to provide general information about the business to partners. The application program handles automatic simulations and provides suggestions during manual simulations.

An agent's website has three types of web pages: simulation settings, inquires, and operations. Simulation setting web pages include a configuration web page, initialization web page, and knowledge base maintenance web page. Through the configuration page, a user determines the simulation method – manual or automatic, production policy – make-to-order or make-to-stock, purchasing and sales strategy, negotiation tactics, inventory plan, and so on. The initialization web page is utilized to set up parameters at the simulation starting point, such as inventory level, purchasing point, production capacity, etc. The knowledge base maintenance web page allows a user to add, delete, and edit knowledge rules which are utilized to provide operation suggestions to users.

Inquiry web pages contain a product categories web page, business history web page, contact information web page, and registration web page. These pages can be accessed by all external businesses and users. Inquiry web pages also include a log-in web page, and other operational information, such as inventory, production plan and sales plan web pages, which can only be accessed by an authorized partner. Operations web pages, which are used to conduct manual simulations, include a negotiation web page, sales web page, purchasing web page, forecast web page, fulfillment web page, communication web page, and so on.

Before an automatic simulation starts, the user can set various strategies and policies using the configuration web page, and set initial operational parameters using the initialization web page. If no changes are made, the system will maintain the strategies and parameters used by the previous simulation. The process for automatic simulation is shown in Figure 4.7(a). After clicking the "Start automatic simulation" button, the application picks up the configuration settings, and starts the preprocessing module. The preprocessing module generates a number of functional threads, including purchasing thread, sales thread, message thread, production thread, fulfillment thread, communication thread, negotiation thread, CRM/SRM thread, forecast thread, decision support thread, and task distributor thread. Each thread will charge its corresponding engine. The communication thread, negotiation thread, decision support thread, production thread, forecast thread, search thread, and CRM/SRM thread are suspended until other functional engines require them. Other threads will sleep, and wake up periodically to carry out their tasks.



(a) Application and message processing (c) Message Processing Module

Figure 4.7 Process for automatic simulation

The sales thread determines if it should sell its products and by what method based on the current situation. The sales process for initialization and periodical check is shown in Figure 4.8. If the system uses the Make-to-Stock approach, it will check the inventory level first. If the inventory level is low, the sales engine will send a message to the production engine (for a manufacturing agent) or the procurement engine (for a commercial agent) for replenishment. If sufficient inventory is available, the process is the same as for the Make-to-Order approach: determine the sales method using knowledge stored in the knowledge base. After obtaining the solution, the system will set the sales thread to sleep for a certain period, and will implement the solution by sending an RFQ or auction message to its partners, or an offer message to its long-term contract partner(s).

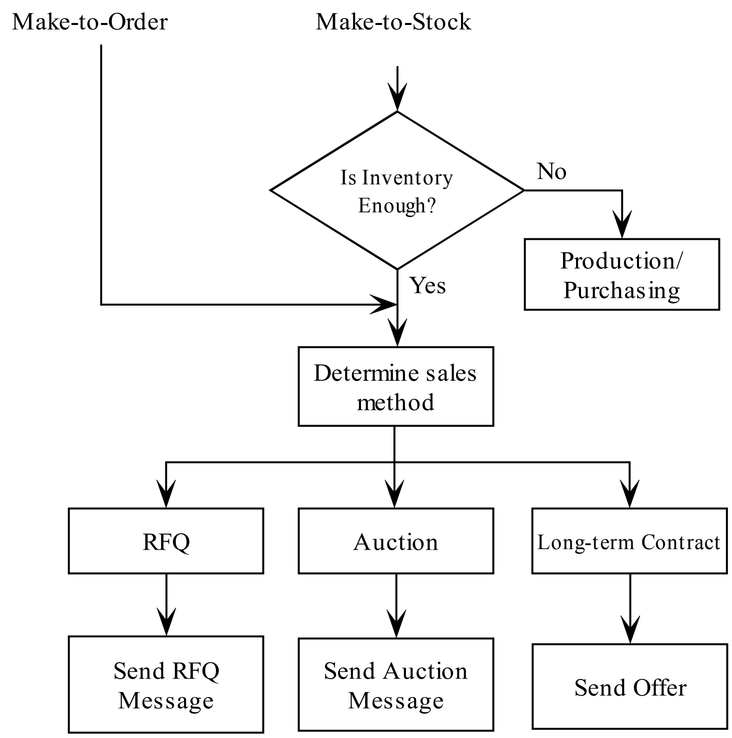


Figure 4.8 Sales process for initialization and periodical check

The purchasing thread decides whether to buy raw materials, components or products and by which procurement method based on its current situation. The procurement process for initialization and periodical check is displayed in Figure 4.9. The system checks the inventory level first and if it is not sufficient, the system will determine the procurement method based on the knowledge available in the knowledge base. After the solution is determined, the system will set the purchasing thread to sleep for a certain period, and will execute the solution by sending an RFQ or auction message to its partners, or an order message to its long-term contract partner(s). Often, the sales thread and purchasing thread will be idle because agents receive offers or orders through long-term contracts or negotiation.

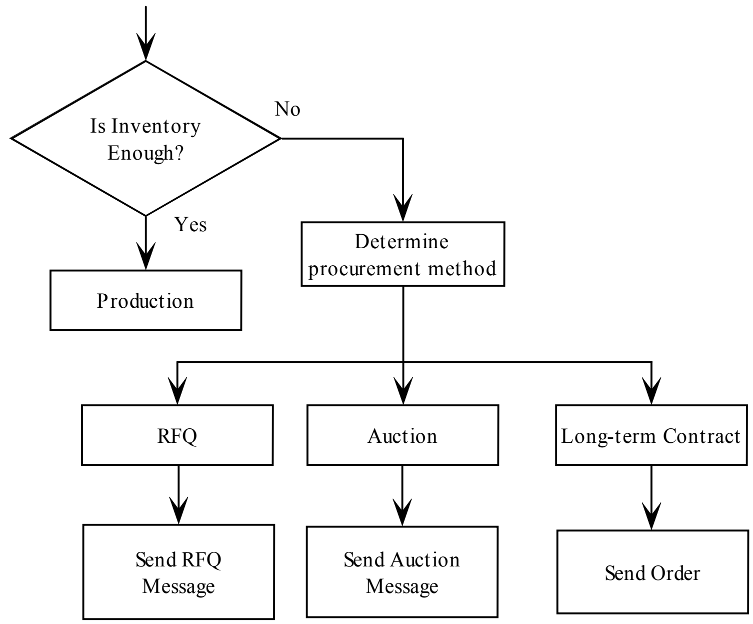


Figure 4.9 Procurement process for initialization and periodical check

The message thread continuously checks for any new messages from other agents in the message queue, several second intervals. If there are messages waiting in the message queue, the system receives and saves them then delivers them to the message processing module. As shown in Figure 4.7(b), messages can be classified into six categories: RFQ, auction announcement, order, delivery, reminder, and negotiation. Internal messages are classified in the same way but are sent out directly through the internal communication engine. If a message is in the standard format, it will be delivered directly to the task distributor engine. If a message is not in the standard format, it will be translated using the message translator, saved and sent to the task distributor. Figure 4.7(c) displays the message processing module. If a message is an RFQ, the task distributor sends it to the sales engine or procurement engine where a proposed offer is generated. If a message is a proposed offer or count-offer, it will be delivered to the negotiation engine. The negotiation engine determines if the offer should be accepted or rejected, or another offer should be generated. For a delivery or reminder message that needs a reply, the system will generate a response message. For an auction announcement message, the system will mark the date.

4.5 Advantages of the Simulation Model

By using this model, many supply chain management techniques can be developed and tested, such as information sharing, forecasting, and decision making. Some of the agent's abilities are as follows:

(1) Determine trading methods: trading methods include auction, RFQ (request-for-quotations), fixed price, and long-term contract. Based on the requirements of each transaction, the agent can select one or more trading methods. If the long-term contract method is not used, the agent may send a request-for-quotation (RFQ) message to each potential trade partner, or may invite them to participate in an appointed auction.

(2) Forecast supply/demand requirements: some forecasting methods, including statistical and artificial intelligence methods, can be implemented.

(3) Evaluate and negotiate offers with partners automatically: if an agent uses the auction method to sell or buy a product, the winner is determined by the auction mechanism. If an agent uses the RFQ method, multi-objective decision making techniques can be utilized to evaluate each offer. Automated negotiation can also be studied.

(4) Determine what information should be shared with partners: designing a flexible database is an important task. Flexibility ensures authorized users are able to manage and access the agent's database easily while blocking unauthorized users' access to the data. The database can conceal or disclose specific data to desired partners as necessary.

(5) Evaluate risks: this is utilized to estimate the probability that a contract cannot be fulfilled.

(6) Determine which pricing method should be adopted in negotiation.

Chapter 5 Design of a Mobile Phone Supply Chain Simulation System

Every mobile phone includes at least the following components: housing, printed circuit board assembly (PCBA), liquid crystal display (LCD), antenna, keypad, battery, speaker, operation system, application programs, instruction, packing box, etc. An entire mobile phone supply chain will involve many enterprises and customers, including raw material providers (plastic, silicon, metals, glass, etc.), electronic and other element manufacturers, component manufacturers or semi-product manufacturers, assembly factories, product design and development companies, software developers, warehouses/distributors, mobile phone service providers, retailers, and final customers.

A fictitious mobile phone supply chain will be used to partially demonstrate how the proposed agent-based simulation system works (Wang and Fang, 2008). To simplify the network without losing the generality, this mobile phone supply chain simulation system will include two raw material providers (Silicon and Metal), two component manufacturers (Housing and PCBA), two mobile phone assembly factories (London and Markham), two mobile phone design and sales companies (Mokia and Notorola), two retailer companies (Logers and Pell), and one customer. In the supply chain simulation system, each participant will be represented by an agent. The network of this mobile phone supply chain is shown in Figure 5.1. Communication between the customer agent

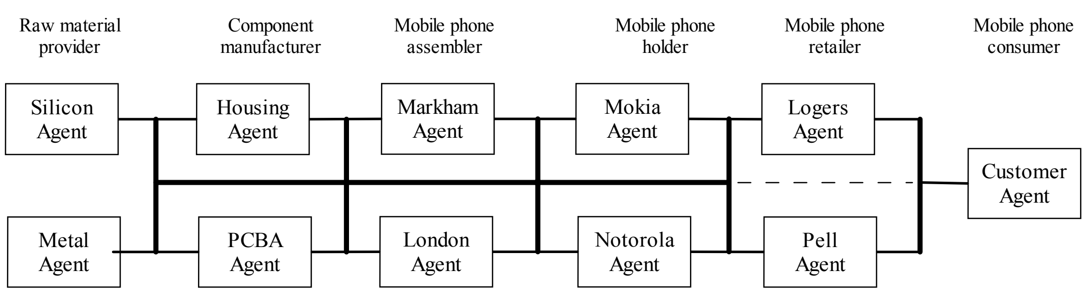


Figure 5.1 Network of the mobile phone supply chain simulation system

and the agents other than the retailer agents is denoted by a dashed line to indicate that customers sometimes do not need to know who upstream suppliers are.

5.1 Description of the Mobile Phone Simulation System

In this simulation system, we have implemented some functional components of the agent structure presented in Figure 4.4, including: Interface, Task Distributor, Fulfillment Engine, Communication Engine, Sales/Procurement Engine, CRM Engine, Database, and Algorithm Base, as shown by the shade boxes in Figure 5.2. The system has six layers, in which, both the Silicon and Metal agents provide raw materials to the Housing agent and the PCBA agent. The Housing and PCBA agents provide components to both Mokia and Notorola mobile phones. Both the Logers and Pell agents sell Mokia and Notorola mobile phones. Both the London and Markham agents assemble Mokia and Notorola mobile phones. The Mokia agent designs and sells only Mokia mobile phones while the Notorola agent designs and sells only Notorola mobile phones. The Customer agent will buy mobile phones from both the Logers and Pell agents. All agents, except Customer agent, have a structure similar to the one shown in

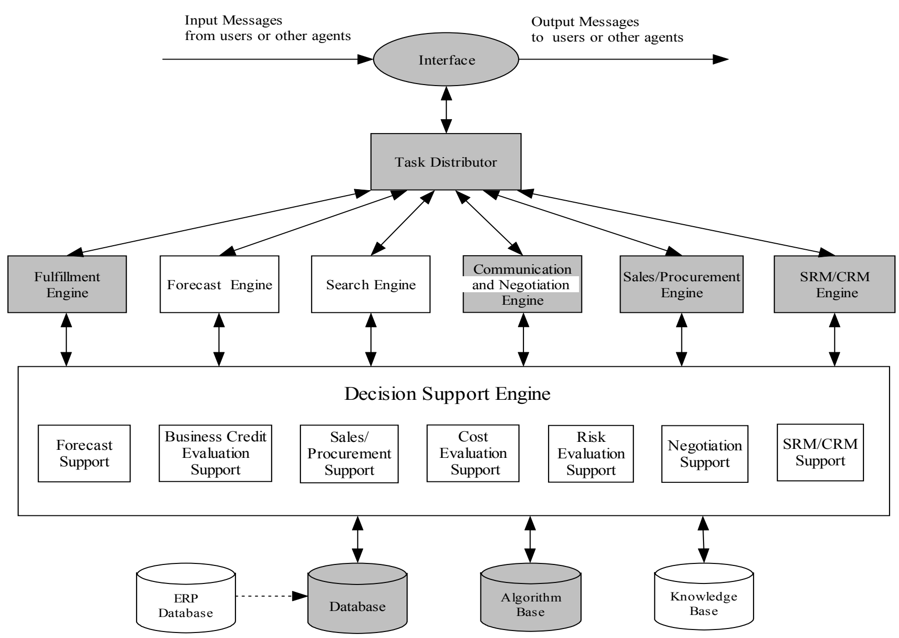
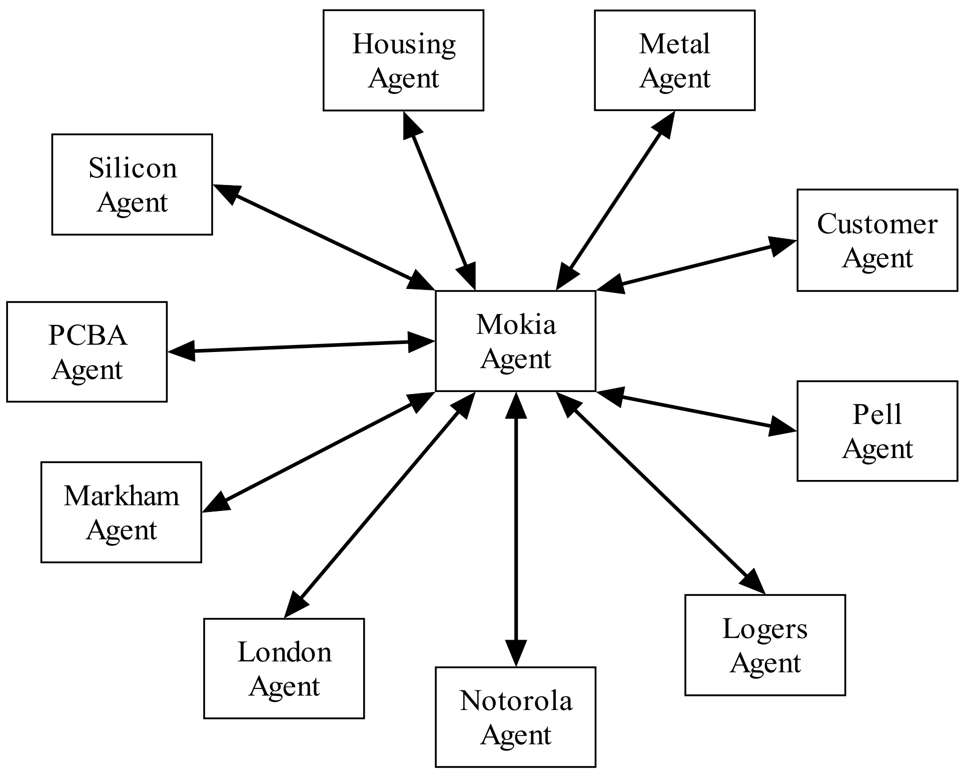
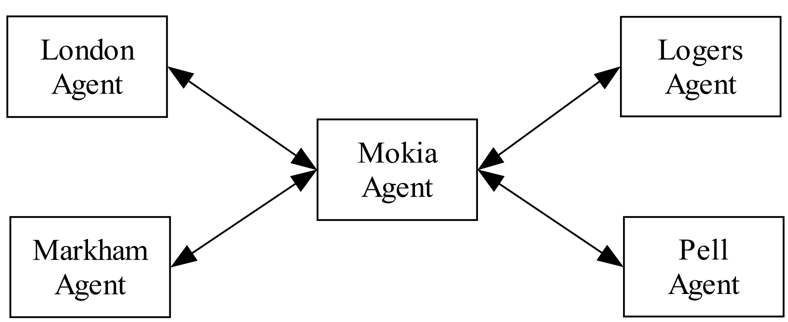


Figure 5.2 Implemented components in the structure of agent as given in Figure 4.4

Figure 4.4. Although each agent has the ability to communicate with all other agents, only adjacent agent layers have purchasing/selling functionalities. For example, if the Metal agent sends a sale message to all other agents, only the Housing and PCBA agents will react and respond to it. Figure 5.3(a) shows possible communication relationships among agents, while Figure 5.3(b) displays typical relationships between the adjacent agents and the Mokia agent.



(a) Possible communication relationships



(b) Supply and demand relationships

Figure 5.3 Relationships among agents

In this supply chain simulation system, the Customer agent will generate individual orders continuously on a daily basis. The number of orders generated in a day is determined using probability distributions. The Logers and Pell agents purchase or compete for the mobile phones from their supplier agents (Mokia and Notorola). The London and Markham agents compete for orders from Mokia and Notorola. The Housing and PCBA agents compete for orders from the London and Markham agents. They may also compete for raw materials when resources are scarce.

5.2 Assumptions and Strategies

The system can simulate a number of years of the entire mobile phone supply chain system. At the beginning of a day, the customer agent randomly generates the total number of orders required for that day (based on certain distribution). The agent will then separate them into equal intervals within 12 hours. The mobile phone brand in each independent purchase is randomly chosen by the probability of the brand market share.

When a certain brand of mobile phone reaches its stock baseline, as determined by its' Decision Support Engine, the retailer agent (Logers or Pell) should make an automatic order for this type of mobile phone. If a retailer agent has sold out of all mobile phones of a certain brand, the buyer may: (1) wait until the brand of mobile phone becomes available with this agent: without knowing how many days it will have to wait (30% probability). The orders are accumulated and sold immediately when the mobile phones become available; (2) buy another brand of mobile phone from this agent (40% probability); or (3) buy the same brand mobile phone from the other retailer agent (30% probability).

If a retailer agent has sold out of both brands of mobile phones, its buyers may: (1) buy mobile phones from the other retailer agent (30% probability); or (2) wait until this type of mobile phone becomes available at this retailer agent (70% probability).

Product agents (Mokia and Notorola) may utilize either Stock-to-Order (STO) which is equivalent to Make-to-Stock (MTS), or Order-to-Order (OTO) equivalent to

Make-to-Order (MTO) policy as determined by the user. The assembler agents (London and Markham), component agents (Housing and PCBA), and raw material agents (Metal and Silicon) may adopt either the Make-to-Stock (MTS) or Make-to-Order (MTO) production policies. The policy an agent adopts is determined by the user running the simulation.

5.3 System Processing

The system process is shown in Figure 5.4 and Figure 5.5. The customer agent buys a number of individual mobile phones from the retailer agents. There are two retailer agents – Logers and Pell who both sell Mokia and Notorola brand mobile phones. The retailer agents purchase mobile phones from product agents – Mokia and Notorola. Product agents order mobile phones from assembler agents who have purchased components and assembled the mobile phones. The two assembler agents – Markham and London, both produce Mokia and Notorola mobile phones. The Component agents – Housing and PCBA purchase raw materials (metal and silicon), manufacture the components, and sell the components to assembler agents. Raw material agents produce raw materials (Metal agent produces metal, and Silicon agent produces silicon), and sell them to component agents. Detailed processes of each agent are described in Section 6.2.

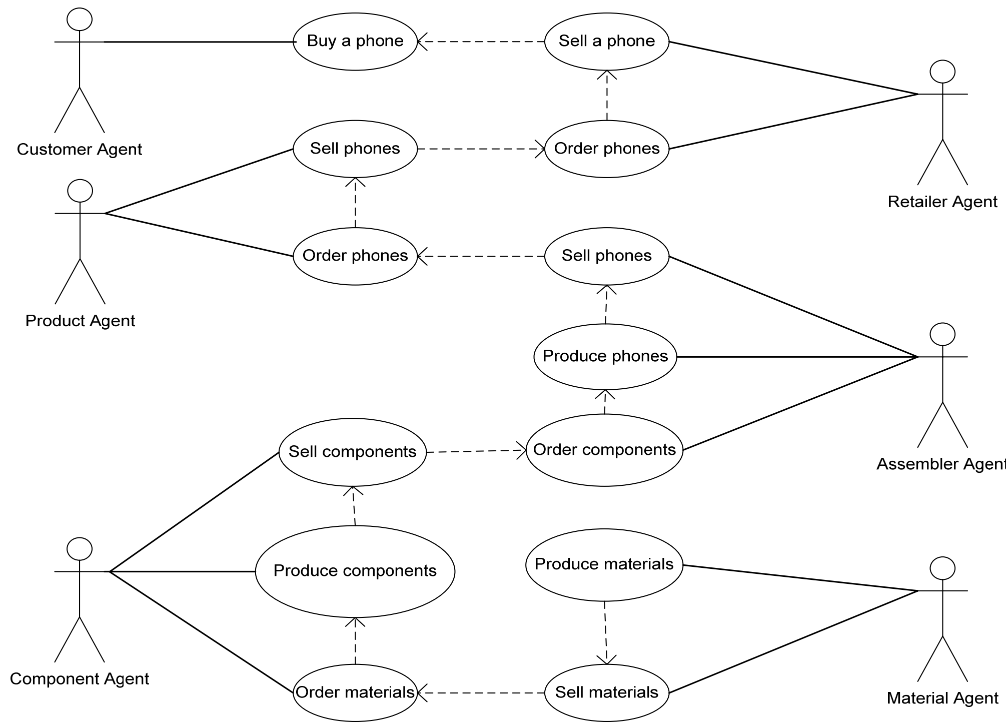


Figure 5.4 Unified Model Language (UML) Use Case of mobile phone simulation system

Before the simulation starts, the user may initialize the environment by setting parameters including: the years to be simulated, average customer orders in a normal workday, company market shares, initial inventories and cash for each company, daily production capacities of each manufacturing company, stock or production strategies, etc. For every six months, the user may adjust each company's strategy.

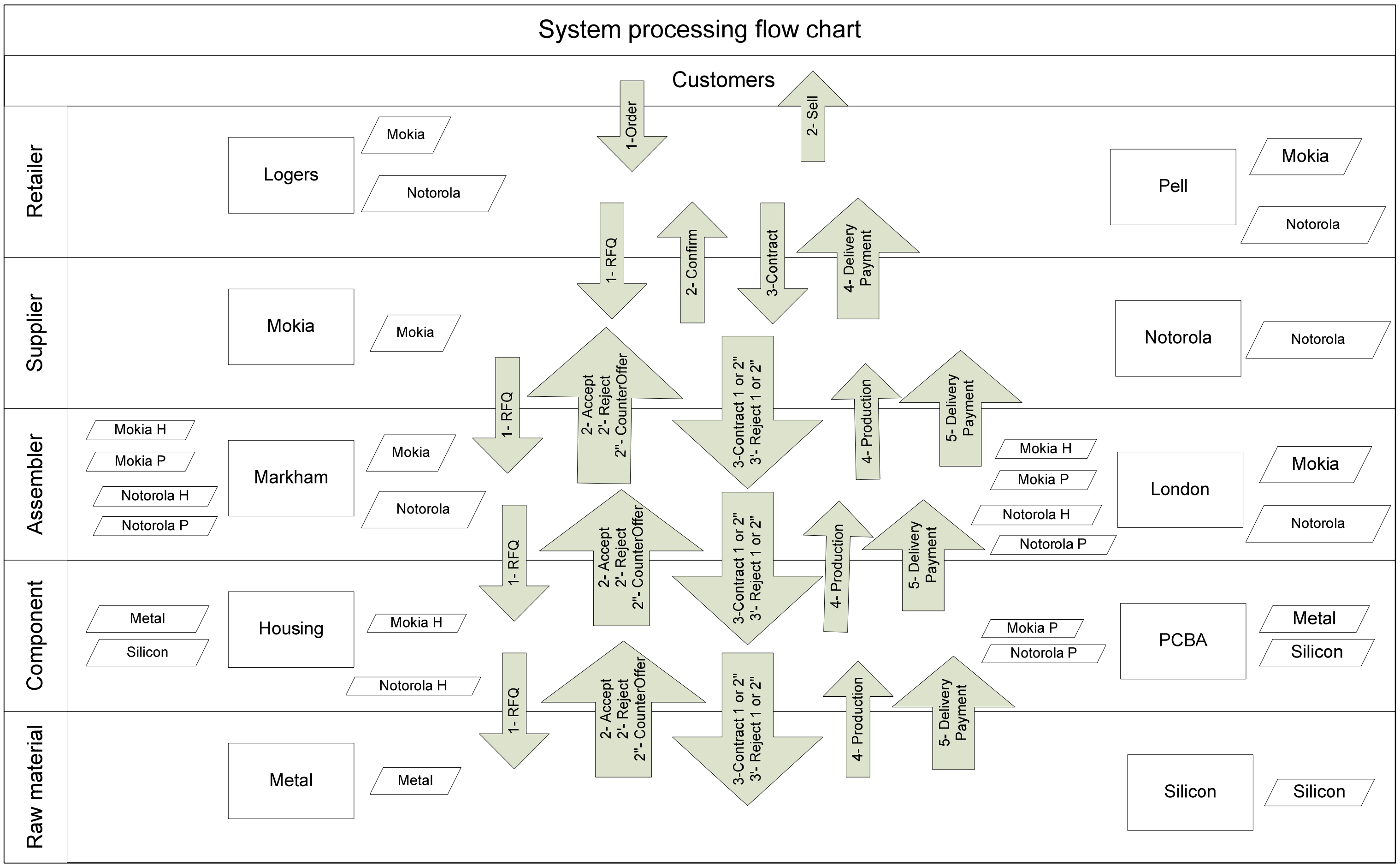


Figure 5.5 System processing flow chart

Chapter 6 Development of a Mobile Phone Supply Chain Simulation System

To demonstrate the designed simulation system, and to test supply chain performance using certain strategies in a certain environment, the author has developed a fictitious mobile phone supply chain simulation system by using VB.NET, SQL-Server and MS-Access. The system has one customer agent, two retailer agents (Logers and Pell), two product holder agents (Mokia and Notorola), two assembler agents (London and Markham), two component agents (Housing and PCBA), and two raw material agents (Metal and Silicon).

6 .1 Initialization of the Simulation

The simulation period is one year (52 weeks). Raw material agents (Silicon and Metal), component agents (Housing and PCBA), assembler agents (London and Markham) and product holder agents (Mokia and Notorola) work 50 weeks (5 days per week) a year (2 weeks are holiday, they do not work). Retailer agents (Logers and Pell) work 364 days a year (only do not work on the New Year day). Customer agent runs 364 days per year, divided into two seasons: normal season – from day 2 to day 351, and holiday (Christmas) season – day 352 to day 365. In the normal customer demand environment, during the normal season, the system will generate 50 to 150 orders each weekday, 100 to 300 orders each Saturday, and 100 to 200 orders each Sunday, in the uniform distribution (each order represents a purchase of one mobile phone). During the holiday season, from day 352 to day 360, the number of orders generated each day will follow the uniform distribution with the mean equal to 20 plus the previous day's mean. From day 361 to day 365, the number of orders generated each day will follow the uniform distribution with the mean equal to the previous day's mean minus 30. In a high customer demand environment, the orders generated each day will follow the same rule, but the mean, upper bound and lower bound will be doubled. Similarly, in a low customer demand environment, the number of orders generated each day also follows the previous rule, but the mean, upper bound and lower bound are divided by two. The user may input the desired mean orders before the system is running. In this system, Mokia has 60% market share and Notorola has 40% market share. In the mobile phone service market, Logers accounts for 70% of all customers while Pell for 30%. For all agents, the saving interest rate is 1%, and the loan interest rate is 5%. All of these parameters, initial financial positions, production capacities, and other initial inventories are adjustable by the user before the simulation starts.

The daily cost (all costs, such as payroll, rental, and advertisement costs, not including product cost) for each agent is: Logers - $2100; Pell - $900; Mokia - $1800; Notorola - $1200; Markham - $400; London - $400; Housing - $400; PCBA - $800; Metal - $200; Silicon - $200.

For both the Logers and Pell agents, the selling price for each Mokia mobile phone is $180, and for each Notorola mobile phone it is $170. The selling price of mobile phones by the Mokia and Notorola agents to the retailers is not constant and depends on a retailer's order size as shown in Table 6.1. The purchase price by the Mokia and Notorola agents from the assembler agents, Markham and London, also depends on the order quantities as shown in Table 6.2. The normal assembly capacity for an assembler agent is 150 units per day, the maximum assembly capacity is 300 units per day, and the minimum assembly capacity is 75 units. All brands of mobile phone have the same productivity, but each agent can only assemble one brand of mobile phone per day. The component costs for the London and Markham agents are given in Table 6.3.

Table 6.1 Unit selling price and order size

Order Size / Brand	< 100	101 to 200	201 to 300	301 to 400	401 to 500	501 to 600	601 to 700	701 to 800	801 to 900	> 901
Mokia	130	120	117	116	115	114	113	112	111	110
Notorola	120	110	107	106	105	104	103	102	101	100

Table 6.2 Unit purchasing price and order size

Brand \ Order size	< 100	101 to 200	201 to 300	301 to 400	401 to 500	501 to 600	601 to 700	701 to 800	801 to 900	≥ 900
Mokia	110	100	97	96	95	94	93	92	91	90
Notorola	100	90	87	86	85	84	83	82	81	80

Table 6.3 Assembler's purchasing prices

Brand \ Costs	Component	
	Housing	PCBA
Mokia	20	35
Notorola	20	30

The normal production capacity for each raw material agent (Metal and Silicon) is 300 units, the maximum capacity is 600 units, and the minimum capacity is 150 units per day. The selling price of both raw materials is $5 per unit as shown in Table 6.4. Each of the component agents (Housing and PCBA) can produce 200 components per day for either Mokia or Notorola Brand at normal production capacity, 400 components at maximum production capacity, and 100 units at minimum capacity. A component agent can only produce one kind of component each day.

Table 6.4 Material purchasing prices in component agents

Brand \ Material	Metal	Silicon
Housing	5	5
PCBA	5	5

6.2 Processes of Agents

6.2.1 Customer Agent

A customer agent will randomly generate orders every day according to certain distribution. Here we use uniform distribution. If it is a weekday, the mean of the distribution is equal to the average orders as defined by the user. If the day is in the Christmas season (day 352 to 365), the mean of the uniform distribution will follow the triangle distribution (on day 360, the mean is equal to 200 plus normal weekday mean order). If the day is a Saturday between day 2 and day 351, the mean of the distribution is equal to 2 times the average orders. If the day is a Sunday between day 2 and day 351, the mean of the distribution is equal to 1.5 times the average orders. If the day is New Year's (day 1), all retailer agents will be closed, and the customer agent will not generate any orders. The customer demand distribution can be changed easily by using a different probability generating function.

If a retailer agent has sold out of all mobile phones of a certain brand, the buyer has two options:

(1) Giving Up: give up the order;

(2) Accumulating: buy another brand of mobile phone from this agent (40% probability); buy the same brand mobile phone from the other retailer agent (30% probability); or, wait until the brand of mobile phone becomes available from this agent (not knowing how many days it will have to wait) (30% probability).

The market share of retailers and product holders can be adjusted by the user at the beginning of the simulation. By default, Logers has 70% market share, Pell has 30%; Mokia has 60%, and Notorola has 40%.

Processes and activities of Customer Agent are shown in Figure 6.1.

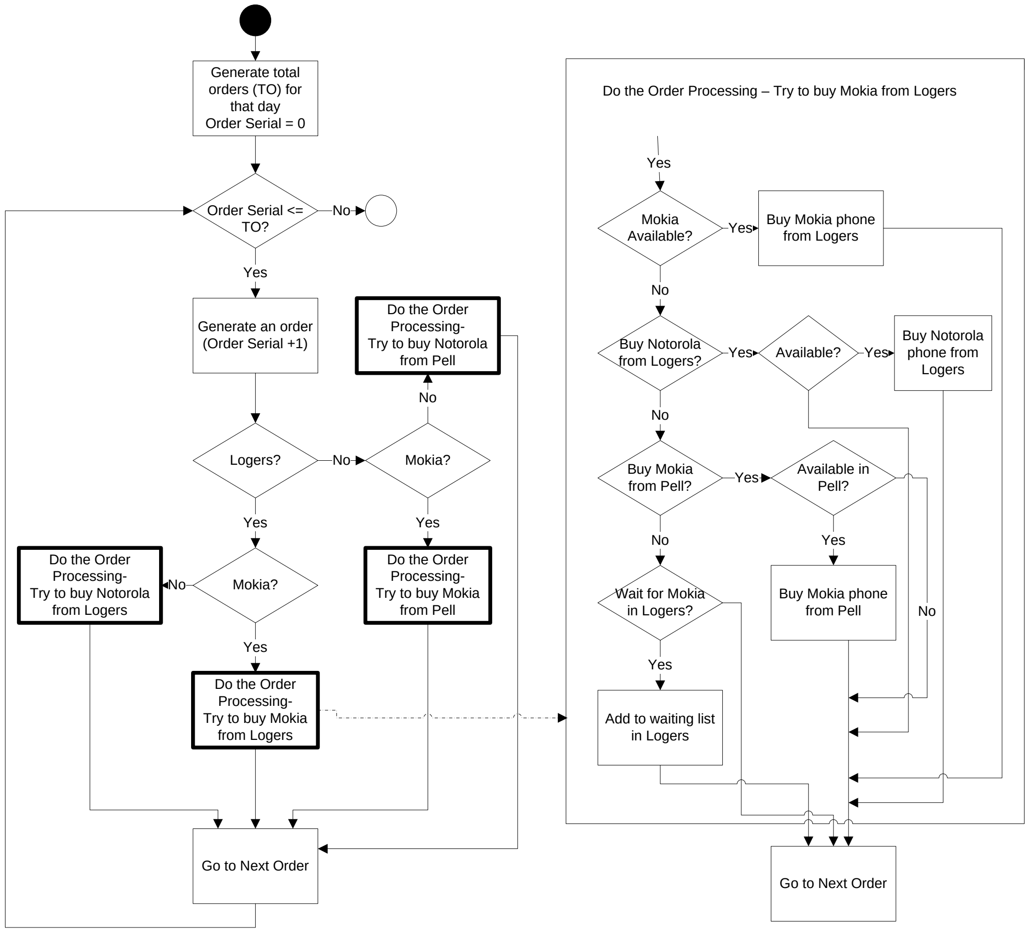


Figure 6.1 Processes and activities of the customer agent

6.2.2 Retailer Agents

The process of a retailer agent is shown in Figure 6.2. There are two retailer agents – Logers and Pell. When a retailer agent receives a customer order, it will sell a phone to the customer if it is in stock. If the retailer is sold out, the customer agent may choose to hold the order until it is available, if the customer is willing to wait. When the inventory of a brand has reached its order point, the retailer agent will send a request-for-quotation (RFQ) to the product agent. An RFQ has the following information: (1) the RFQ identification number, (2) the brand of mobile phone, (3) the quantity desired, (4) the unit price, and (5) the delivery date. If the product agent can fulfill the RFQ, it will accept the RFQ, and transfer it to a contract. If it cannot satisfy the RFQ, it will be rejected and the retailer agent will send another RFQ the next working day.

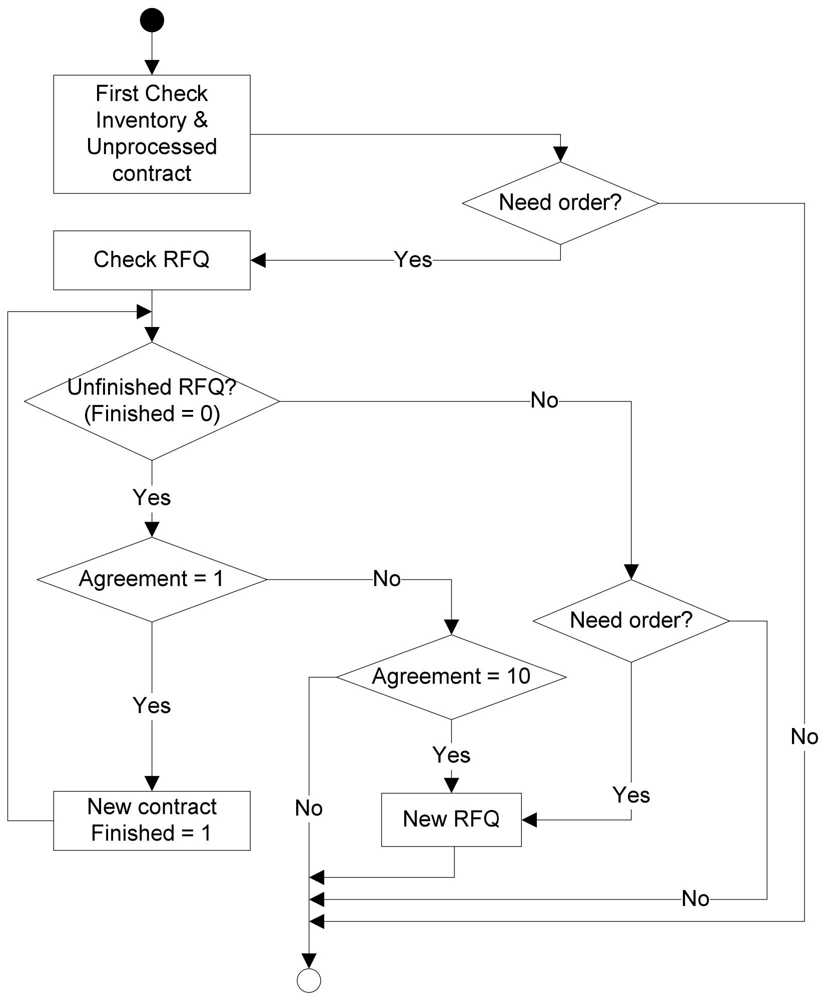


Figure 6.2 Processes of a retailer agent

A retailer agent may adopt either the Same Order Amount or the In Proportion order policy for the order amount in an RFQ. The Same Order Amount Policy means that all RFQs of all retailer agents have the same order amount. In this system, the Same Order Amount Policy means that the order amount for a retailer is 400 units. The In Proportion policy means that the order amount in an RFQ is proportional to the market share. For example, the Logers share is 70% and the Pell share is 30% of total customer orders. Mokia has a 60% share of the market while Notorola has a 40% share. The average daily order for weekdays is 100. If an RFQ order is equal to two weeks sales, the amount for an RFQ is calculated as follows: total market needs for two weeks is 1700 ($=(5\times100 + 1.5\times100 + 2\times100)\times2$) (5 weekdays, 1 Saturday, and 1 Sunday). The amount in

Logers' RFQ for Mokia is 714 ($1700\times70\%\times60\%$) and for Notorola is 476 ($1700\times70\%\times40\%$). The amount in Pell's RFQ for Mokia is 306 ($1700\times30\%\times60\%$) and for Notorola is 204 ($1700\times30\%\times40\%$).

6.2.3 Product Holder Agents

There are two product agents – Mokia and Notorola. The process of a product agent is shown in Figure 6.3. A product agent purchases mobile phones from assembler agents, and sells them to retailer agents. It may adopt different inventory strategies in response to a retailer agent's order – Stock-to-Order (STO) or Order-to-Order (OTO). The user has the opportunity to adjust the inventory strategy every six months.

If the product agent adopts the STO strategy, sufficient inventory will be maintained to satisfy the retailer's RFQs. When inventory reaches its order point, the product agent will generate two identical request-for-quotation (RFQ^1 and RFQ^2) – one for the London agent and the other for the Markham agent. If both the assembler agents agree, the product agent will choose one and convert it to a contract. The assembler agent will be chosen randomly and with equal probability. If only one assembler agent confirms the RFQ, the product agent will convert it to a contract. If both assembler agents reject the RFQs, the product agent will generate new RFQs.

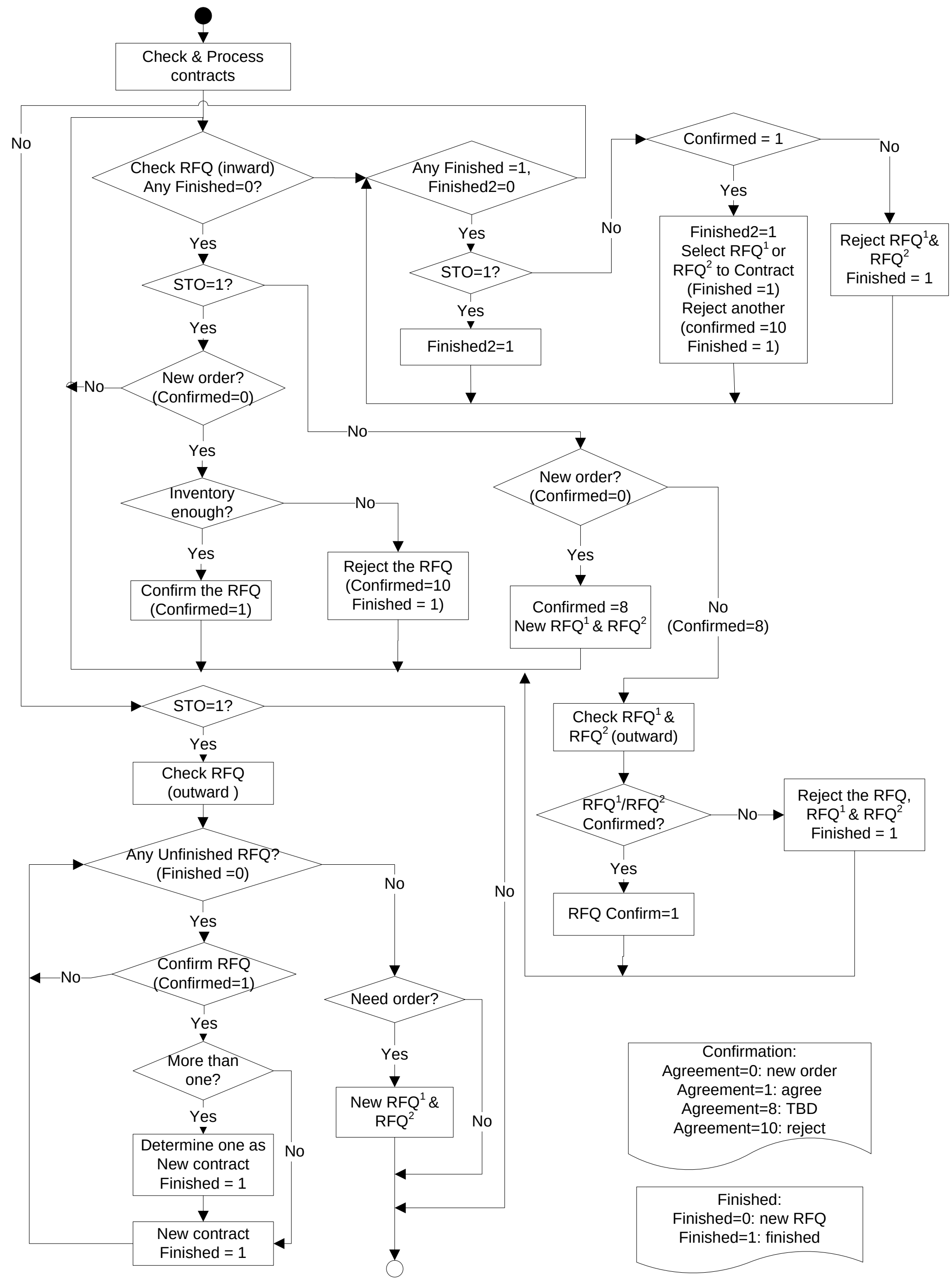


Figure 6.3 Processes of a product agent

If the product agent adopts the OTO strategy, it will keep a small amount of inventory. When it receives an RFQ, it will mark the RFQ as status pending. It will then generate two identical request-for-quotation (RFQ^1 and RFQ^2) one for the London agent and the other for the Markham agent containing the same information as the received

RFQ. The product agent will confirm the retailer agents RFQ when at least one assembler agent confirms (RFQ^1 or RFQ^2). If both assembler agents confirm, the product agent will randomly with equal probability choose one and convert it to a contract and refuse the other. If only one assembler agent confirms the RFQ, the product agent will convert it to a contract. If both assembler agents reject the RFQs, the product agent will reject the retailer's RFQ and the retailer agent will have to generate a new RFQ for the product agent.

6.2.4 Assembler Agents

There are two assembler agents – London and Markham. The process of an assembler agent is shown in Figure 6.4. An assembler agent purchases components from component agents, produces (assembles) mobile phones according to the production schedule, and sells the mobile phones to product agents. Both assembler agents can produce two kinds of mobile phones – Mokia and Notorola. The production capacity of the assembler agents is initialized by the user at the beginning of simulation.

An assembler agent may adopt MTO (make-to-order) or MTS (make-to-stock) production strategy and may change their production strategy every six months. The MTS strategy provides the best opportunity to obtain a product agent's order while the MTO strategy reduces inventory costs for the assembler agent.

When the MTS strategy is adopted, the assembler agent tries to keep the inventory of mobile phones high to satisfy two agents' orders. When the inventory of a component reaches its order point, the assembler agent generates an RFQ to that component agent. The production schedule is based on product and component inventories. When the assembler agent receives an RFQ from a product agent, it will check its' product inventory first. If the inventory is not less than the order amount in the RFQ, the agent confirms the order. If the inventory is less than the RFQ, the agent will reject the RFQ.

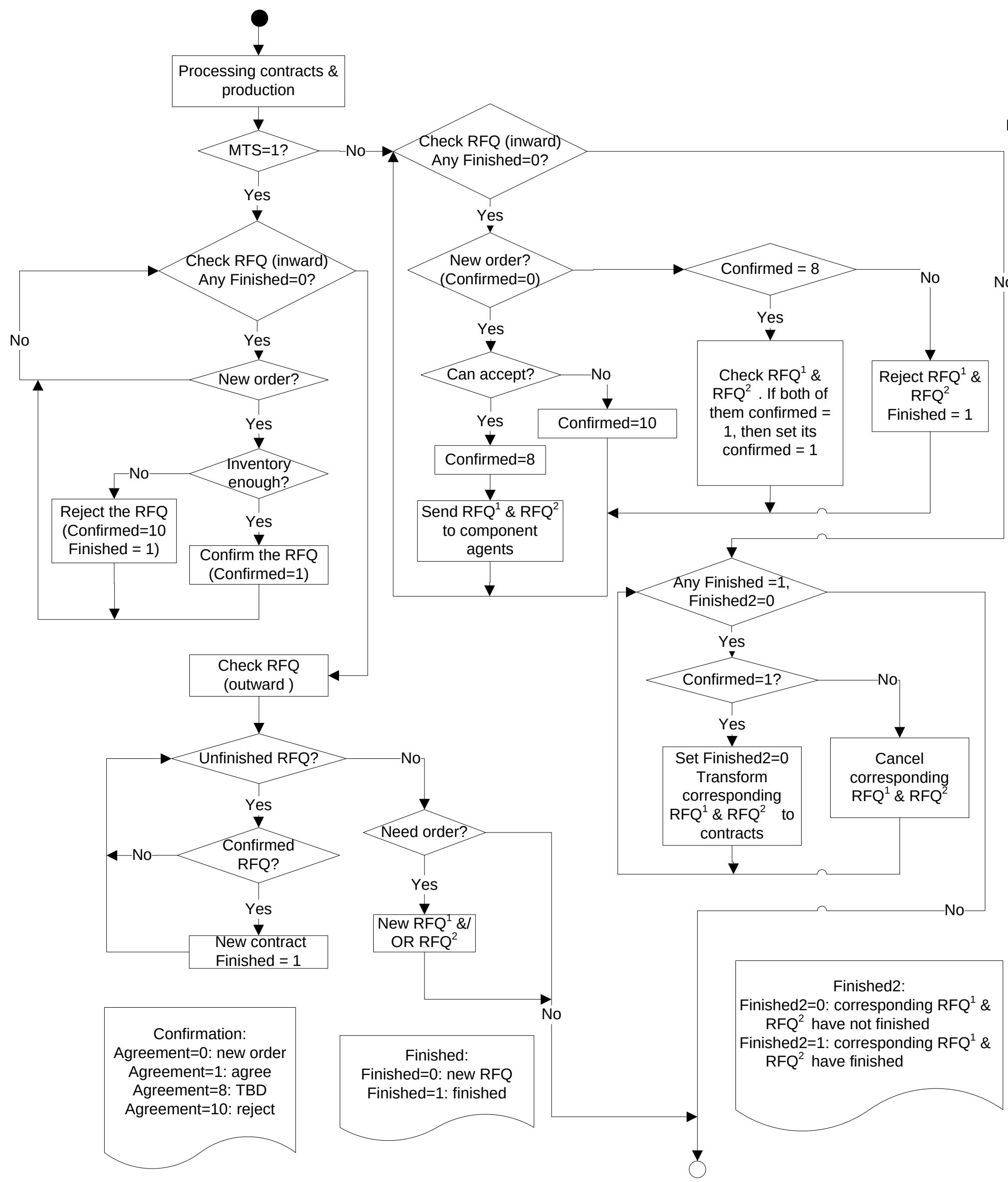


Figure 6.4 Processes of an assembler agent

When an assembler agent adopts the MTO strategy, it keeps a low inventory of products and components. When an RFQ is received from a product agent, the assembler agent checks the fulfillment possibility from the production perspective. If it cannot satisfy the RFQ it will be rejected. If it can be fulfilled the assembler converts the RFQ to pending status and generates two new corresponding RFQs (RFQ^1 and RFQ^2) to component agents in order to purchase components. Both components are required. If at least one of the component agent rejects RFQ (RFQ^1 and RFQ^2), the assembler agent will reject the original RFQ. If both component agents confirmed the RFQ^1 and RFQ^2, the assembler agent will confirm the original product agent's RFQ. When the product agent has selected an assembler agent as the supplier of the RFQ, the assembler agent will transfer the RFQ^1 and RFQ^2 to contracts, and begin to produce the products. If the assembler agent has accepted the RFQ, but the product agent cancels it (the product agent has selected another assembler agent as the supplier of RFQ), the assembler agent has to cancel its RFQ^1 and RFQ^2 with the components' agents.

6.2.5 Component Agents

There are two component agents – Housing and PCBA. The housing agent produces two kinds of housing components – Mokia housing and Notorola housing, and the PCBA agent manufactures two kinds of PCBA components – Mokia PCBA and Notorola PCBA. The process of a component agent is similar to the assembler agent (shown in Figure 6.4). A component agent purchases raw materials from material agents, produces the components according to the production scheduling, and sells the components to assembler agents. The production capacity of the component agents is fixed and can be initialized by the user at the beginning of the simulation.

A component agent may adopt the MTS or MTO production strategy and may change its' production strategy every six months. When an agent adopts the MTS strategy, components are produced until the inventories reach their upper boundary. When the inventory of a material reaches its order point, it will generate an RFQ to the corresponding material agent. When the component agent receives an RFQ from an assembler agent, it will check the component inventory first. If the inventory is not less than the order amount in the RFQ, the agent will confirm the order. If the inventory is not sufficient, the agent will reject the RFQ.

When the MTO strategy is adopted, components and materials inventories are kept low. When an RFQ is received from an assembler agent, it will check the possibility of fulfilling the order from the production perspective. If the RFQ cannot be satisfied, the agent will reject the RFQ. If it can be fulfilled, it will mark the RFQ as pending status, and generate two new corresponding RFQs (RFQ^1 and RFQ^2) to material agents to purchase raw materials. If at least one material agent rejects RFQs (RFQ^1 and RFQ^2), the component agent will reject the original RFQ. When both material agents confirmed the RFQs (RFQ^1 and RFQ^2), the component agent will confirm the original RFQ. Once the assembler agent has transferred the RFQ to a contract, the component agent will transfer RFQ^1 and RFQ^2 to contracts, and begin to produce the components. If the component agent has accepted the RFQ, but the assembler agent cancels it (the product agent has selected another assembler agent as its supplier), the component agent has to cancel its RFQ^1 and RFQ^2 with the materials agents.

6.2.6 Raw Material Agents

There are two raw material agents – Metal and Silicon. The Metal agent only produces metal, while the silicon agent only produces silicon. The production capacity of both raw material agents can be initialized by the user at the beginning of the simulation. The process of a raw material agent is shown in Figure 6.5.

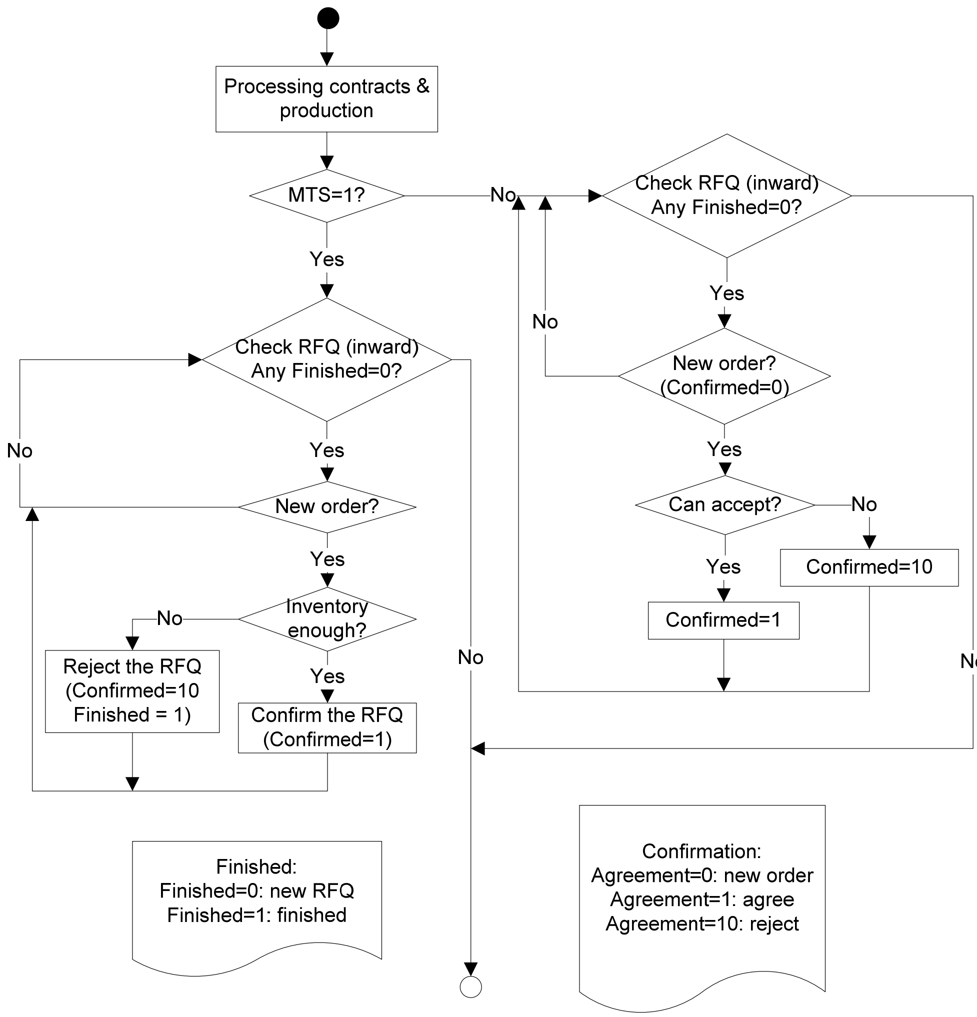


Figure 6.5 Processes of a raw material agent

A raw material agent may adopt the MTS or MTO production strategy and may change its production strategy every six months. When an agent adopts the MTS strategy, raw materials are produced until the inventory reaches its upper boundary. When the raw material agent receives an RFQ from a component agent, it will check the inventory first. If the inventory is not less than the order amount in the RFQ, the agent will confirm the order, and the component agent will transfer the RFQ to a new contract. If the inventory is not enough to fulfill the RFQ, the agent will reject the RFQ.

When a raw material agent adopts the MTO strategy, material inventories are kept low. When an RFQ is received from a component agent, the raw material agent will confirm its ability to fulfill the order from the production perspective. If the RFQ cannot be satisfied, the agent will reject the RFQ. Otherwise, it will confirm the RFQ. After the component agent transfers the RFQ to a contract, the material agent will start to produce the material. If the agent has confirmed the RFQ, but the component agent cancels it, the material agent will not produce the material.

6.3 Database of the System

A database structure is a key factor in a complex simulation system. It should record all the information generated during the simulation. In this system, the author uses SQL Server – a relational database to store and process the simulation information. The database includes two parts – initialized data and generated data (simulation data). The database structure is shown in Figure 6.6.

Initialized data is utilized to set up the simulation environment and the initial status of the system. There are four tables to store the information – Company, Common, Price, and Product. Detailed contents of each initialized table are shown in Figure 6.7.

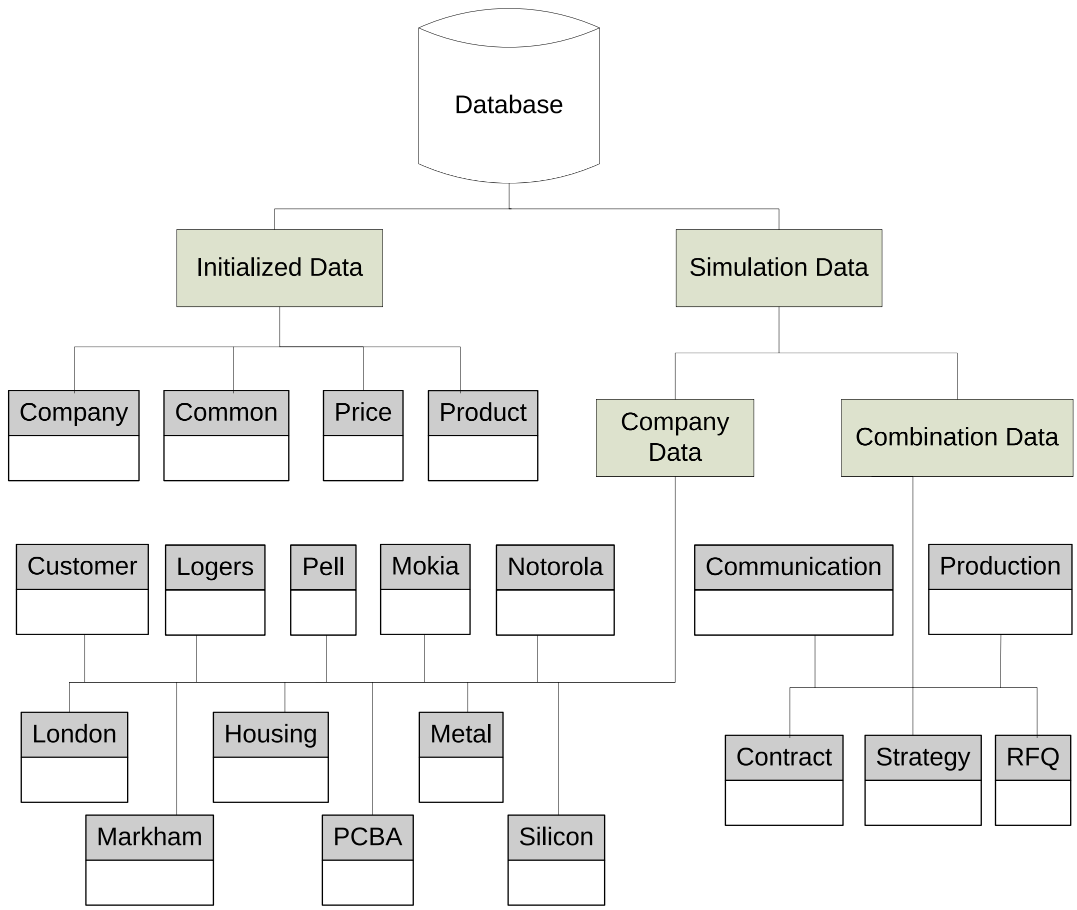


Figure 6.6 Outline of the database in simulation system

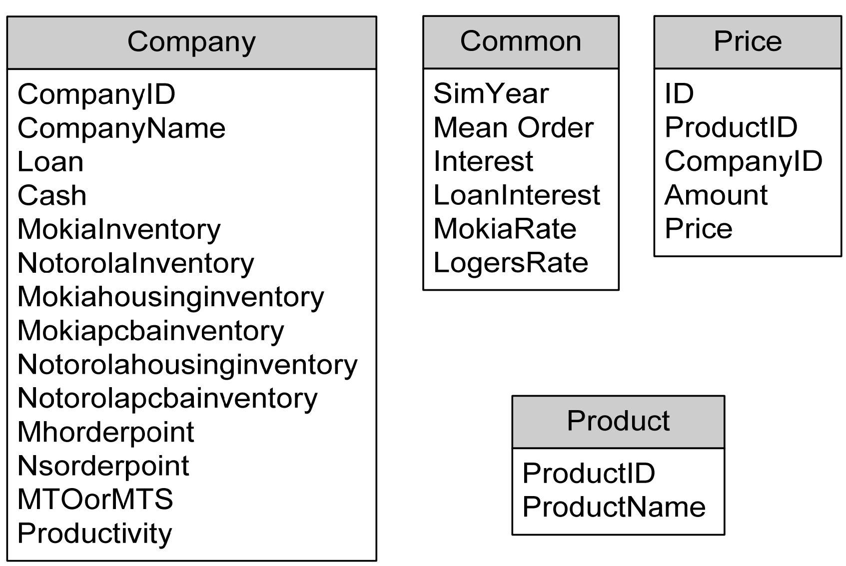


Figure 6.7 Initialized data

Simulation data is the data generated during the simulation. It can be classified into two sub-categories – Company (Agent) data (see Figure 6.8) and Combination data (see Figure 6.9). A company table is used to record the daily sales, production, inventories, transaction(s), and financial balance of the company (agent). A combination table is utilized to record any requests, communication, production, and strategy changes.

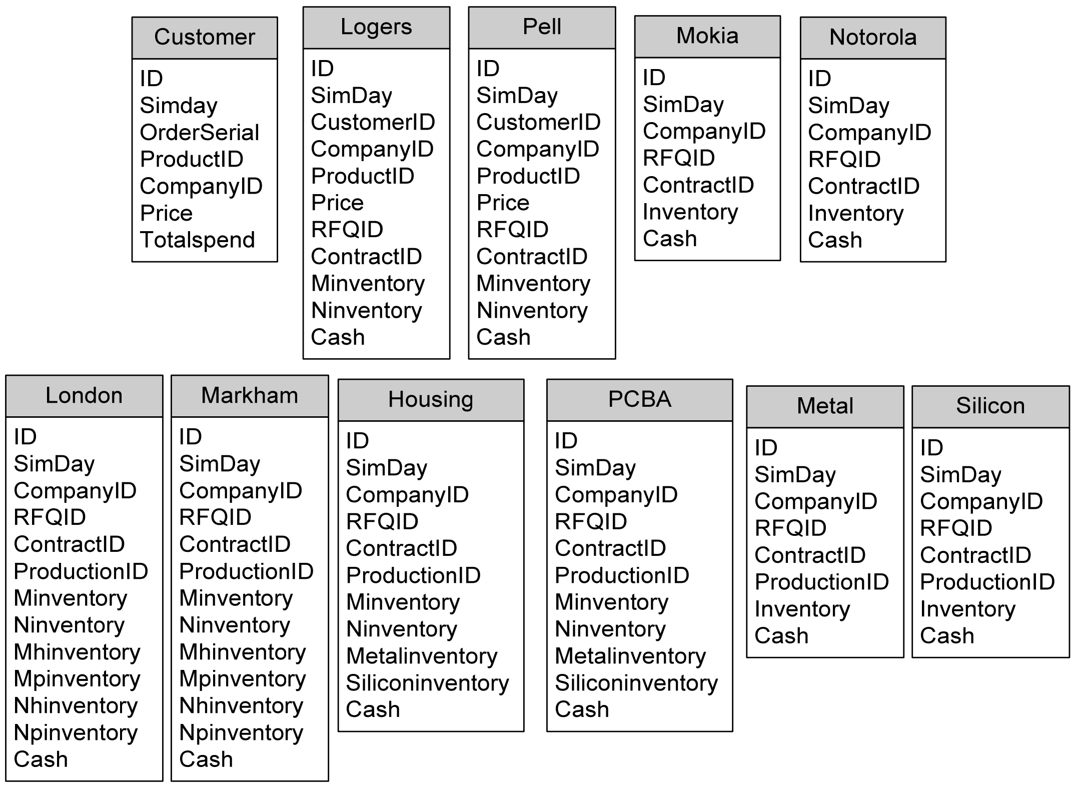


Figure 6.8 Detailed company data

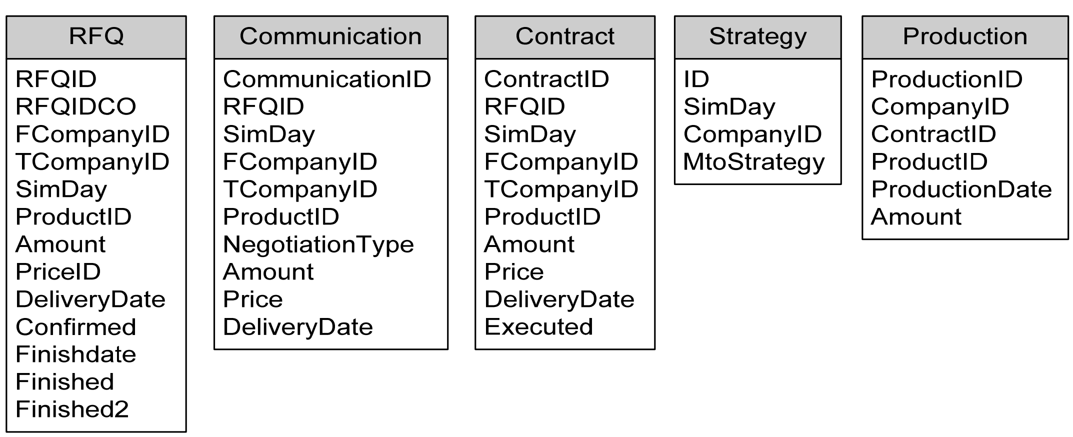


Figure 6.9 Detailed combination data

6.4 Factors and Parameters in the System

Since a supply chain is a network of companies, any environmental settings or changes in an agent or the market will influence all agents as well as the efficiency of the whole supply chain. When market demand by customers is high, every agent will realize more profit if the capacities of all agents are adequate. If market demand by customers is high, but the production capacity of a component agent is minimum, all agents may not increase profit as much as expected. If market demand by customers is low, any agent may see its profit decrease, and may even experience bankruptcy. Factors that may influence the performance of the supply chain as well as their possible values are listed in Table 6.5. The detailed interpretations about each parameter are given in Chapters 7 and 8.

Table 6.5 Factors and parameters in the simulation system

Agent	Parameter	Value
Customer	Demand (DC)	1-Normal
		2-High
		3-Low
	Behavior (CB)	0-Giving Up
		1-Accumulating
Retailer	Order Amount (OA)	0-In Proportion
		1-Same
	Order Point (OP)	0-Conservative
		1-Positive
Product Holder	Order Amount (OA)	0-In Proportion
		1-Same
	Order Point (OP)	0-Conservative
		1-Positive
	Stock Strategy (SS)	0-Order-to-Order
		1-Order-to-Stock
		2-Change Iteratively
Assembler	Order Amount (OA)	0-In Proportion
		1-Same
	Order Point (OP)	0-Conservative
		1-Positive
	Production Strategy (PS)	0-Make-to-Order
		1-Make-to-Stock
		2-Change Iteratively
	Production Capacity (PC)	0-Normal
		1-Maximum
		2-Minimum
Component	Order Amount (OA)	0-In Proportion
		1-Same
	Order Point (OP)	0-Conservative
		1-Positive
	Production Strategy (PS)	0-Make-to-Order
		1-Make-to-Stock
		2-Change Iteratively
	Production Capacity (PC)	0-Normal
		1-Maximum
		2-Minimum
Raw Material	Production Strategy (PS)	0-Make-to-Order
		1-Make-to-Stock
		2-Change Iteratively
	Production Capacity (PC)	0-Normal
		1-Maximum
		2-Minimum

This simulation system is a multi-agent system and all agents will start working at the same time. At the beginning, all agents except for the Customer agent have default inventories which may be changed by the user. Table 6.6 shows the default settings and strategies for the system. These can be changed by the user at the beginning of the simulation.

Table 6.6 The initialized data in the simulation system

Agent	Parameter	Initial Value	Agent	Parameter	Initial Value
Common	Simulation year	2	London	Loan	200000
	Saving Interest rate	1%		Cash	200000
	Loan Interest rate	5%		Mokia Inventory	800
	Mokia Share	60%		Notorola Inventory	800
	Notorola Share	40%		Mokia Housing Inventory	500
	Logers Share	70%		Mokia PCBA Inventory	500
	Pell Share	30%		Notorola Housing Inventory	500
Customer	Daily Mean Orders	100		Notorola PCBA Inventory	500
	Behavior	Giving Up		Production Capacity	150
Logers	Loan	200000		Production Strategy	MTO
	Cash	200000		Order Point Strategy	Conservative
	Mokia Inventory	300		Order Amount Policy	Same
	Notorola Inventory	300	Housing	Loan	150000
	Order Point Strategy	Conservative		Cash	150000
	Order Amount Policy	Same		Metal Inventory	1000
Pell	Loan	200000		Silicon Inventory	1000
	Cash	200000		Mokia Housing Inventory	600
	Mokia Inventory	300		Notorola Housing Inventory	600
	Notorola Inventory	300		Production Capacity	200
	Order Point Strategy	Conservative		Production Strategy	MTO
	Order Amount Policy	Same		Order Point Strategy	Conservative
Mokia	Loan	200000		Order Amount Policy	Same
	Cash	200000	PCBA	Loan	150000
	Inventory	200		Cash	150000
	Inventory Strategy	STO		Metal Inventory	1000
	Order Point Strategy	Conservative		Silicon Inventory	1000
	Order Amount Policy	Same		Mokia PCBA Inventory	600
Notorola	Loan	200000		Notorola PCBA Inventory	600
	Cash	200000		Production Capacity	200
	Inventory	200		Production Strategy	MTO
	Inventory Strategy	STO		Order Point Strategy	Conservative
	Order Point Strategy	Conservative		Order Amount Policy	Same
	Order Amount Policy	Same	Metal	Loan	100000
Markham	Loan	200000		Cash	100000
	Cash	200000		Inventory	2000
	Mokia Inventory	1000		Production Capacity	300
	Notorola Inventory	1000		Production Strategy	MTO
	Mokia Housing Inventory	400	Silicon	Loan	100000
	Mokia PCBA Inventory	400		Cash	100000
	Notorola Housing Inventory	400		Inventory	2000
	Notorola PCBA Inventory	400		Production Capacity	300
	Production Capacity	150		Production Strategy	MTO
	Production Strategy	MTO			
	Order Point Strategy	Conservative			
	Order Amount Policy	Same			

6.5 Interfaces of Initializing the System

When starting the simulation system, the system requires the user to set the initial parameters. Different initial environments will bring different results. Figure 6.10 to Figure 6.16 are the system's initializing interfaces.

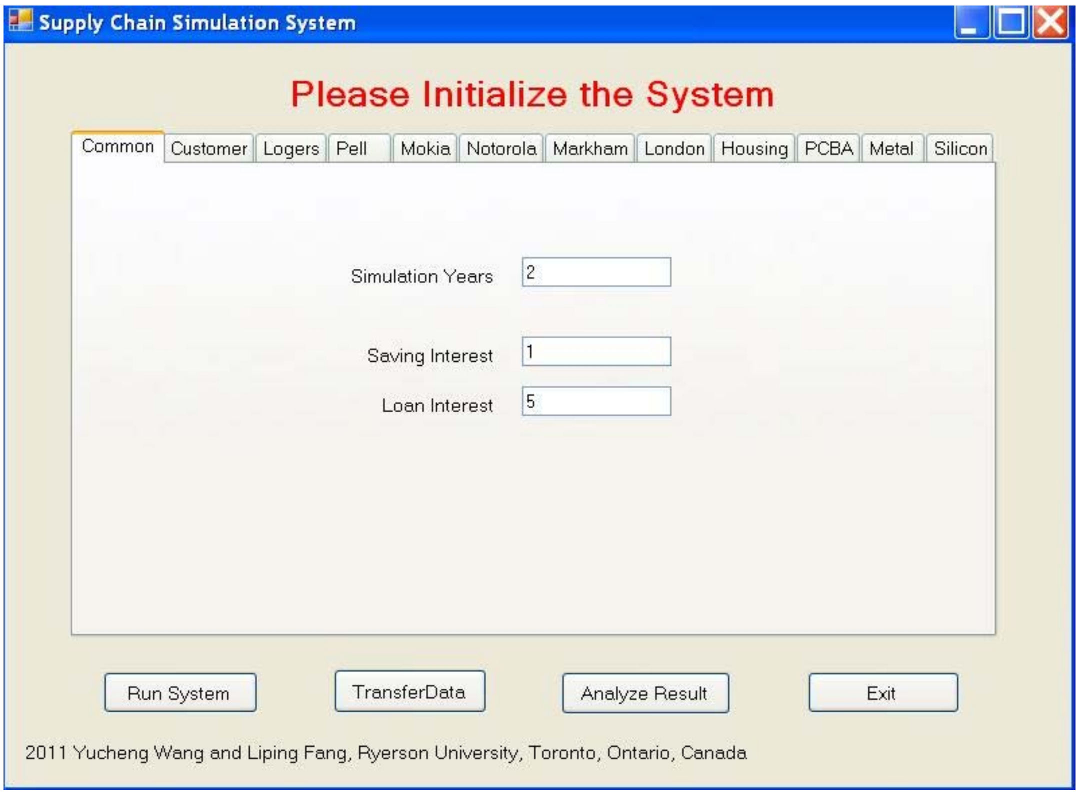


Figure 6.10 Interface for initializing common parameters

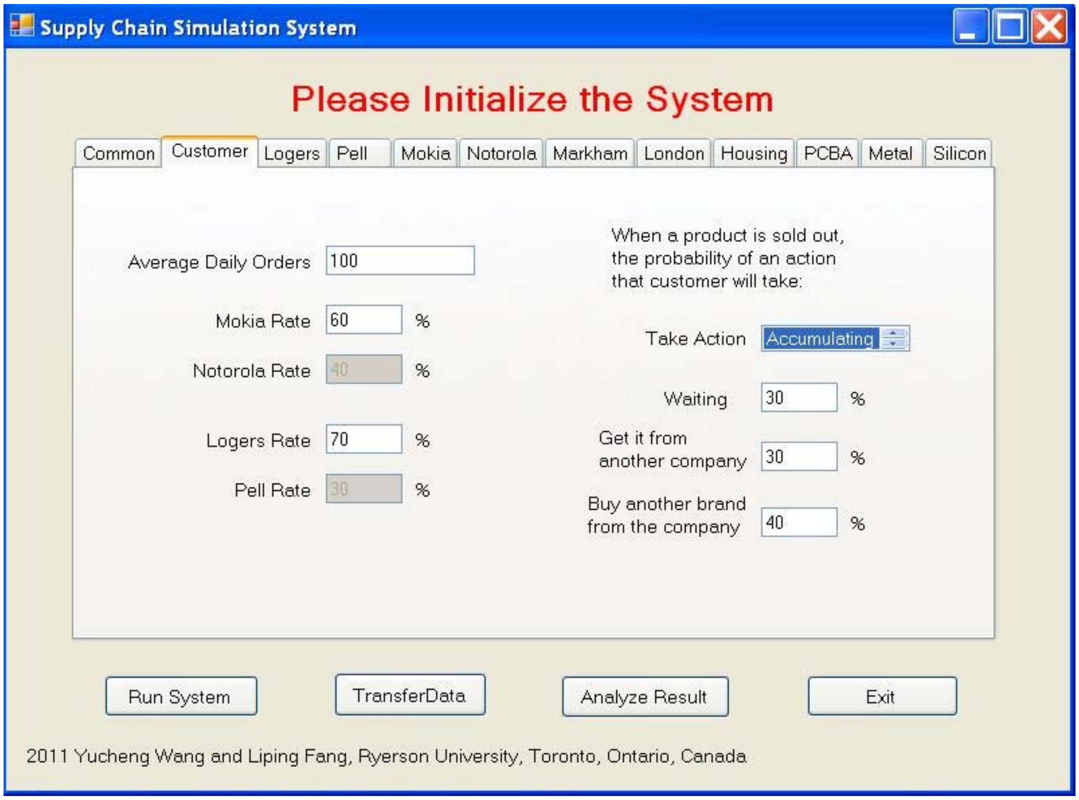


Figure 6.11 Interface for initializing customer agents

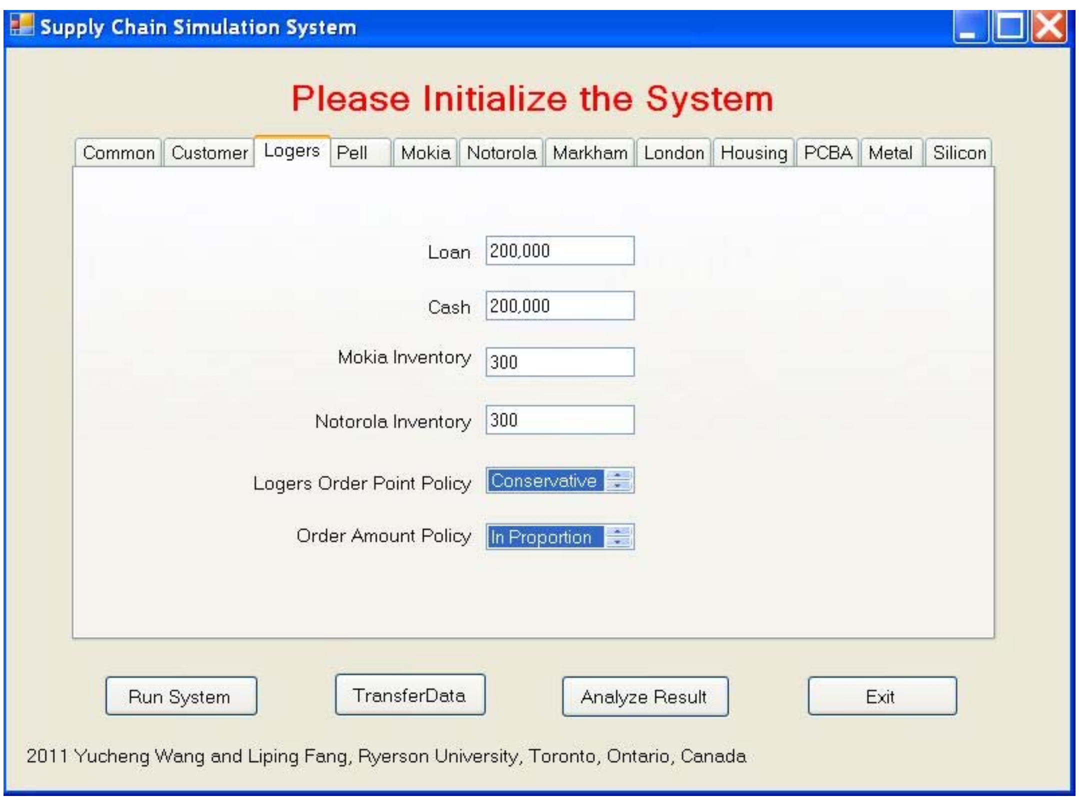


Figure 6.12 Interface for initializing retailer agents

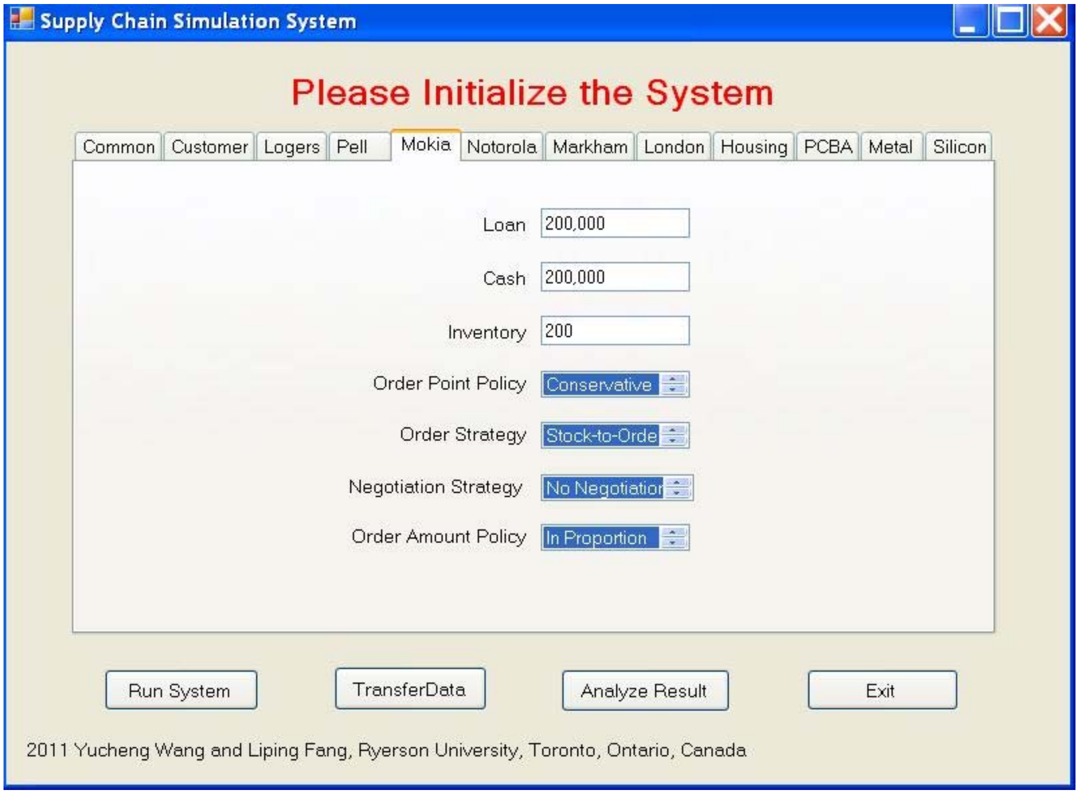


Figure 6.13 Interface for initializing product holder agents

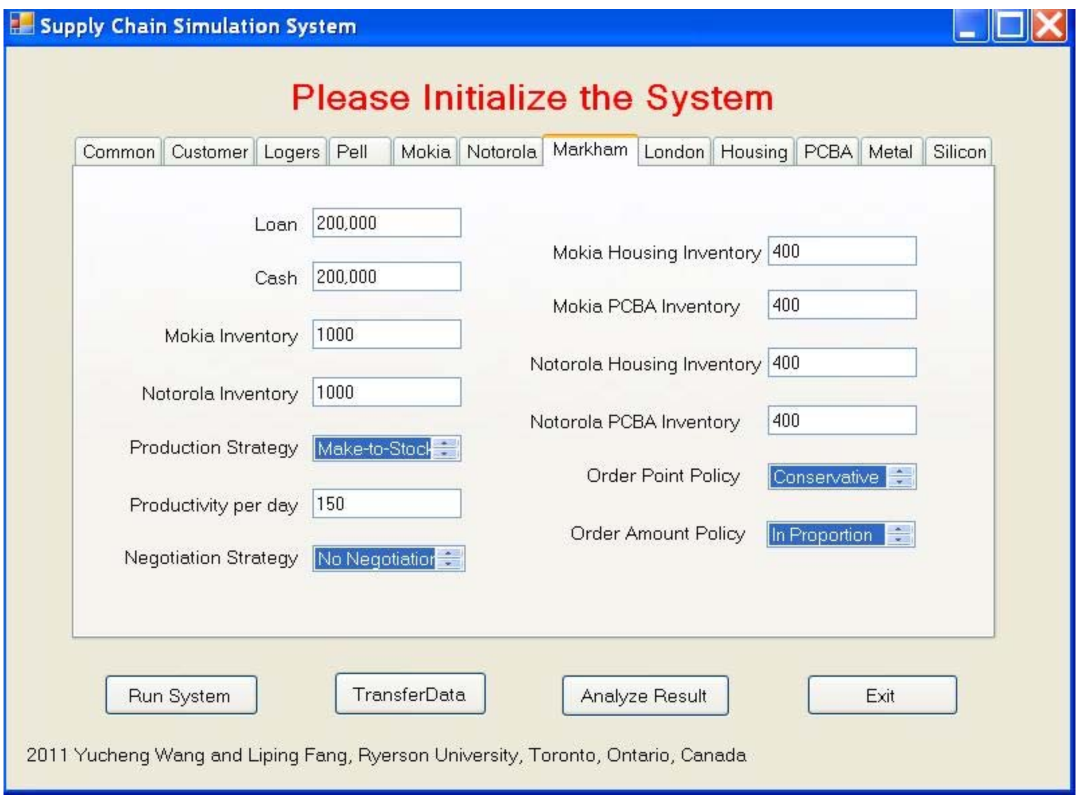


Figure 6.14 Interface for initializing assembler agents

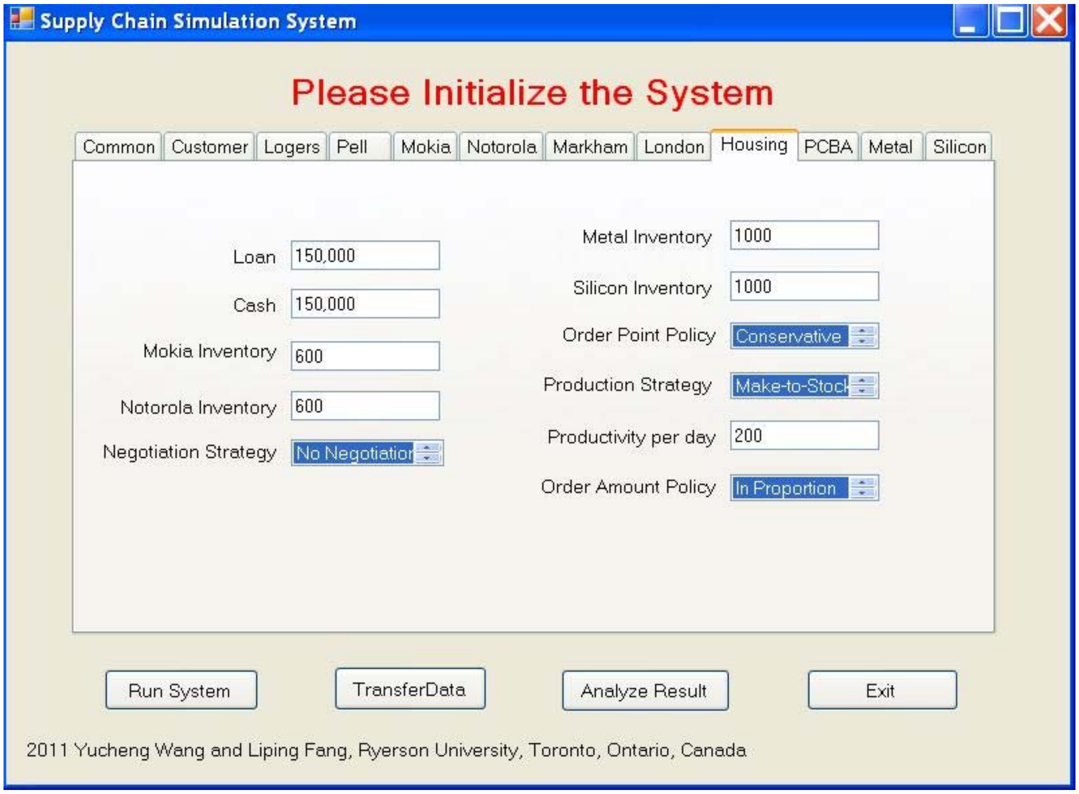


Figure 6.15 Interface for initializing component agents

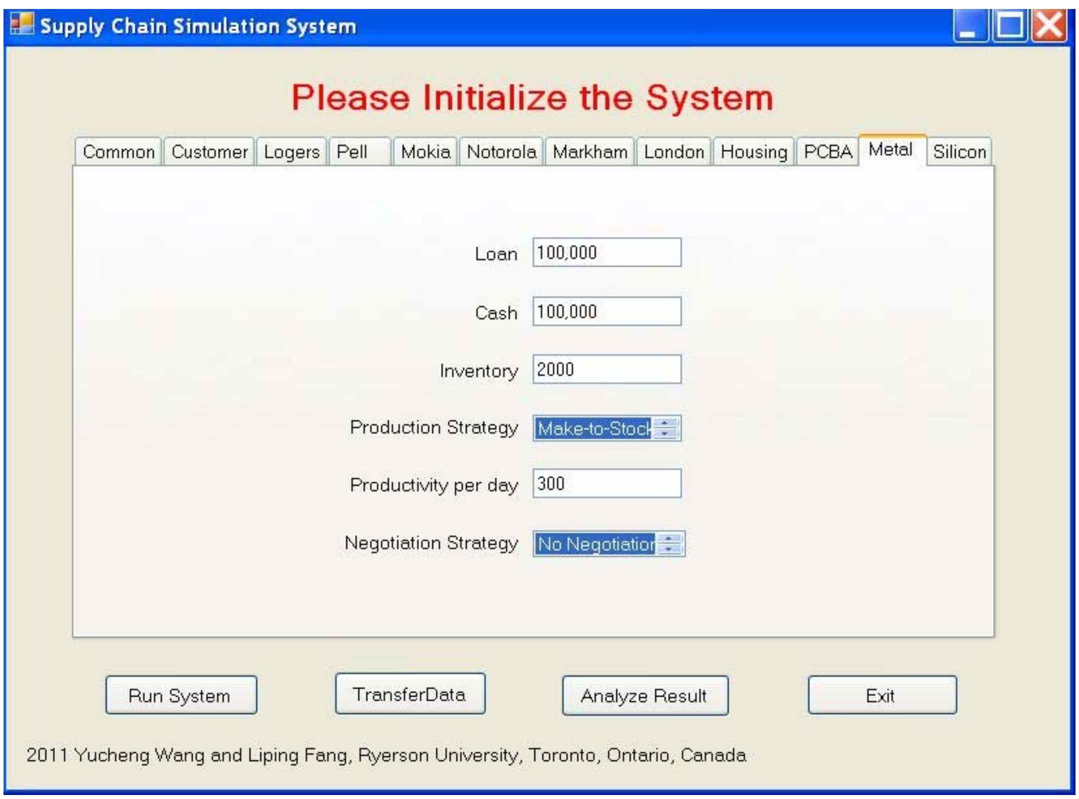


Figure 6.16 Interface for initializing material agents

Chapter 7 System Testing and Validation

7.1 Overview of Simulation Scenarios

Section 6.4 demonstrated that there are many factors and parameters that will affect the supply chain performance. Figure 7.1 uses a multi-dimensional graph to illustrate how those factors and parameters are utilized in the simulation. Cube G in Figure 7.1 represents that in a Normal market environment, a material agent (Metal or Silicon) will adopt one production strategy (Make-to-Order, Make-to-Stock, or Change Strategy Iteratively). To simplify this simulation, fixed values are adopted for the parameters in Table 6.6. For example, for the market demand parameter, the value of the High market demand is exactly twice the Normal demand, while the value of the Low market demand is exactly half of Normal demand. To test all situations, thousands of different scenarios would have to be run. The total scenarios can be calculated as follows:

$$\text{Total Scenarios} = \prod C_{Agent}^{Parameter}$$

$$= C_{CM}^{DC} C_{CM}^{CB} C_{LG}^{OA} C_{LG}^{OP} C_{PL}^{OA} C_{PL}^{OP} C_{MO}^{OA} C_{MO}^{OP} C_{MO}^{SS} C_{NO}^{OA} C_{NO}^{OP} C_{NO}^{SS} C_{MH}^{OA} C_{MH}^{OP} C_{MH}^{PS} \times$$

$$C_{MH}^{PC} C_{LD}^{OA} C_{LD}^{OP} C_{LD}^{PS} C_{LD}^{PC} C_{HO}^{OA} C_{HO}^{OP} C_{HO}^{PS} C_{HO}^{PC} C_{PB}^{OA} C_{PB}^{OP} C_{PB}^{PS} C_{PB}^{PC} C_{MT}^{PS} C_{MT}^{PC} C_{SI}^{PS} C_{SI}^{PC}$$

$$= C_{CM}^{DC}(3,1) C_{CM}^{CB}(2,1) C_{LG}^{OA}(2,1) C_{LG}^{OP}(2,1) C_{PL}^{OA}(2,1) C_{PL}^{OP}(2,1) C_{MO}^{OA}(2,1) C_{MO}^{OP}(2,1) \times$$

$$C_{MO}^{SS}(3,1) C_{NO}^{OA}(2,1) C_{NO}^{OP}(2,1) C_{NO}^{SS}(3,1) C_{MH}^{OA}(2,1) C_{MH}^{OP}(2,1) C_{MH}^{PS}(3,1) C_{MH}^{PC}(3,1) \times$$

$$C_{LD}^{OA}(2,1) C_{LD}^{OP}(2,1) C_{LD}^{PS}(3,1) C_{LD}^{PC}(3,1) C_{HO}^{OA}(2,1) C_{HO}^{OP}(2,1) C_{HO}^{PS}(3,1) C_{HO}^{PC}(3,1) C_{PB}^{OA}(2,1) \times$$

$$C_{PB}^{OP}(2,1) C_{PB}^{PS}(3,1) C_{PB}^{PC}(3,1) C_{MT}^{PS}(3,1) C_{MT}^{PC}(3,1) C_{SI}^{PS}(3,1) C_{SI}^{PC}(3,1)$$

$$=3\times2\times2\times2\times2\times2\times2\times2\times3\times2\times2\times3\times2\times2\times3\times3\times2\times2\times3\times3\times2\times2\times3\times 3\times2\times2\times3\times3\times3\times3\times3\times3$$

$$=3^{15}\times2^{17}$$

$$=1.88\times10^{12} \tag{7.1}$$

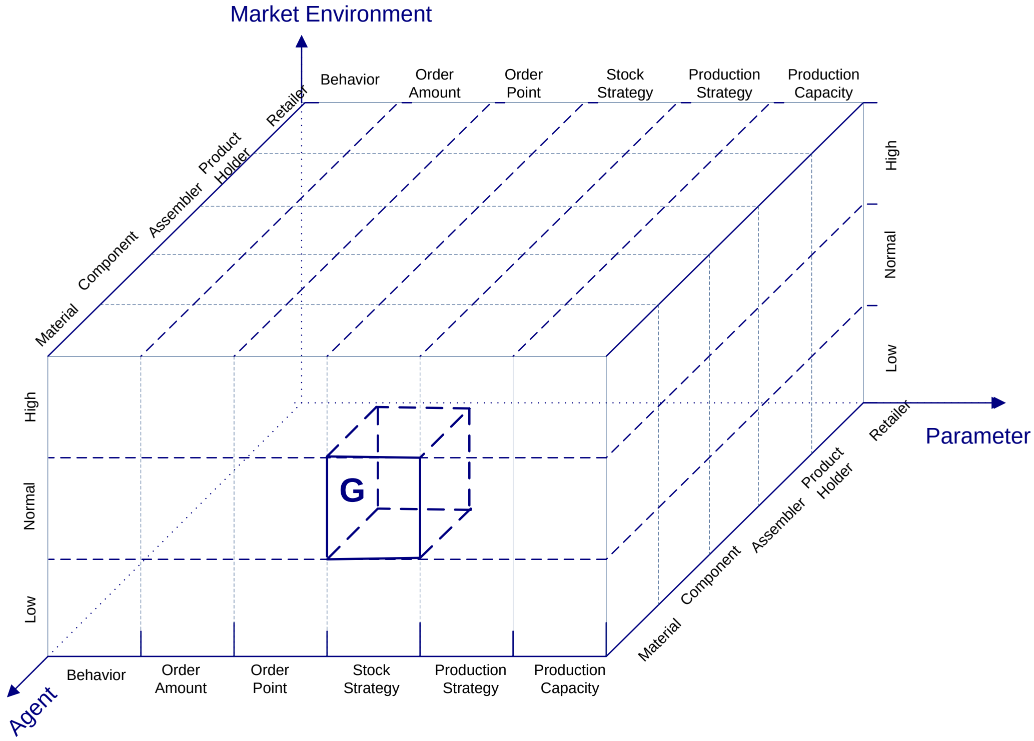


Figure 7.1 A comprehensive illustration of the simulation

The structure in Figure 7.1 can be used to analyze the influence of each parameter on the performance of the whole supply chain. The plane(s) can be used to dissect the structure, as shown in Figure 7.2. Plane A can be used to analyze Market Environment; Plane B to analyze agents; and Plane C to analyze other parameters. In Figure 7.2, dissecting by Plane A shows how High market demand will affect the whole supply chain (each agent); dissecting by Plane B shows how the behavior of Markham or London agent will affect the whole supply chain (other agents); and dissecting by Plane C shows how an Order Amount Strategy (0 – In Proportion, or 1 – Same) parameter affects the whole supply chain. The Point D is the point where the three planes intersect and has special meaning: in a High market demand environment, how the Order Amount Strategy of Markham or London affects the whole supply chain. To analyze the whole supply chain performance influenced by Point D, all situations of other parameters' combinations have to be tested. According to permutations and combinations, the total number of scenarios (combinations) under High market demand and a certain Order Amount Strategy (Same or In Proportion) is:

$$(\prod C_{Agent}^{Parameter})/C_{CM}^{DC}/C_{MH}^{OA} = 1.88\times 10^{12}/3/2$$
$$= 3.13\times 10^{11} \qquad (7.2)$$

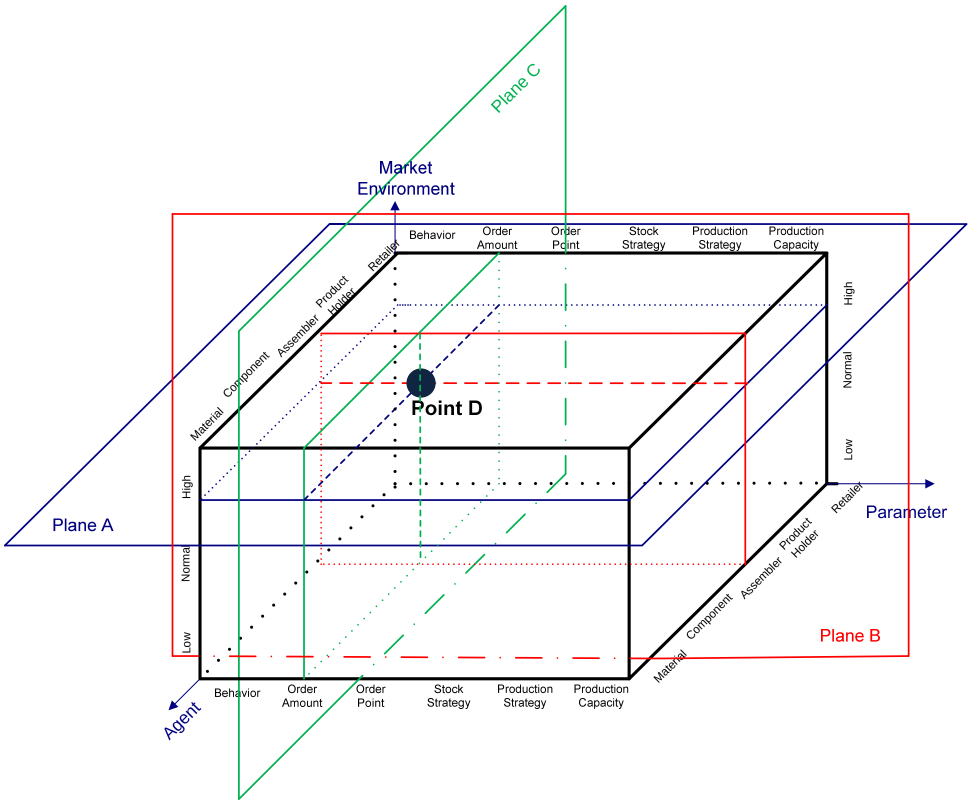


Figure 7.2 The point that a simulation may focus on

The number of scenarios for Point D is so huge, it is impossible to test all of them. Therefore only some representative scenarios are tested. Table 7.1 shows a few of the typical scenarios when Markham adopts the Same Order Amount Strategy in the High market demand environment. The detailed scenarios used in this dissertation are shown in Appendix A.

This simulation system can be utilized in practice in a variety of ways, including:

- As an analysis tool for an entity in a supply chain. From a particular supply chain entity's perspective, various management strategies and behaviors can be examined to test their impacts on the performance of a supply chain.

- As a tool for analyzing supply chain coordination and integration. From the perspective of an entire supply chain, or portion of it, various coordination and integration strategies and behaviors can be studied to test their performance.
- As an analysis tool used by a supply chain entity or analyst to design supply chains. Various “what-if” questions can be tested using the simulation system.

Table 7.1 Part of scenarios when Markham adopts Same Order Amount strategy

Scenario	Customer		Logers		Pell		Mokia			Notorola			Markham				London				Housing				PCBA				Metal		Silicon	
	DC	CB	OA	OP	OA	OP	OA	OP	SS	OA	OP	SS	PS	PC	**OA**	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	PS	PC
17	2	0	1	0	1	0	1	0	1	1	0	1	1	0	**1**	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
20	2	0	1	0	1	0	1	0	1	1	0	1	1	1	**1**	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
23	2	1	1	1	1	1	1	0	1	1	0	1	1	0	**1**	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
30	2	0	1	1	1	1	1	0	1	1	0	1	1	0	**1**	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
34	2	0	1	0	1	0	1	0	1	1	0	1	1	0	**1**	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
36	2	0	1	1	1	0	1	0	1	1	0	1	1	0	**1**	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
38	2	0	1	0	1	0	1	0	1	1	0	1	1	0	**1**	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
40	2	0	1	0	1	0	1	1	1	1	0	1	1	0	**1**	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
42	2	0	1	0	1	0	1	1	1	1	1	1	1	0	**1**	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
44	2	0	1	0	1	0	0	1	1	0	1	1	1	0	**1**	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
46	2	0	1	0	1	0	1	1	1	0	1	1	1	0	**1**	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
48	2	0	1	0	1	0	1	0	0	1	0	0	1	0	**1**	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
50	2	0	1	0	1	0	1	0	1	1	0	0	1	0	**1**	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

7.2 Extracting, Classifying and Summarizing Data for Analysis

The database for this simulation system stores all of the information about settings, production, RFQs, communication, contracts, transactions, cash flow statements etc. As shown in Figure 6.6, the data can be classified into two categories – Initialized Data and Simulation Data. Initialized Data is used to set the environment including: simulation period, interest rate, market share of agents, market demand, product prices, inventories of agents, strategies and policies of agents, production capacities of agents, initial loans and cash of agents. This information is very important when analyzing the supply chain performance, as different environments will result in different performance.

Simulation Data stores all of the processing data, which can be divided into two groups – independent data (for each agent) and communication and combination data. Independent data for any agent will record sales (contracts), inventories, production status, communication records (RFQ), cash balance, and so on. Communication and combination data will save every agent's daily communication, transaction and production information. This data is utilized to analyze an agent's behavior and the performance of the whole supply chain.

To analyze the performance of the whole supply chain, each agent's revenue has to be calculated at the end of the simulation. The final asset value of the agent is used to replace its revenue and should include cash and the cash value of the inventory:

$$\text{Asset of agent } j = \text{Cash}(j) + \sum_{i=1}^{n(j)} Inventory(i) \times price(i) \tag{7.3}$$

where j is the agent to be evaluated; i is a product or component possessed by agent j; $n(j)$ is the total number of products and/or components possessed by agent j; $Inventory(i)$ is the inventory amount of product or component i held by agent j; and $price(i)$ is the price of product or component i.

To study an agent's performance, its RFQs, contracts, and production information must be extracted from the RFQ table, Contract table, and Production table. To see how an RFQ became a contract, or why it was refused, all of this communications about that RFQ should be collected. Based on this observation, different strategies for that agent must be tested to determine how the performance of the whole supply chain and the agent changed. Ultimately, suitable strategies under certain environments for an agent can be determined.

The asset results of all scenarios tested in this dissertation are shown in Appendix B, and the summary results are shown in Appendix C.

7.3 System Validation

To test the system, some typical scenarios are simulated to ascertain whether the results are reasonable and the system operates reliably. Table 7.2 lists some typical tested scenarios with the simulation results shown in Table 7.3. Scenario 16 is a situation with the following parameters: market demand is Normal; all retailer, product holder, assembler and component agents adopt the Same Order Amount Policy and Conservative Order Point Strategy; all product holders adopt the Stock-to-Order Inventory Strategy; all assembler, component and material agents adopt the Make-to-Stock Production Policy and Normal Production Capacity Strategy. In addition, Logers has 70% market share and Pell has 30%, while Mokia has 60% market share and Notorola has 40%. Scenarios 17 and 18 are the same as Scenario 16, except that market demand is High and Low respectively. The results show that although market demand was High, the overall supply chain performance did not improve because the manufacturing agents could not provide sufficient supplies. This is compared with Scenarios 19 to 21 which are the same as Scenarios 16 to 18, except that all of the manufacturing agents adopted the Maximum Production Capacity Strategy. As a result, the whole supply chain performance improved significantly except when market demand was Low. The revenues of retailers and product holders were close to their market share (Scenario 17 is an exception which will be analyzed in Chapter 8).

Next, simulation results are examined when retailers have an equal market share. Scenarios 118, 119, 122 and 123 show the simulation results when retailers had an equal market share. Scenario 118 and 119 are similar to Scenarios 19 and 20, and Scenarios 122 and 123 are similar to Scenarios 16 and 17, except that Logers and Pell had the same market share (50%, 50%). The results show that the revenues of Logers and Pell were very similar, and the overall performance of the supply chain were similar to the scenarios with unequal market shares. Situations where the product holders had an equal market share resulted in the same conclusions. Scenarios 128, 129, 130 and 131 are similar to Scenarios 16 and 17, except that Mokia and Notorola have an equal market share (50%, 50%). The results show that the revenues of Mokia and Notorola were similar (Scenario 129 and 131 are exceptions which will be discussed in Chapter 8), and the overall performance of the supply chains were similar to scenarios with unequal market shares.

The author further tests three situations with 10 runs each. The first group of 10 scenarios given as Scenarios 190 to 199 in Appendix A has exactly the same set of parameters settings:

- market demand by customers is Normal;
- customer agent adopts the Accumulating policy;
- all retailer agents adopt the Same Order Amount and the Conservative Order Point Strategy;
- all product holder agents adopt the In Proportion Order Amount, the Conservative Order Point, and the Order-to-Order policies;
- Markham and all component agents adopt the Same Order Amount, the Conservative Order Point, Normal Production Capacity, and the Make-to-Stock policies;
- London agent adopts the In Proportion Order Amount, the Conservative Order Point, the Make-to-Order, and Normal Production Capacity strategies;

- all material agents adopt Normal production capacity, and the Make-to-Stock policies;
- Logers has 70% market share, and Pell has 30%;
- Mokia has 60% market share, and Notorola has 40%.

The second group of 10 scenarios listed as Scenarios 201 to 210 in Appendix A has exactly the same situation, which is the same as in the first group except for Markham and London:

- Markham agent adopts the In Proportion Order Amount, the Conservative Order Point, the Make-to-Order, and Normal Production Capacity strategies;
- London agent adopt the Same Order Amount, the Conservative Order Point, Normal Production Capacity, and the Make-to-Stock policies;

The third group of 10 scenarios given as Scenarios 212 to 221 in Appendix A has exactly the same situation as follows:

- market demand by customers is Normal;
- customer agent adopts the Giving Up order policy;
- all retailer agents adopt the In Proportion Order Amount and the Conservative Order Point Strategy;
- all product holder agents adopt the In Proportion Order Amount, the Conservative Order Point, and the Order-to-Order policies;
- all assembler and component agents adopt the In Proportion Order Amount, the Conservative Order Point, the Make-to-Order, and Normal Production Capacity strategies;
- all material agents adopt Normal production capacity, and the Make-to-Order policies;
- both Logers and Pell have 50% market share;
- both Mokia and Notorola have 50% market share.

Simulation results for those scenarios are given in Appendix B and Appendix C. It is shown that within a group, all runs have very similar simulation result. Based on those testing, the system functions as designed. The system can be used to simulate generic six-layer supply chain networks. A copy of the system developed can be obtained from Professor Liping Fang (lfang@ryerson.ca) upon request.

Table 7.2 Some typical simulation scenarios

Scenario	Customer		Logers		Pell		Mokia			Notorola			Markham				London				Housing				PCBA				Metal		Silicon	
	DC	CB	OA	OP	OA	OP	OA	OP	SS	OA	OP	SS	PS	PC	**OA**	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	PS	PC
16	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
17	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
18	3	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
19	1	0	1	0	1	0	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
20	2	0	1	0	1	0	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
21	3	0	1	0	1	0	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
Scenarios 100 to 127, Logers and Pell have equal market share																																
118	1	0	1	0	1	0	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
119	2	0	1	0	1	0	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
122	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
123	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
Scenarios 128 to 145, Mokia and Notorola have equal market share																																
128	1	0	1	**0**	1	**0**	1	**0**	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
129	2	0	1	**0**	1	**0**	1	**0**	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
130	1	0	1	1	1	1	1	**1**	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
131	2	0	1	1	1	1	1	**1**	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Table 7.3 Final assets of agents for simulation scenarios in Table 7.2 (in thousand dollars)

Scenario	Logers	Pell	Mokia	Notorola	Markham	London	Housing	PCBA	Metal	Silicon
16	1898	964	1628	1125	817	768	474	1379	582	582
17	1720	1271	1172	1649	749	801	478	1321	582	582
18	449	309	367	278	494	432	200	618	329	329
19	2082	990	1738	1209	984	739	534	1574	667	667
20	3680	2096	3671	1958	1305	1355	902	2650	1049	1049
21	503	306	405	294	517	465	220	671	366	366
118	1549	1539	1717	1232	964	774	534	1568	668	668
119	3543	3547	3935	3026	1563	1495	1085	3119	1218	1218
122	1473	1390	1534	1187	817	793	478	1371	582	582
123	1556	1410	1875	919	833	791	473	1435	582	582
128	1838	962	1535	1147	792	796	474	1387	582	582
129	1678	1248	1970	802	825	774	478	1355	582	582
130	1868	943	1369	1347	750	811	481	1336	582	582
131	1751	1188	2033	761	801	804	466	1418	582	582

Chapter 8 Illustrative Applications of the Simulation System

The mobile phone simulation system has the ability to simulate many situations and agent behaviors. When the market environment or an agent situation changes, other agents should adjust their strategies and actions to keep them and the whole supply chain efficient. The author has examined a number of scenarios in the mobile phone supply chain environment. In this chapter, the performance of every agent in variety of situations will be examined, and the best strategies and actions for each agent will be discussed. All simulation results are based on a two year simulation period.

Different initialization data may produce different results, especially for cash values of agents. After testing many different initialization environments, a set of fixed initialization data is adopted for all scenarios in this research. According to the simulation theory, we should use initialization data based on the system data after the system has run for a while and reached a steady state. Based on the following reasons, we choose a set of fixed initialization data for our simulation study: first, this set of initialization data is determined from many possible initialization conditions after numerous tests, and the data set brings reasonable results for all tested scenarios; second, we use a duration of two years as the simulation period which is long enough for the simulation study.

8.1 Scenarios of the System Simulation

Based on the system parameters in the system shown in Table 6.5, there are a total of 32 factors that may affect the performance of the supply chain. Each type of agent has two individual agents except for the customer agent, and each factor has 2 to 3 choices. This would result in billions of scenarios if all the situations were to be tested. Therefore, only some typical scenarios will be tested. Table 8.1 will be used to describe some scenarios in order to improve understanding of the whole environment and situations. All of the scenarios tested in this chapter are shown in Appendix A, and a summary of the testing results is shown in Appendix B. The following acronyms are used in the table:

DC –Demand by Customers

CB – Customer Behavior when a product sold out

OA – Order Amount Policy

OP – Order Point Strategy

SS – Inventory Strategy for product holder agents

PS – Production Strategy for assembler and component agents

PC – Production Capacity for manufacturing agents

The meaning of the values used in Table 8.1 and Appendix A have been illustrated in Table 6.5 and they will also be described in detail in the analysis section for each agent.

Scenario 1 represents the following situation:

- market demand by customers is Normal;
- when a customer faces a sold out product, the order is given up;
- Logers and Pell adopt the In Proportion Order Amount Policy and the Conservative Order Point Strategy;
- Mokia and Notorola adopt the In Proportion Order Amount Policy, Conservative Order Point Strategy, and Stock-to-Order Inventory Strategy;
- Markham, London, Housing and PCBA adopt the In Proportion Order Amount Policy, Conservative Order Point Strategy, Make-to-Stock Inventory Strategy, and production capacity is Normal;
- Metal and Silicon adopt the Make-to-Stock Inventory Strategy, and production capacity is Normal.
- Logers has 70% market share while Pell has 30% market share;

- Mokia has 60% market share and Notorola has 40% market share.

The environments and situations in Scenarios 2 and 3 are similar to Scenario 1, except that market demand in Scenario 2 is high while in Scenario 3 it is low.

Scenario 19 denotes the following situation:

- market demand by customers is Normal;
- when a customer faces a sold out product, the order is given up;
- Logers and Pell adopt the Same Order Amount Policy and the Conservative Order Point Strategy;
- Mokia and Notorola adopt the Same Order Amount Policy, the Conservative Order Point Strategy, and the Stock-to-Order Inventory Strategy;
- Markham, London, Housing and PCBA adopt the Same Order Amount Policy, the Conservative Order Point Strategy, the Make-to-Stock Inventory Strategy, and production capacity is Normal;
- Metal and Silicon adopt the Make-to-Stock Inventory Strategy, and production capacity is Normal;
- Logers has 70% market share while Pell has 30%;
- Mokia has 60% market share and Notorola has 40%.

The environment and situation in Scenario 20 are similar with Scenario 19, except that market demand in Scenario 20 is high.

Scenario 57 describes the following situation:

- market demand by customers is Normal;
- when a customer faces a sold out product, the order is given up;
- Logers and Pell adopt the Same Order Amount Policy and the Conservative Order Point Strategy;
- Mokia adopts the Same Order Amount Policy, the Conservative Order Point Strategy, and the Stock-to-Order Inventory Strategy;
- Notorola adopts the Same Order Amount Policy, the Conservative Order Point Strategy, and the inventory strategy changing iteratively every six months with

the starting strategy determined by the system randomly. Each inventory strategy can be selected initially with a probability of 0.5;

- Markham, London, Housing and PCBA adopt the Same Order Amount Policy, the Conservative Order Point Strategy, the Make-to-Stock Inventory Strategy, and production capacity is Normal;
- Metal and Silicon adopt the Make-to-Stock Inventory Strategy, and production capacity is Normal;
- Logers has 70% market share while Pell has 30%;
- Mokia has 60% market share and Notorola has 40%.

Scenario 72 represents the following setting:

- market demand by customers is high;
- when a customer faces a sold out product, the order is given up;
- Logers and Pell adopt the Same Order Amount Policy and the Conservative Order Point Strategy;
- Mokia and Notorola adopt the Same Order Amount Policy, the Conservative Order Point Strategy, and the Stock-to-Order Inventory Strategy;
- Markham adopts the Same Order Amount Policy, the Conservative Order Point Strategy, inventory strategy changing iteratively, and production capacity is Normal;
- London, House and PCBA adopt the Same Order Amount Policy, the Conservative Order Point Strategy, the Make-to-Stock Inventory Strategy, and production capacity is Normal;
- Metal and Silicon adopt the Make-to-Stock Inventory Strategy, and production capacity is Normal;
- Logers has 70% market share while Pell has 30%;
- Mokia has 60% market share and Notorola has 40%.

The environment and situation in Scenario 73 is similar to Scenario 72, but in Scenario 73 the market demand by customers is Normal, Markham adopts the

Make-to-Stock Inventory Strategy, and London adopts the changing inventory strategy iteratively.

Table 8.1 Simulation scenarios

Scenario	Customer		Logers		Pell		Mokia			Notorola			Markham				London				Housing				PCBA				Metal		Silicon	
	DC	CB	OA	OP	OA	OP	OA	OP	SS	OA	OP	SS	PS	PC	**OA**	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	PS	PC
1	1	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
2	2	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
3	3	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
19	1	0	1	0	1	0	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
20	2	0	1	0	1	0	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
57	1	0	1	0	1	0	1	0	1	1	0	2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
72	2	0	1	0	1	0	1	0	1	1	0	1	1	2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
73	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	2	1	0	1	0	1	0	1	0	1	0	1	0	1	0

8.2 Customer Agent Analysis

Customers are the foundation of any supply chain. If no customer buys a particular product, the supply chain for that product could not exist. A factor influencing the supply chain is the customer's purchasing power and willingness, called Market Demand by Customers (DC). The possible values for DC are:

1- Normal;

2- High (two times Normal orders); and

3- Low (half Normal orders).

Another factor is the action taken by a customer (CB), when a retailer has sold out of a product. There are three possible Customer actions:

(1) Buy another brand of phone from the retailer agent;

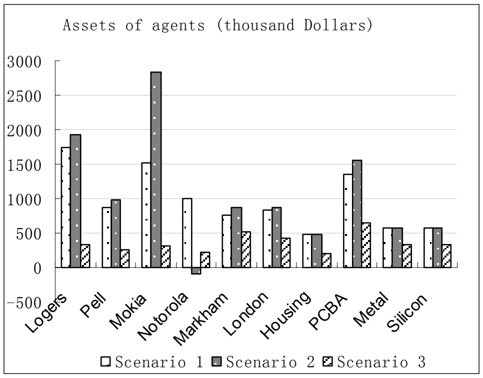
(2) Buy the same brand of phone from another retailer agent;

(3) Wait until the phone is available from the original retailer agent; and

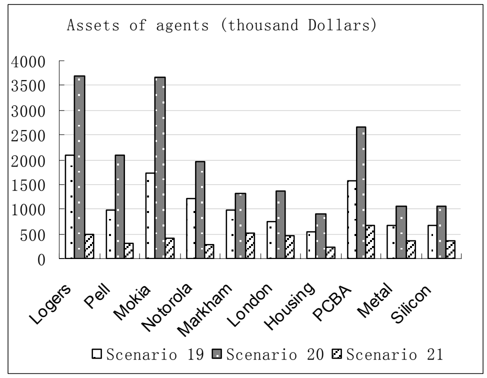
In this simulation system, there will be two possible values:

- 0 – Giving Up: give up the order;
- 1 – Accumulating: buy another brand from the same retailer (40% probability), buy the same brand from another retailer (30% probability), or wait until the brand of mobile phone becomes available from this retailer (30% probability).

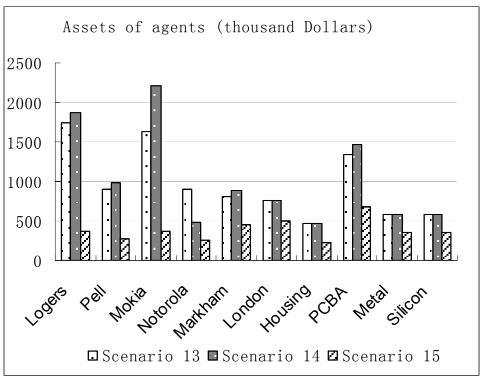
High demand by customers is always a good thing for all agents in the supply chain, and low demand by customers is a disaster for all agents. Figure 8.1 shows how the agents' assets change when customer behavior and demand by customers change.



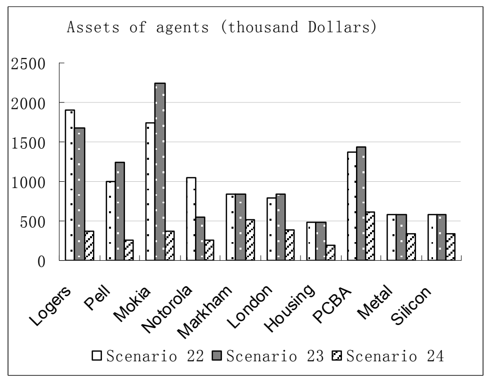
(a) Scenario 1 to Scenario 3



(c) Scenario 19 to Scenario 21



(b) Scenario 13 to Scenario 15



(d) Scenario 22 to Scenario 24

Figure 8.1 Final assets of agents versus customer behavior and demand by customers

In Group (a) (Scenarios 1 to 3) the customer gives up the order when the desired retailer has sold out of the desired brand of mobile phone. Retailer agents, product agents, assembler agents, and material agents adopt the In Proportion Order Amount and the Conservative Order Point policies. Product agents adopt the Stock-to-Order policy, and all manufacturing agents adopt the Make-to-Stock strategy and have Normal production capacities.

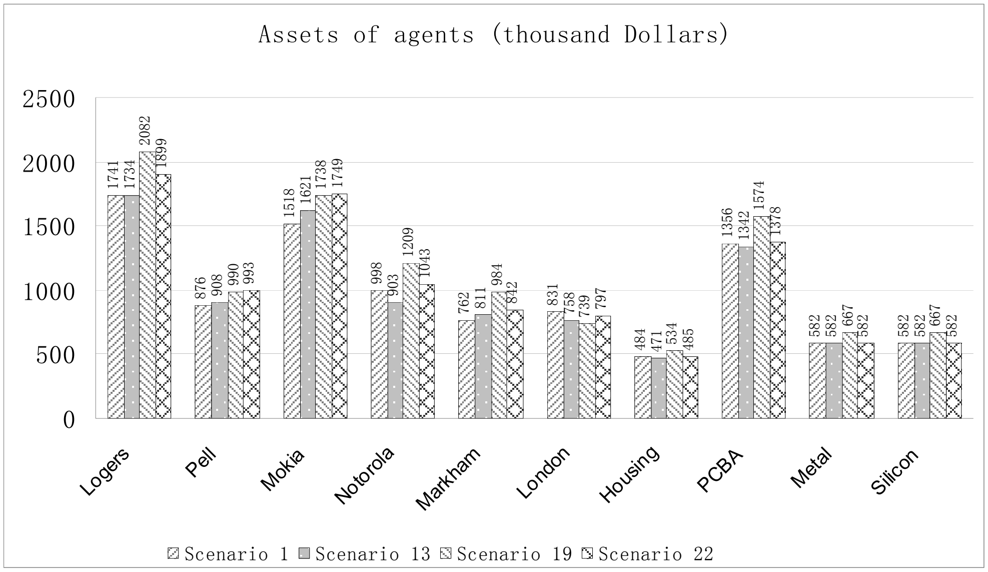
Group (b) (Scenarios 13 to 15) is similar to Group (a), except that the customer agent adopts the Accumulating customer order strategy.

In Group (c) (Scenarios 19 to 21) the customer agent adopts the Giving Up policy when the product has been sold out; all retailer agents adopt the Same Order Amount

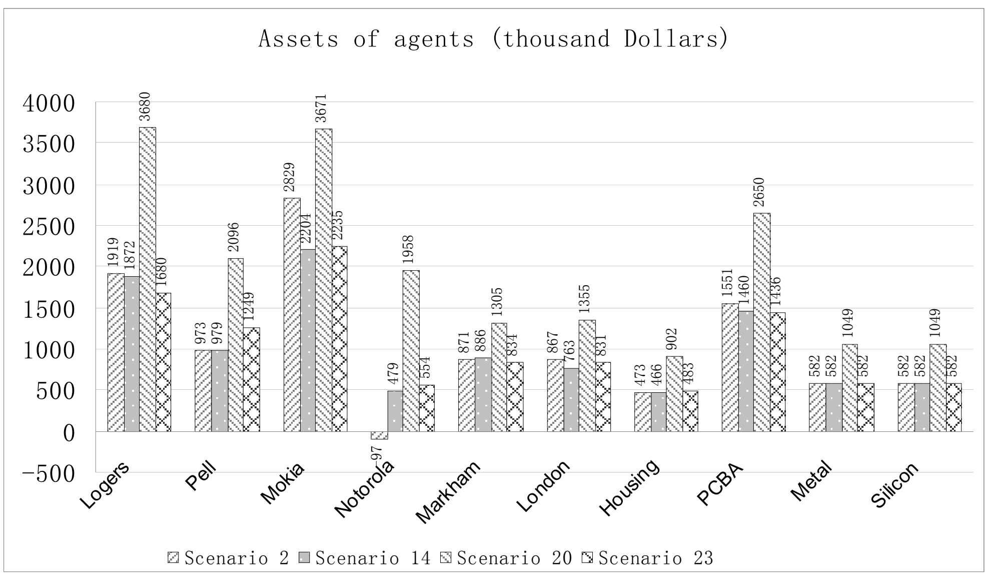
Policy, and the Conservative Order Point Strategy. All product agents adopt the Same Order Amount Policy, the Conservative Order Point Strategy, and the Stock-to-Order inventory policies. All assembler and component agents adopt the Same Order Amount Policy, the Conservative Order Point Strategy, the Make-to-Order inventory policy, and the Maximum production capacity strategy. All material agents adopt the Make-to-Order inventory policy, and the Maximum production capacity strategy.

In Group (d) (Scenarios 22 to 24) the customer agent adopts the Accumulating customer order strategy when the product has been sold out. All retailer agents adopt the Same Order Amount Policy, and the Positive Order Point Strategy. Product agents adopt the Same Order Amount Policy, the Conservative Order Point Strategy, and the Stock-to-Order inventory policies. All assembler and component agents adopt the Same Order Amount Policy, the Conservative Order Point Strategy, the Make-to-Order inventory policy, and the Normal production capacity strategy. All material agents adopt the Make-to-Order inventory policy, and the Normal production capacity strategy.

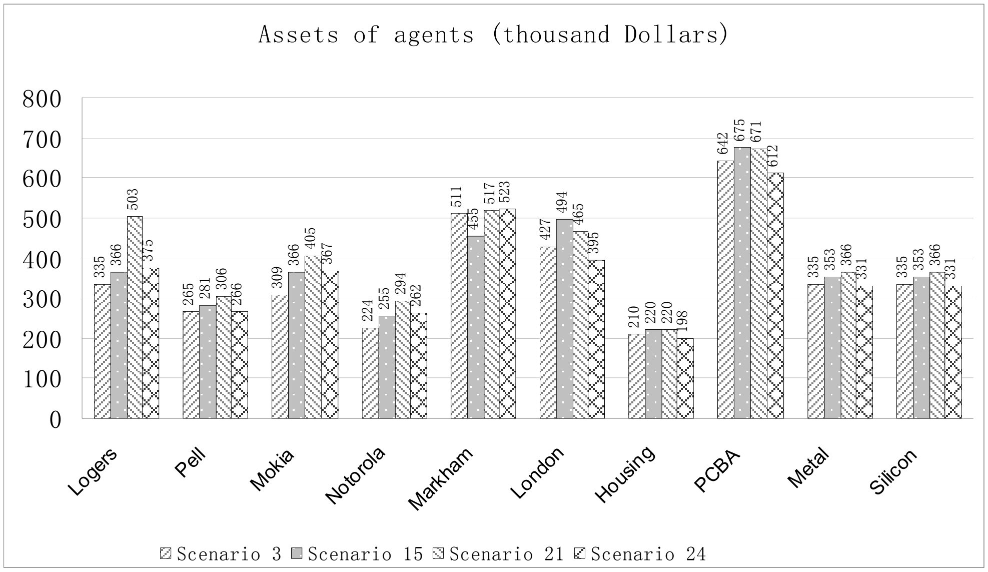
In each group, the first scenario represents Normal market demand, the second scenario denotes High demand by customers (daily customer orders are two times Normal customer order amount), and the third scenario describes the Low demand by customers (daily customer orders are half of the Normal order amount). Figure 8.2 shows a vertical comparison of the changes in agents' assets when customer behavior and demand by customers change.



(a) Normal demand by customers



(b) High demand by customers



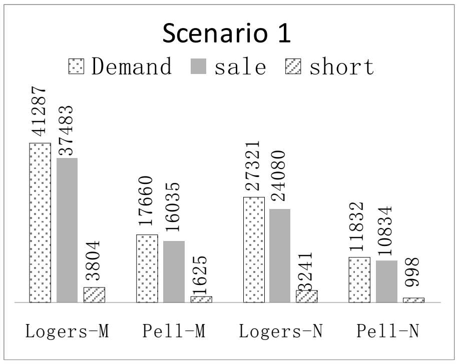
(c) Low demand by customers

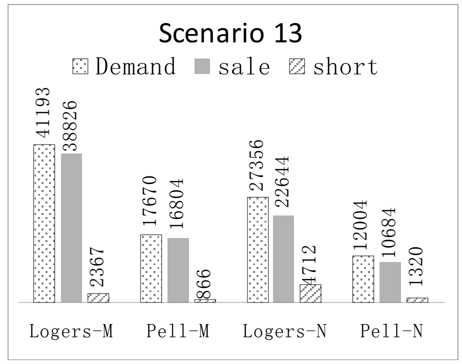
Figure 8.2 Vertical comparisons of final agent assets

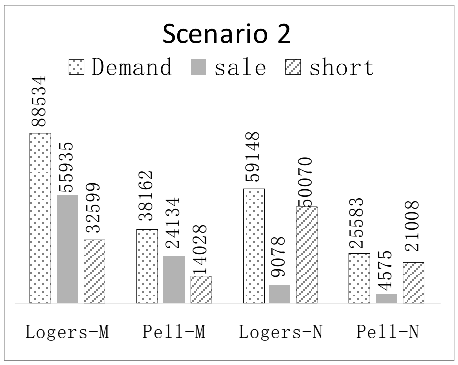
Supply chain performance influenced by the customer agent

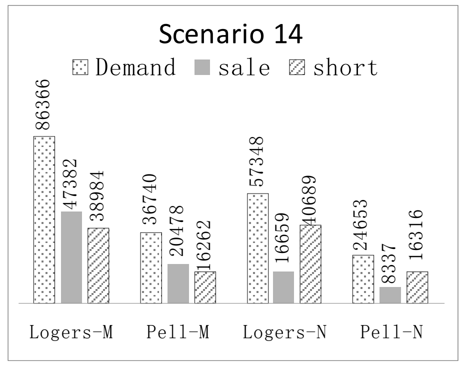
Demand by Customers: The graphs in Figure 8.1 and Figure 8.2(c) show that when market demand is Low, comparing with Normal market demand, the asset of every agent will decrease in all situations. When market demand is High (Scenario 20), if all manufacturing agents increase their production capacity, all agents will earn more profits (Figure 8.2(b)). However, if not all manufacturing agents increase their production capacities (Scenarios 2, 14 and 23) the benefits will not be as high as expected. When market demand is Normal, all agents' final assets will not change significantly in all situations unless all manufacturing agents increase their production capacities (Figure 8.2(a)).

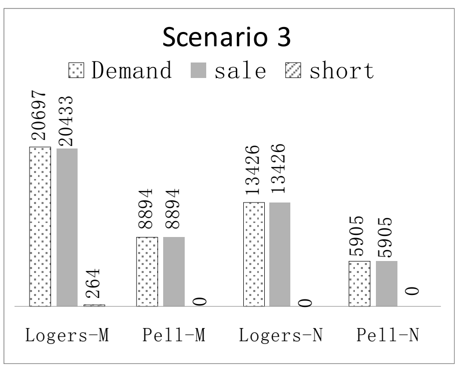
Customer Behavior: Figure 8.3 is a comparison of customer order fulfillment between the Accumulating order and Giving Up order options. The first column shows the results of Giving Up orders, and the second column shows the result of Accumulating orders. The results show that when the customer adopts Accumulating policy, order fulfillments are not improved significantly when market demand by customers is Normal or High.

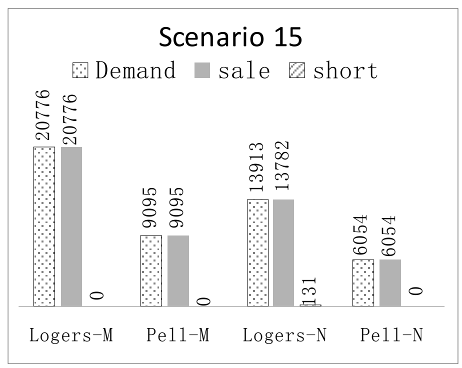

Scenario 1
Demand sale short
41287 37483 3804
17660 16035 1625
27321 24080 3241
11832 10834 998
Logers-M Pell-M Logers-N Pell-N

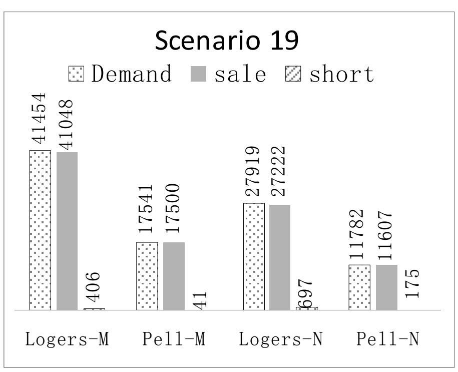

Scenario 13
Demand sale short
41193 38826 2367
17670 16804 866
27356 22644 4712
12004 10684 1320
Logers-M Pell-M Logers-N Pell-N

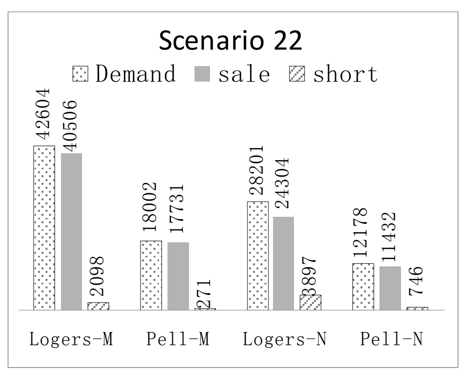

Scenario 2
Demand sale short
88534 55935 32599
38162 24134 14028
59148 9078 50070
25583 4575 21008
Logers-M Pell-M Logers-N Pell-N


Scenario 14
Demand sale short
86366 47382 38984
36740 20478 16262
57348 16659 40689
24653 8337 16316
Logers-M Pell-M Logers-N Pell-N


Scenario 3
Demand sale short
20697 20433 264
8894 8894 0
13426 13426 0
5905 5905 0
Logers-M Pell-M Logers-N Pell-N


Scenario 15
Demand sale short
20776 20776 0
9095 9095 0
13913 13782 131
6054 6054 0
Logers-M Pell-M Logers-N Pell-N


Scenario 19
Demand sale short
41454 41048 406
17541 17500 41
27919 27222 697
11782 11607 175
Logers-M Pell-M Logers-N Pell-N


Scenario 22
Demand sale short
42604 40506 2098
18002 17731 271
28201 24304 3897
12178 11432 746
Logers-M Pell-M Logers-N Pell-N

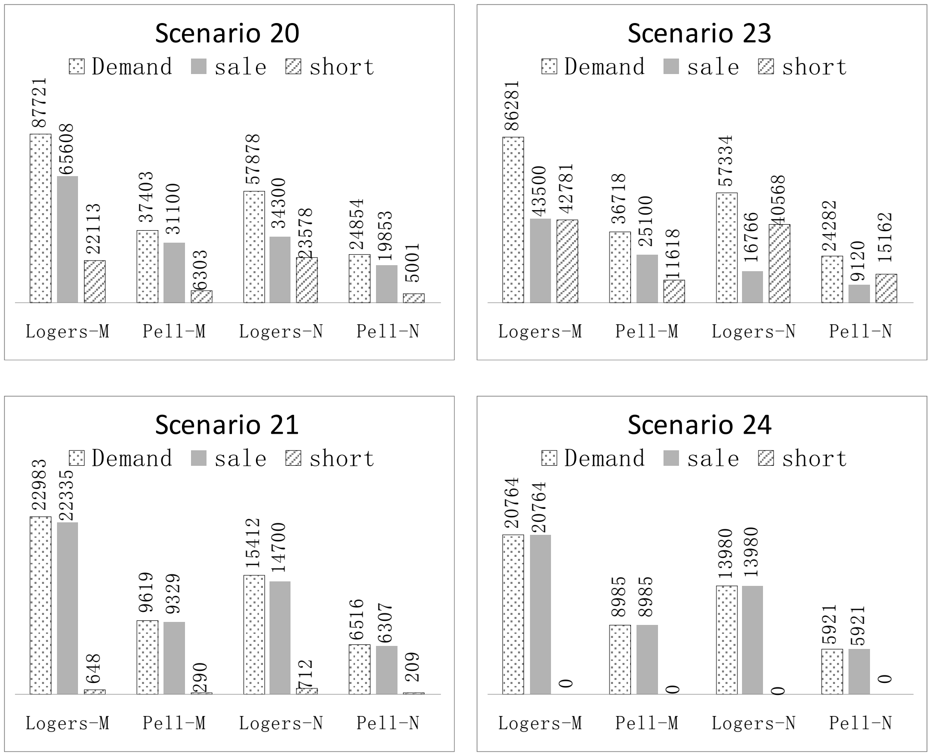


Figure 8.3 Comparison of customer order fulfillment between Accumulating order and Giving Up order

Analysis of the customer agent

When market demand by customer is High, all agents' assets will not be improved remarkably if all production agents have not increased their production capacities. This is because the supply chain works as a whole and a one point limitation will influence the performance of the whole chain. Retailer agents often confront product shortages (Scenarios 2, 14 and 23 in Figure 8.3). If all producing agents increase their production capacities, all agents will benefit from the High market demand because customer order fulfillment has been enhanced (comparison of Scenarios 2, 14 and 23 with 20 in Figure 8.3).

Similar to the customer market demand parameter, the Accumulating order policy does not obviously improved customer order fulfillment. The production limitation by manufacturing agent(s) restricts the sales of the retailer agents. Figure 8.4 shows the comparison results of Scenario 2 and Scenario 14, in which Scenario 2 uses Giving

Up customer orders while Scenario 14 uses Accumulating customer orders. The figure indicates that Accumulating order policy does not enhance the whole supply chain performance significantly.

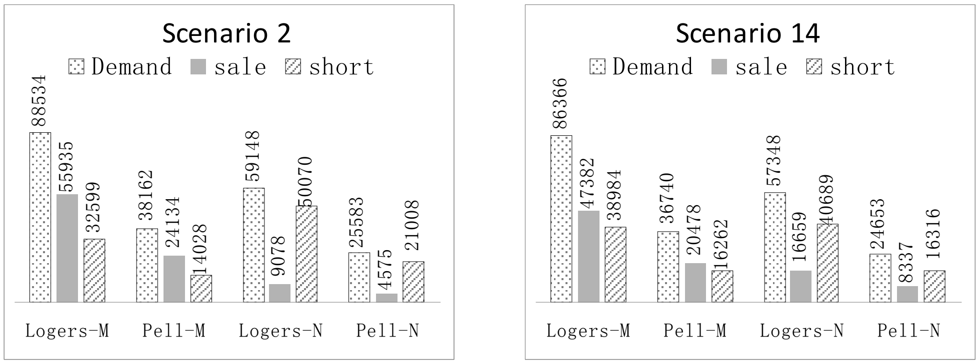


Figure 8.4 Comparison of customer order fulfillments

8.3 Retailer Agent Analysis

A retailer is the bridge between customers and product holders. The retailer's factors that influence supply chain performance include the retailer's inventory strategy (product Order Amount Policy, and Order Point Strategy), product selling prices, promotion strategies, and customer service policies (product return, product change, product discount, etc.). In this system, we will only consider the retailer's inventory strategy.

Order Amount Policy (OA) has two possible values:

0 – In Proportion: the product order amount relies on the product's market share;

1 – Same: all product order amounts are equal.

Order Point Strategy has two possibilities:

0 – Conservative: a retailer sends an order for a product when its inventory is less than adequate for two weeks of sales;

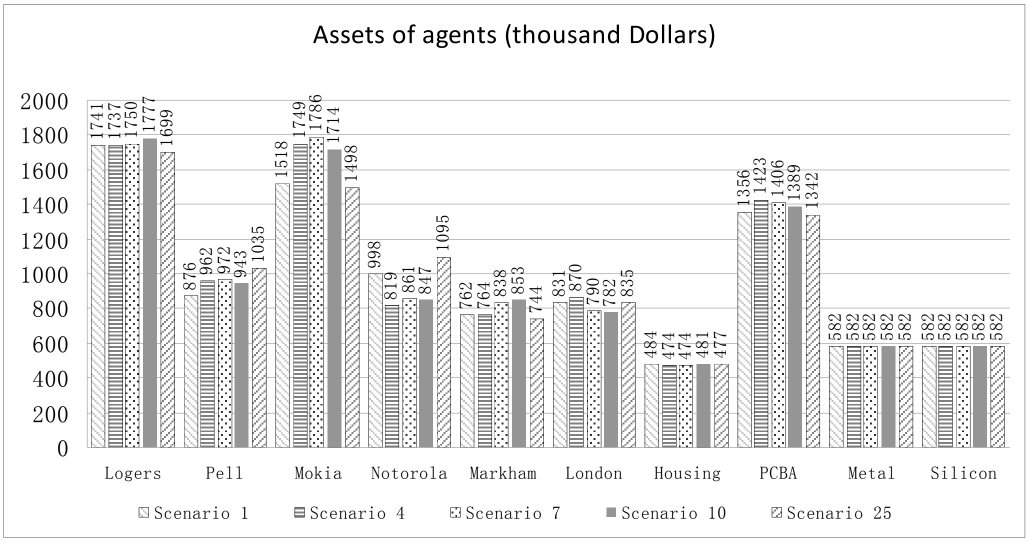
1 – Positive: which means a retailer sends an order request for a product when its inventory is less adequate for three weeks of sales.

Retailer Agent's Order Amount Policy Analysis

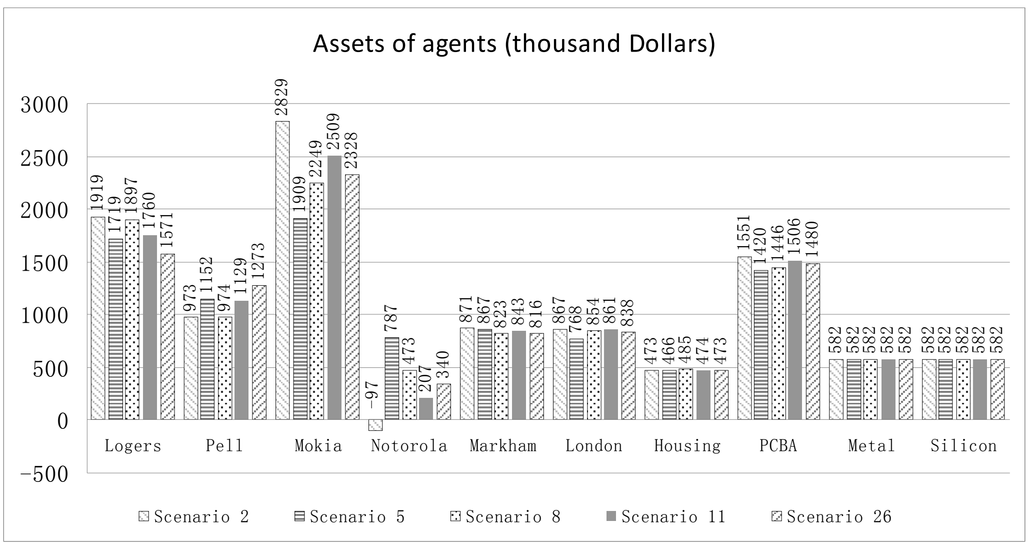
Figures 8.5 and 8.6 show the overall performance of the supply chain when retailers adopt different order amount policies in various environments. The environment in Figure 8.5 is as follows:

- customer agent adopts the Giving Up order policy;
- retailer agents adopt the Conservative Order Point Strategy;
- product holder agents adopt the In Proportion Order Amount, the Conservative Order Point, and the Stock-to-Order policies;
- assembler and component agents adopt the In Proportion order amount, the Conservative Order Point, Normal production capacity, and the Make-to-Stock policies;
- material agents adopt Normal production capacity, and the Make-to-Stock policies;
- Logers has 70% market share, and Pell has 30%.

For Scenarios 1 and 2, both retailers adopt the In Proportion Order Amount Policy. In Scenarios 4 and 5, Logers adopts the Same Order Amount Policy while Pell adopts the In Proportion policy. In Scenarios 7 and 8, Logers adopts the In Proportion policy while Pell adopts the Same Amount Policy. In Scenarios 10 and 11, both Logers and Pell adopt the Same Amount Policy. In Scenarios 25 and 26, both retailers adopt the In Proportion Order Amount Policy, and Mokia and Notorola adopt the Same Order Amount Policy. The environment in Figure 8.6 is the same as in Figure 8.5 except that both Logers and Pell have 50% market share.

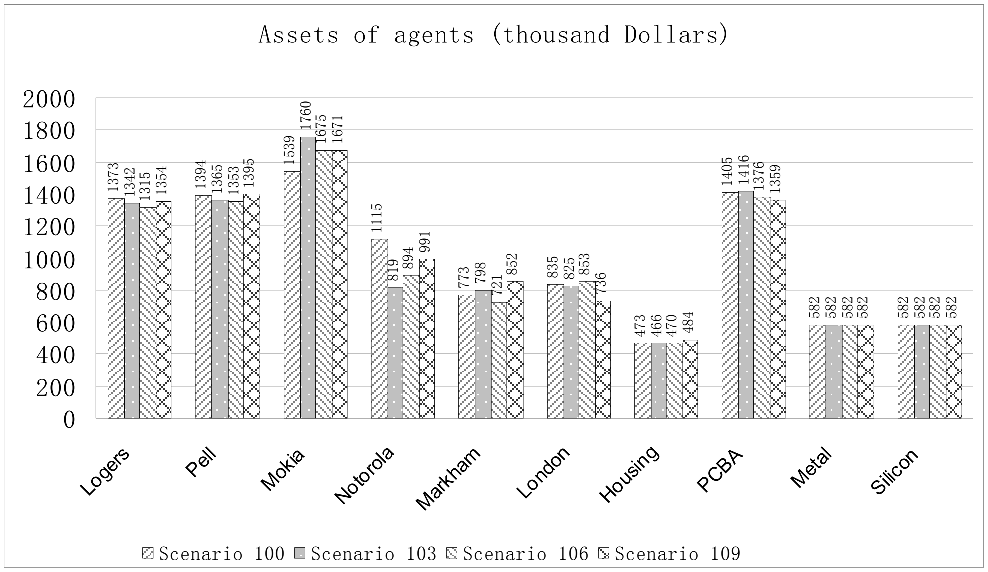


(a) Normal demand by customers

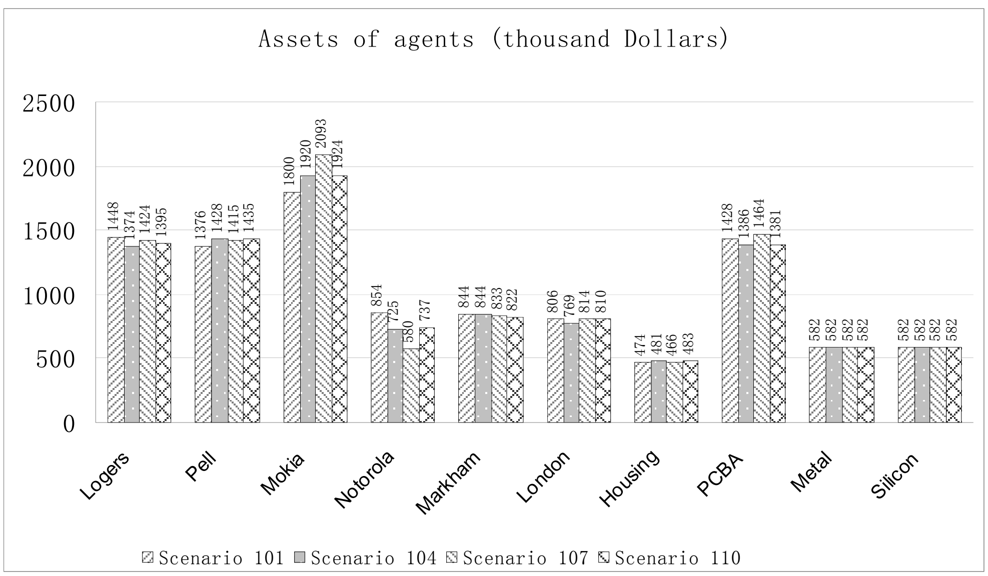


(b) High demand by customers

Figure 8.5 Supply chain performance when retailer agents change order amount policy in the normal environment (Logers has 70% market share, while Pell has 30%)



(a) Normal demand by customers



(b) High demand by customers

Figure 8.6 Supply chain performance when retailer agents change order amount policy in the normal environment (Both Logers and Pell have 50% market share)

Figure 8.5 shows that in the normal environment, when customer demand is Normal, changes to the retailer agents' order amount policy results in no significant difference. This is because the production capacities of the manufacturing agents have been adequate to meet market demands. When demand is High, most agents except product holders, will receive similar revenues as when market demand is Normal. Mokia will earn more profit while Notorola will lose some profit. If all agents and not just retailer agents adopt the In Proportion Order Amount Policy, Notorola will lose their whole market share (bankrupt) and Mokia will receive more profit than with other order combinations of amount policies. This is because the manufacturing agents have production limitations and Mokia has more market share. Mokia is sold very fast, and obtains most of the contracts and as a results take most of the manufacturing agent's production. Notorola obtains few contracts, therefore retailers often face shortages for Notorola's product. Figure 8.7 has clearly identified this point: the total sales of the Mokia product are 80069 (55935 + 24134) in Scenario 2, more than Scenario 1 sales which are 53418 (37483 + 16035). The total sales of Notorola product are 13653 (9078 + 4575) in Scenario 2, less than Scenario 1 sales which are 34914 (24080 + 10834).

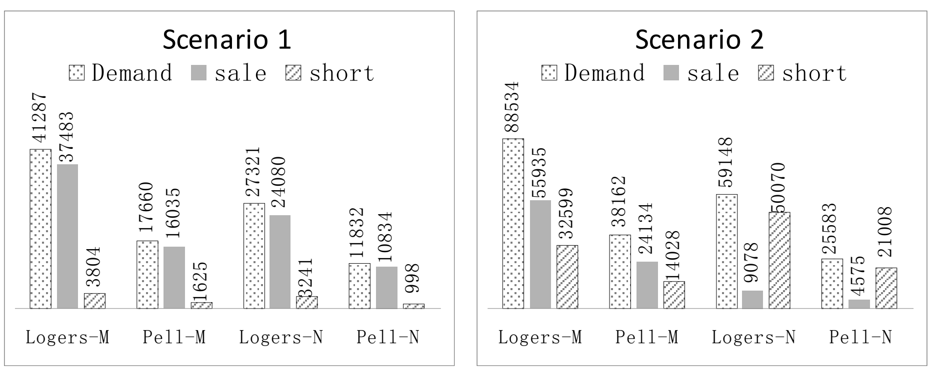


Figure 8.7 Retailers' performance for customer orders

Figure 8.6 shows that when retailer agents have equal market share in the normal environment, and market demand by customers is Normal or High, there is no significant difference in the performance of all agents' with all combinations of retailers' order amount policies. Figure 8.8 shows the detailed sales information for each of the retailers.

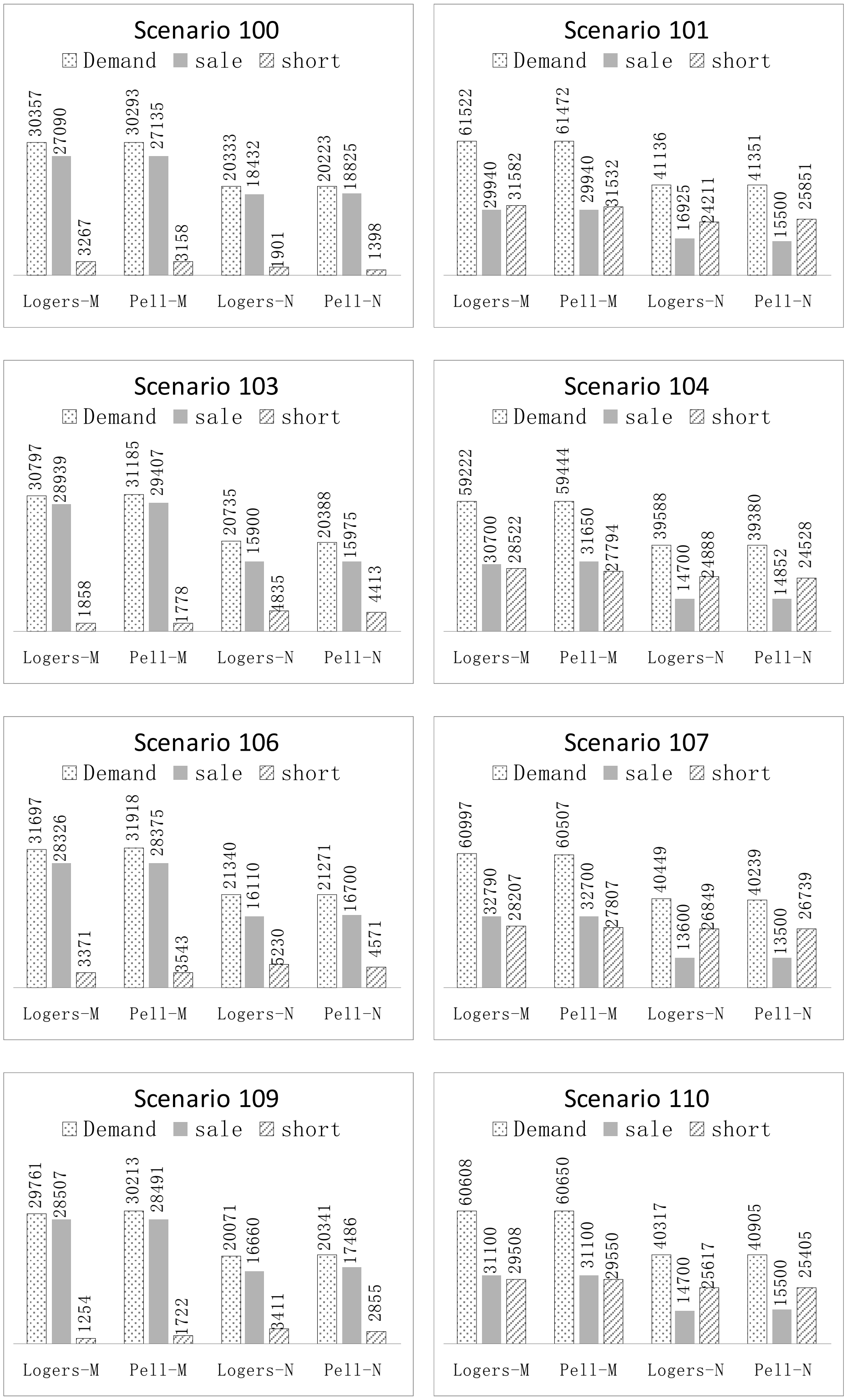


Figure 8.8 Retailers' performance for customer orders

Retailer Agent's Order Point Strategy Analysis

To investigate the influence of the retailer's Order Point Strategy, three group situations were tested. The first group, shown in Figure 8.9, uses the following situation:

- the customer agent adopts the Giving Up order policy;
- retailer agents adopt the Same Order Amount Policy;
- product holder agents adopt the Same Order Amount, Conservative Order Point, and Stock-to-Order policies and strategies;
- assembler and component agents adopt the Same Order Amount, Conservative Order Point, Normal production capacity, and Make-to-Stock policies and strategies;
- material agents adopt the Normal production capacity, and Make-to-Stock policies;
- Logers has 70% market share, and Pell has 30%.

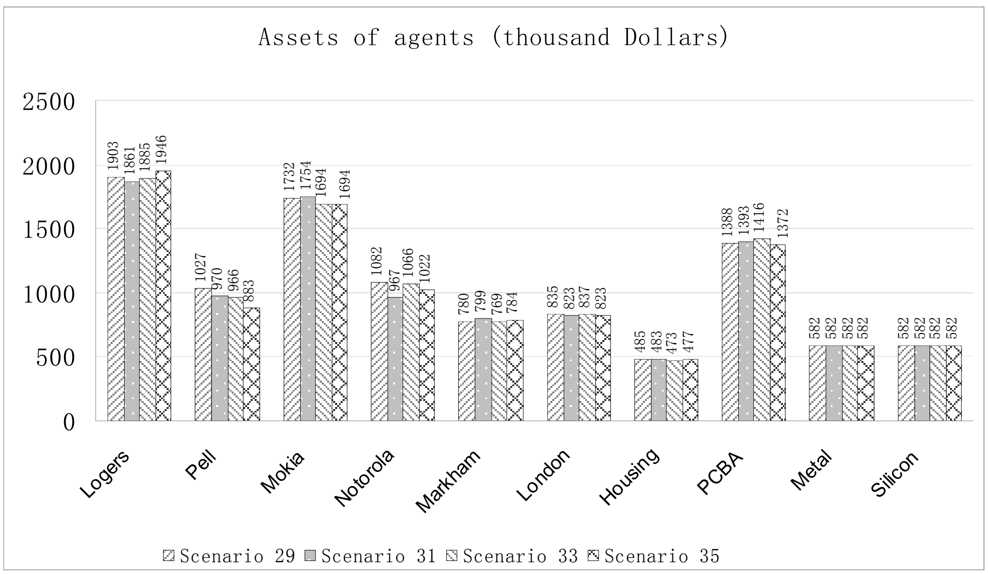
In Scenarios 29 and 30, both retailers adopt the Positive Order Point Strategy. In Scenarios 31 and 32, Logers adopts the Conservative Order Point Strategy while Pell adopts the Positive Order Point Strategy. In Scenarios 33 and 34, both Logers and Pell adopt the Conservative Order Point Strategy. In Scenarios 35 and 36, Logers adopts the Positive Order Point Strategy while Pell adopts the Conservative Order Point Strategy.

The second group, shown in Figure 8.10, uses the following settings:

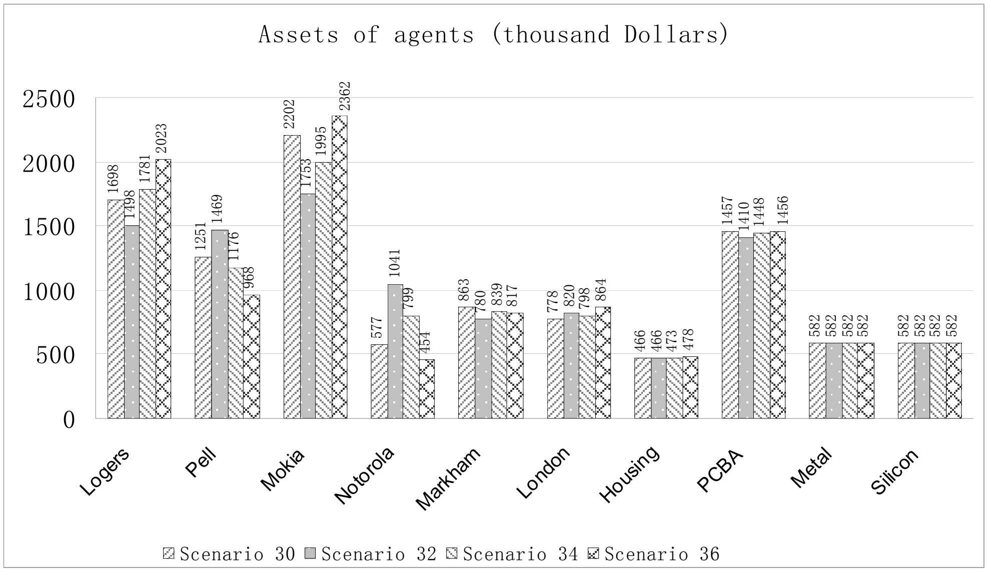
- Logers and Pell have equal market share (50% each);
- the customer agent adopts the Giving Up order policy;
- retailer agents adopt the Same Order Amount Policy;
- product holder agents adopt the Same Order Amount, Conservative Order Point, and Stock-to-Order policies and strategies;

- assembler and component agents adopt the Same Order Amount, Conservative Order Point, Normal production capacity, and Make-to-Stock policies and strategies;
- material agents adopt the Normal production capacity, and Make-to-Stock policies.

In Scenarios 122 and 123, both Logers and Pell adopt the Conservative Order Point Strategy. In Scenarios 124 and 125, Logers adopts the Positive Order Point Strategy while Pell adopts the Conservative Order Point Strategy. In Scenarios 126 and 127, both retailers adopt the Positive Order Point Strategy.

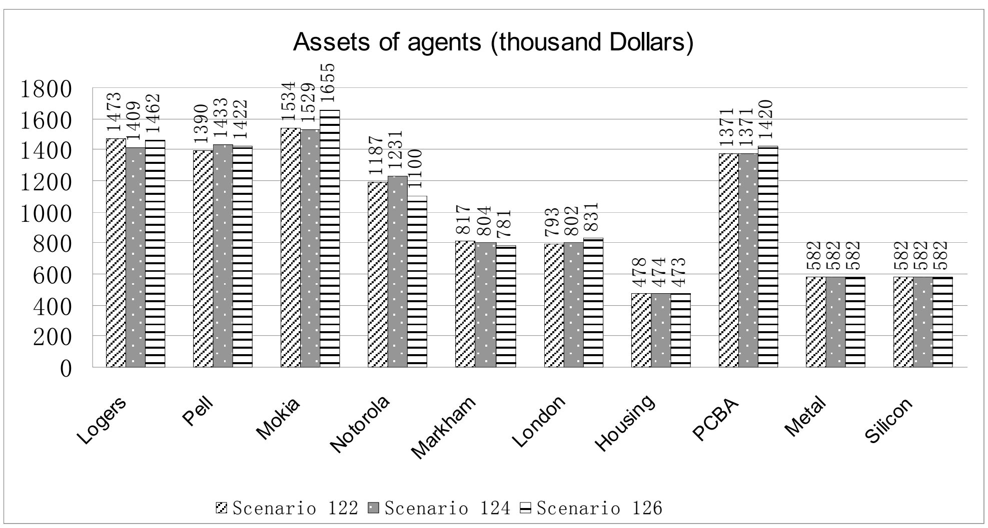


(a) Normal demand by customers

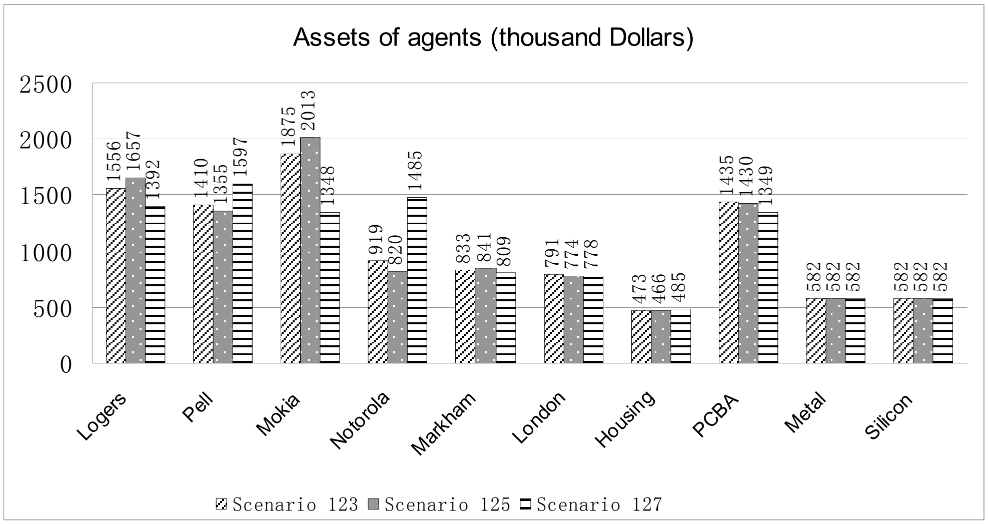


(b) High demand by customers

Figure 8.9 Supply chain performance when retailer agents change order point strategies in the normal environment (Logers has 70% market share, Pell has 30%)



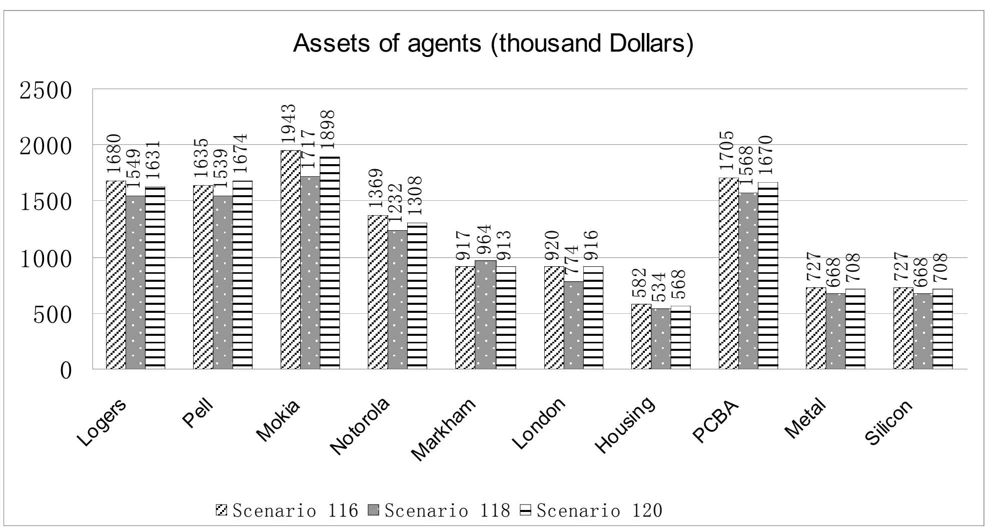
(a) Normal demand by customers



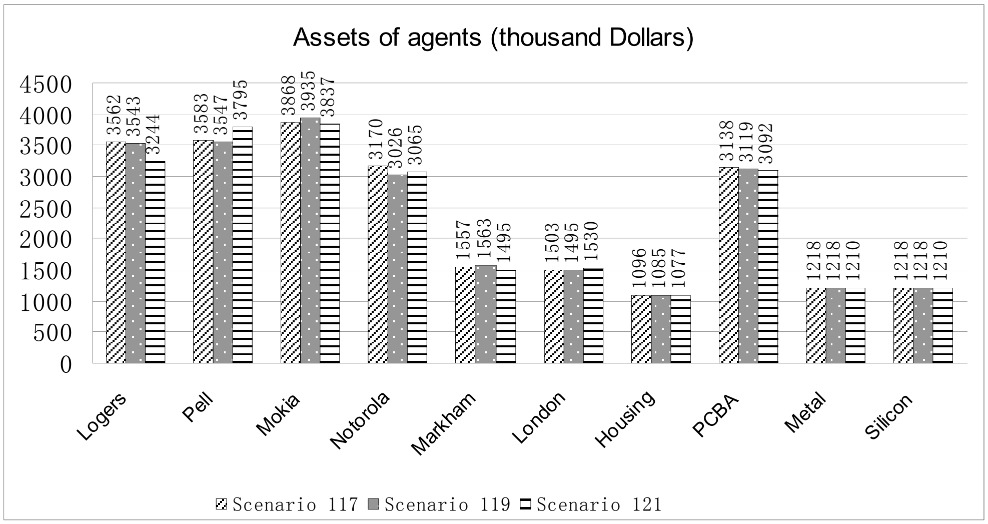
(b) High demand by customers

Figure 8.10 Supply chain performance when retailer agents change order point strategies in the normal environment (Both Logers and Pell have 50% market share)

The last group, shown in Figure 8.11, is similar to the second group in Figure 8.10, except that all manufacturing agents have the Maximum production capacities.



(a) Normal market demand by customers



(b) High market demand by customers

Figure 8.11 Supply chain performance when retailer agents change order point strategies in the extreme environment (Both Logers and Pell have 50% market share)

Figure 8.9 shows that when the environment and customer demand are normal, there is no significant change for any agent among all scenarios (Figure 8.9(a)). If the Customer demand is High (Figure 8.9(b)), Pell will always obtain more profit, and Logers will usually lose some profit. In Scenarios 29 and 30, both Logers and Pell adopted the Positive Order Amount Policy, Logers lost 10% of its assets (\$1903000 vs. \$1698000) and Pell gained 22% more assets (\$1027000 vs. \$1251000). In Scenarios 31 and 32, Logers adopted the Conservative policy while Pell adopted the Positive policy. Pell sold 28788 (17771 + 11017) and 38522 (24622 + 13900) phones, and its assets were \$970000 and \$1469000. Figure 8.13 shows the sales figures for these scenarios. Pell increased its sales by 34% and its assets by 51%. Logers sold 63893 (40518 + 23375) and 56600 (34300 + 22300) phones and Logers' assets were \$1861000 and \$1498000. Logers lost 11.4% sales and 19.5% of its assets. In Scenarios 33 and 34, both Logers and Pell adopted the Conservative policy, Logers lost 5.5% of its assets (\$1885000 vs. \$ 1781000) while Pell gained 21.7% more assets (\$966000 vs. \$1176000). In Scenarios 35 and 36, Logers adopted the Positive policy while Pell adopted the Conservative policy. Logers sold 65640 (40559 + 25081) phones in Scenario 35 and 66955 (51095 + 15900) phones in Scenario 36 (2%

increase). Its assets were $1946000 in Scenario 35 and $2023000 in Scenario 35 (4% increase). Pell sold 27011 (16324 + 10687) phones in Scenario 35 and 28600 (19900 + 8700) phones in Scenario 36 (6% increase). Its assets were $883000 in Scenario 35 and $968000 in Scenario 36 (10% increase).

In most cases, Mokia gains more profit while Notorola loses some profit except in the situation where Logers adopts the Conservative Order Amount Policy and Pell adopts the Positive policy. Comparing Scenarios 29 and 30, Mokia gained 27% more assets while Notorola lost 47% of its assets. Comparing Scenarios 31 and 32, Notorola gained 7.6% more assets while Mokia's assets almost the same. Comparing Scenarios 33 and 34, Mokia gained 18% more assets while Notorola lost 25% of its assets. Comparing Scenarios 35 and 36, Mokia gained 39% more asset while Notorola lost 56% of its assets. Table 8.2 provides detailed contract information for retailers, product holders, and assemblers. It also provides detailed production information about the assemblers. The term Ratio refers to the actual market share of the product in that scenario. The results in Table 8.2(a) and (b) shows that Mokia always has more market share (62% - 75%) than it should be (60%), and Notorola always loses market share when customer demand is High and there is no increase in production capacity by the manufacturing agents. Table 8.2(e) shows that nearly 50% of working days all assembler agents cannot assemble mobile phones, although the market demand is High. This is because the limited production capacity of component and raw material agents.

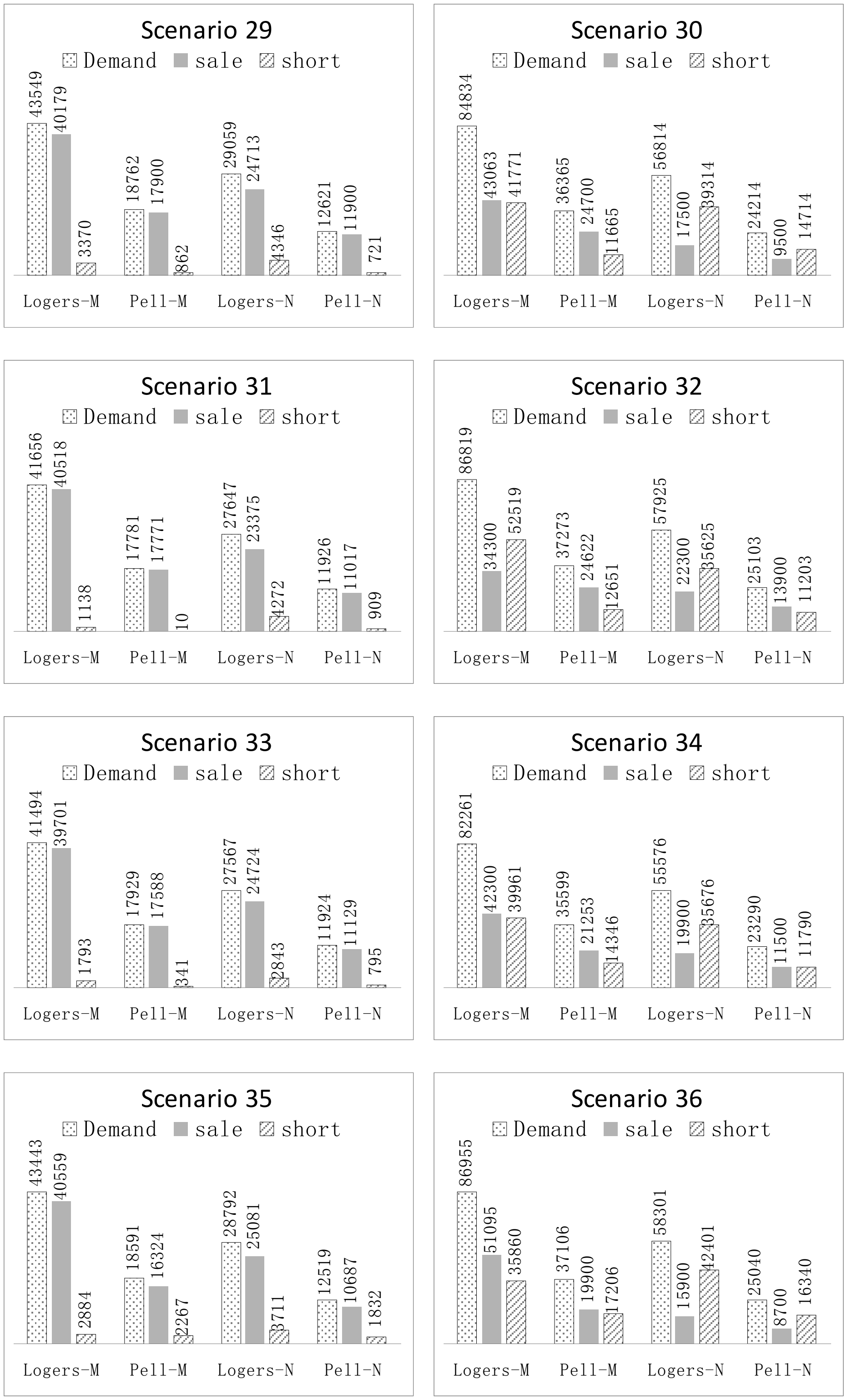


Figure 8.12 Retailers' performance for customer orders

Table 8.2 Contract and production information

(a) Contracts received by Mokia from retailers

Mokia	Logers				Pell			Mokia's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 30	108	400	43200		62	400	24800	0.72
Scenario 32	86	400	34400		62	400	24800	0.624
Scenario 34	107	400	42800		53	400	21200	0.675
Scenario 36	129	400	51600		50	400	20000	0.749

(b) Contracts received by Notorola from retailers

Notorola	Logers				Pell			Notorola's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 30	43	400	17200		23	400	9200	0.28
Scenario 32	55	400	22000		34	400	13600	0.376
Scenario 34	49	400	19600		28	400	11200	0.325
Scenario 36	39	400	15600		21	400	8400	0.251

(c) Contracts offered to assemblers by Mokia

Mokia	Markham				London			Mokia's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 30	59	600	35400		55	600	33000	0.722
Scenario 32	49	600	29400		50	600	30000	0.627
Scenario 34	53	600	31800		54	600	32400	0.677
Scenario 36	58	600	34800		61	600	36600	0.748

(d) Contracts offered to assemblers by Notorola

Notorola	Markham				London			Notorola's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 30	23	600	13800		21	600	12600	0.278
Scenario 32	27	600	16200		32	600	19200	0.373
Scenario 34	27	600	16200		24	600	14400	0.323
Scenario 36	19	600	11400		21	600	12600	0.252

(e) Assemblers' production days

	Markham			London		
	Mokia	Notorola	Total	Mokia	Notorola	Total
Scenario 30	230	86	316	215	79	294
Scenario 32	191	102	293	195	123	318
Scenario 34	210	102	312	211	91	302
Scenario 36	226	70	296	242	80	322

(f) Components' production days

	Housing			PCBA		
	Mokia	Notorola	Total	Mokia	Notorola	Total
Scenario 30	336	119	455	337	127	464
Scenario 32	292	163	455	292	172	464
Scenario 34	316	144	460	319	148	467
Scenario 36	352	112	464	346	115	461

Figure 8.10 shows that in the normal environment, when retailers have equal market share, and customer demand is Normal, changes in order point strategies by retailers result in no significant change to any agent's assets. But when customer demand is High, the assets of product holder agents will change if retailers change their order point strategies. When both Logers and Pell adopt the Conservative Order Point Strategy (Scenarios 122 and 123), Mokia earned 22% more assets while Notorola lost 23% of its assets. Although Mokia should have 60% market share, the actual market share of Mokia is 64.5%, and the Notorola share is only 35.5%. When Logers adopted the Positive Order Point Policy and Pell adopted the Conservative policy (Scenarios 124 and 125), Mokia earned 32% more assets while Notorola lost 33% of its assets. When both Logers and Pell adopted the Positive policy (Scenarios 126 and 127) Mokia lost 19% of its assets and Notorola earned 35% more assets. Figure 8.13 shows retailers' performance when demand by customers is High. The result is similar with Group one (Figure 8.9).

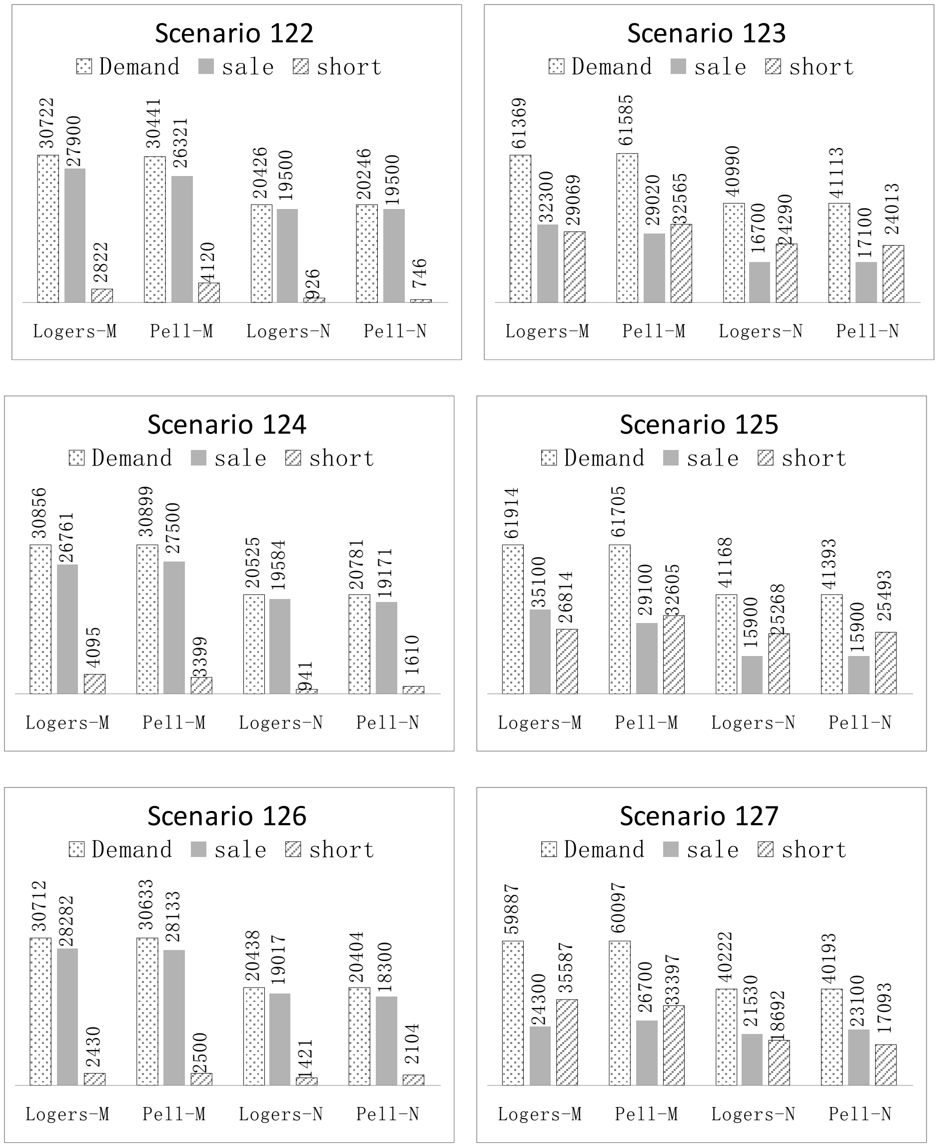


Figure 8.13 Retailers' performance for customer orders

Figure 8.11 shows that in the extreme environment, if retailers have equal market share, and market demand by customers is either Normal or High, there is no significant difference in Order Amount Policy combinations for all of agents. This is because in the extreme environment, the production capacities of all manufacturing agents can meet most of the market needs, and most of customers' orders are fulfilled. Figure 8.14 demonstrates this (only a small number of customer orders have been lost).

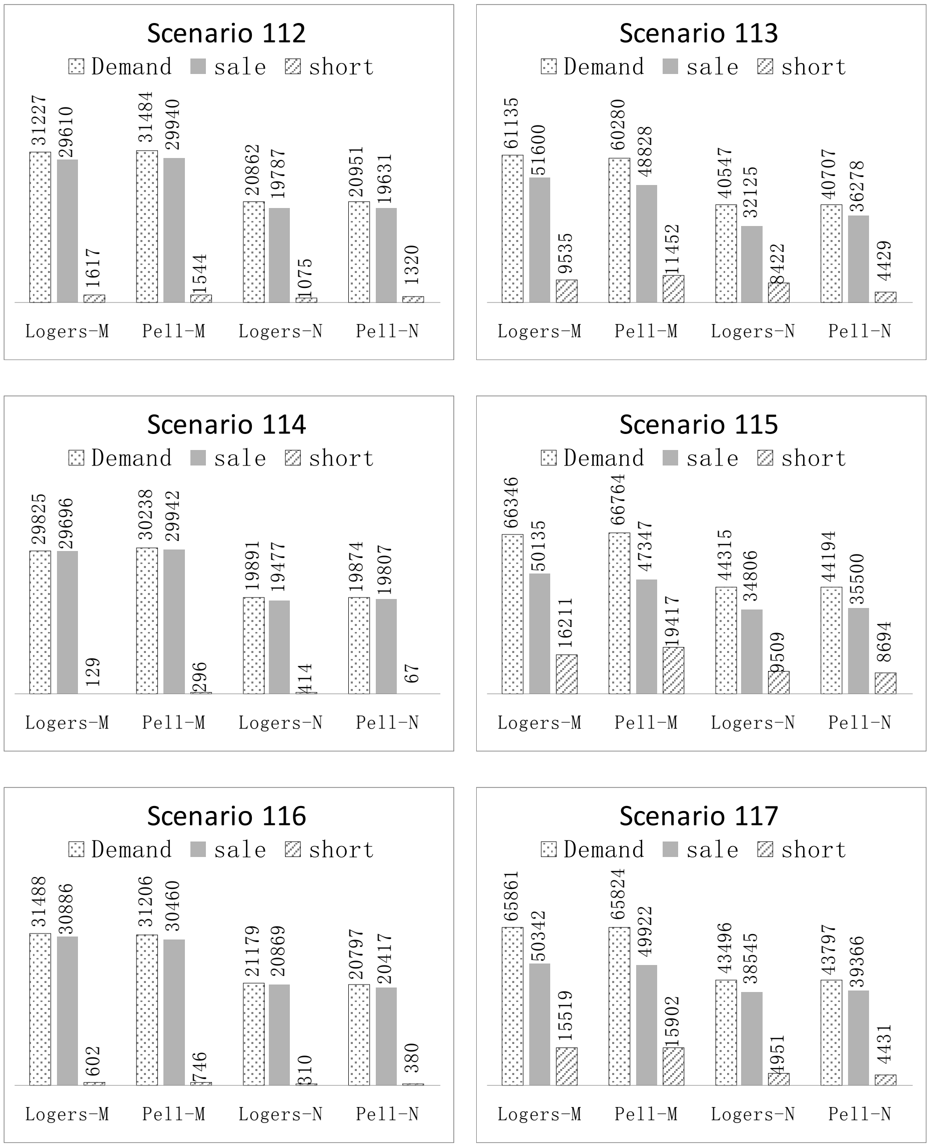


Figure 8.14 Retailers' performance for customer orders

8.4 Product Holder Agent Analysis

A product holder is the core of a supply chain. Factors pertaining to product holders that influence the performance of the whole supply chain include product quality, product selling prices, customer service quality, inventory strategy, product Order Amount Policy, Order Point Strategy, and promotion strategies, etc. In this system, inventory strategy, Order Amount Policy, and Order Point Strategy will be considered.

Inventory strategy has three possible values:

0 – Order-to-Order: product holder carries no inventory. When an RFQ is receives from a retailer, it is transferred to the assemblers. If at least one assembler can satisfy the RFQ, the product holder will accept the retailer's RFQ;

1 – Stock-to-Order: product holder will keep a certain amount of inventory. Inventory is checked first and if the inventory is no less than the order amount, the RFQ is accepted. If the inventory is insufficient, the RFQ will be rejected;

2 – Changing Policy Iteratively: starting at Stock-to-Order policy, product holder will change its inventory policy every six months with the starting policy be determined by the system randomly.

Order Amount Policy has two options:

0 – In Proportion: product's order amount is based on the product's market share;

1 – Same: all order amounts are the same.

Order Point Strategy has two options:

0 – Conservative: a product holder sends an order request when its inventory is lower than two weeks sales;

1 – Positive: a product holder sends an order request when its inventory is lower than three weeks sales.

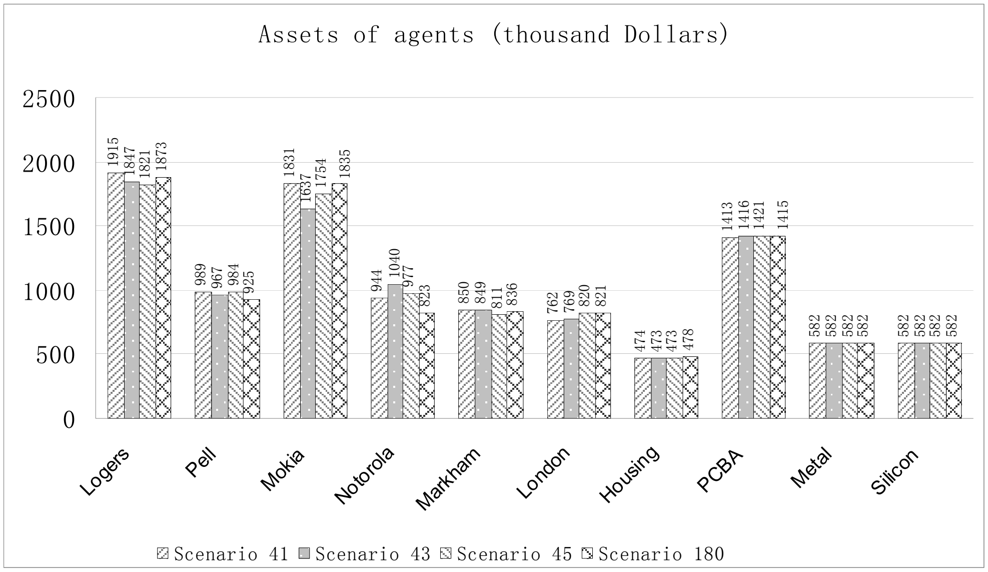
Product Holder's Order Amount Policy Analysis

Product holders use a different Order Amount Policy in order to maintain inventories, and to endeavor to sell as many phones as possible to retailers. Figures 8.15 and 8.17 show the overall performances of the supply chain when product holders adopt different order amount policies in various environments. The environment in Figure 8.15 is as follows:

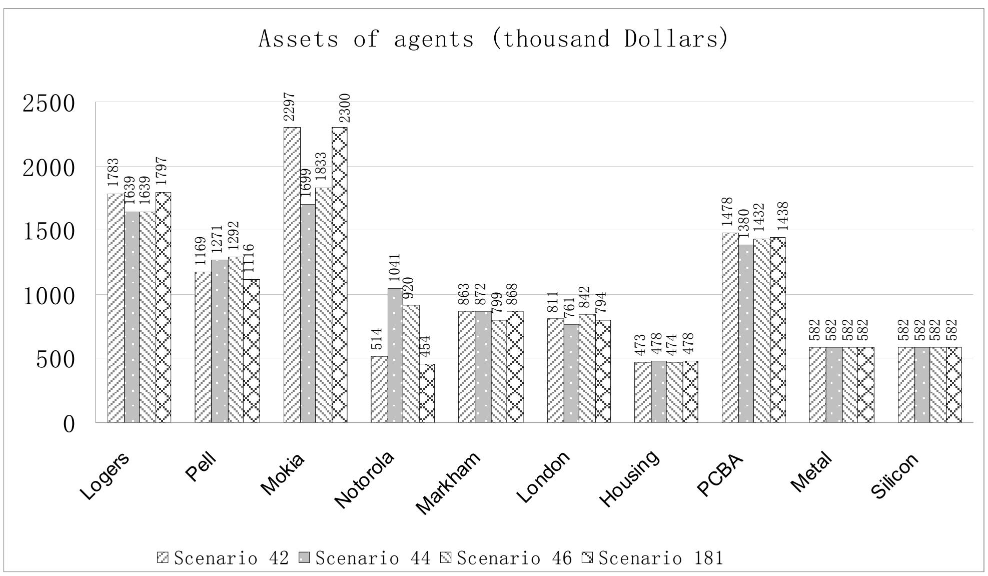
- customer agent adopts the Giving Up order policy;
- retailer agents adopt the Same Order Amount Policy and the Conservative Order Point Strategy;
- product holder agents adopt the Positive Order Point and the Stock-to-Order inventory policies;
- assembler and component agents adopt the Same Order Amount, Conservative Order Point, Normal production capacity, and Make-to-Stock inventory policies;
- material agents adopt the Normal production capacity, and Make-to-Stock inventory policies;
- Mokia has 60% market share, and Notorola has 40% market share.

In Scenarios 41 and 42 product holders adopt the Same Order Amount Policy. In Scenarios 43 and 44 product holders adopt the In Proportion Amount policy. In Scenarios 45 and 46 Notorola adopts the In Proportion policy while the Mokia adopts Same Amount Policy. In Scenarios 180 and 181 Mokia adopts the In Proportion policy while Notorola adopts the Same Amount Policy.

Figure 8.15 shows that that in a normal environment, when market demand by customers is Normal, changes in a product holder agent's Order Amount policy result in no significant difference for any agent. When market demand by customers is High, the only way Notorola can minimize profit loss is to adopt the In Proportion Order Amount Policy. Otherwise, Notorola will lose significant sales while Mokia gains those extra sales.



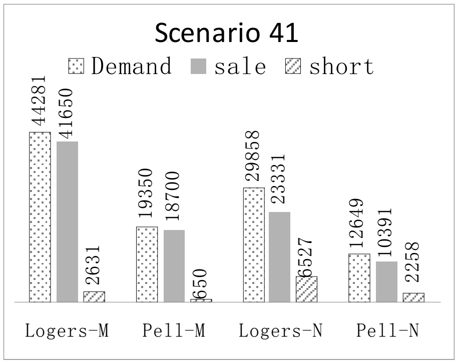
(a) Normal demand by customers

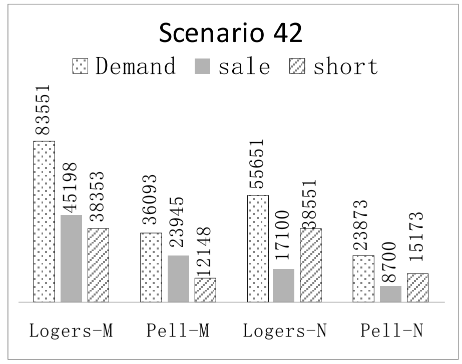


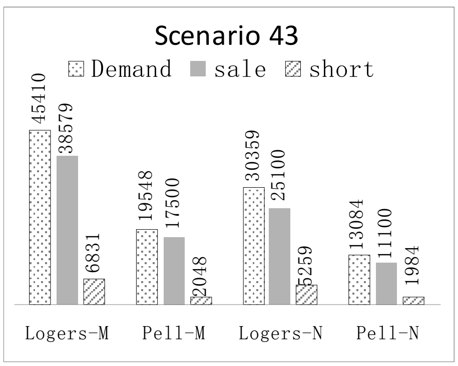
(b) High demand by customers

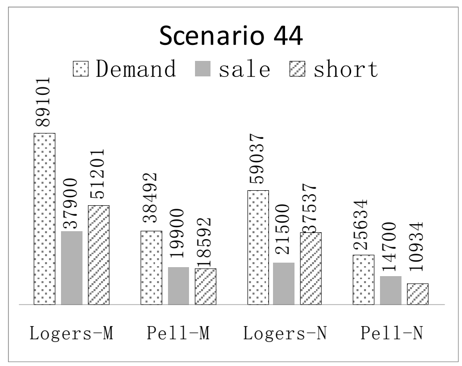
Figure 8.15 Supply chain performance when product holders change order amount policy in the normal environment (Mokia has 60% and Notorola has 40% market share)

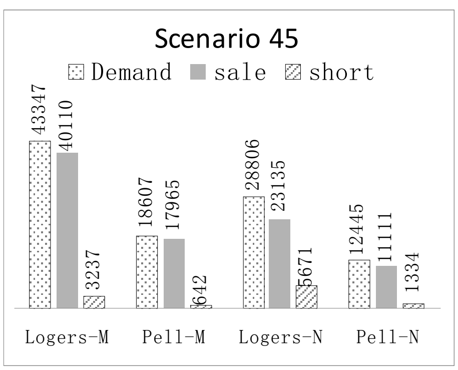
Figure 8.16 (retailer's performance) shows that Mokia has sold more phones in Scenarios 42 and 181 than in Scenarios 41 and 180 while Notorola lost some sales. Table 8.3 gives the detailed contract information for those scenarios. In the table the term Ratio indicates the actual market share of Mokia and Notorola. The market share of Mokia increased to 73% in Scenario 42 from 64% in Scenario 41, and increased to 74% in Scenario 181 from 65% in Scenario 180. There is no significant difference between Scenarios 43 and 44 or between Scenarios 45 and 46.











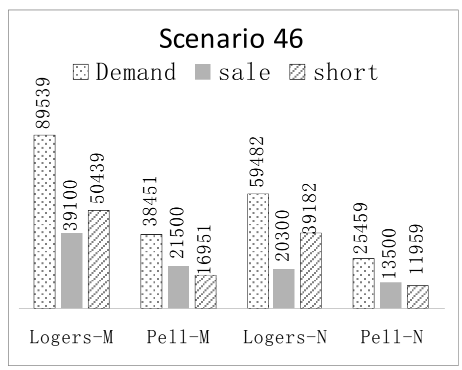


Figure 8.16 Retailers' performance for customer orders

Table 8.3 Contract information for Scenarios 41 to 46 as well as 180 and 181

(a) Contracts received by Mokia from retailers

Mokia	Logers			Pell			Mokia's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units	Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 41	104	400	41600	46	400	18400	0.64
Scenario 42	114	400	45600	60	400	24000	0.73
Scenario 43	98	400	39200	44	400	17600	0.61
Scenario 44	95	400	38000	50	400	20000	0.62
Scenario 45	102	400	40800	45	400	18000	0.63
Scenario 46	98	400	39200	54	400	21600	0.64
Scenario 180	106	400	42400	45	400	18000	0.65
Scenario 181	116	400	46400	58	400	23200	0.74

(b) Contracts received by Notorola from retailers

Notorola	Logers			Pell			Notorola's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units	Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 41	59	400	23600	26	400	10400	0.36
Scenario 42	42	400	16800	21	400	8400	0.27
Scenario 43	62	400	24800	27	400	10800	0.39
Scenario 44	53	400	21200	36	400	14400	0.38
Scenario 45	58	400	23200	28	400	11200	0.37
Scenario 46	51	400	20400	33	400	13200	0.36
Scenario 180	55	400	22000	25	400	10000	0.35
Scenario 181	40	400	16000	20	400	8000	0.26

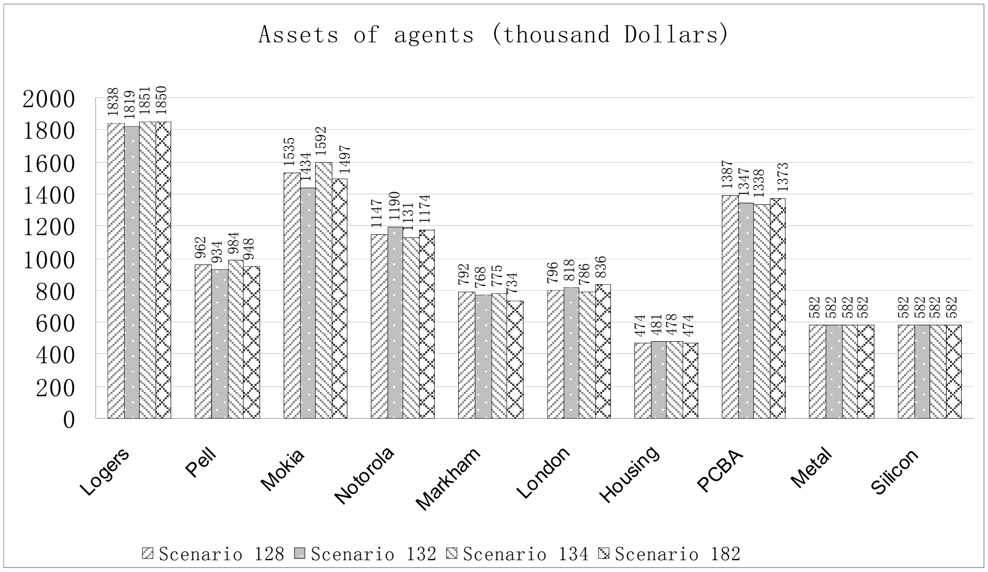
(c) Contracts offered to assemblers by Mokia

Mokia	Markham				London			Mokia's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 41	52	600	31200		48	600	28800	0.64
Scenario 42	59	600	35400		58	600	34800	0.74
Scenario 43	25	1140	28500		25	1140	28500	0.61
Scenario 44	27	1140	30780		24	1140	27360	0.61
Scenario 45	47	600	28200		52	600	31200	0.63
Scenario 46	49	600	29400		52	600	31200	0.64
Scenario 180	26	1140	29640		28	1140	31920	0.66
Scenario 181	32	1140	36480		29	1140	33060	0.74

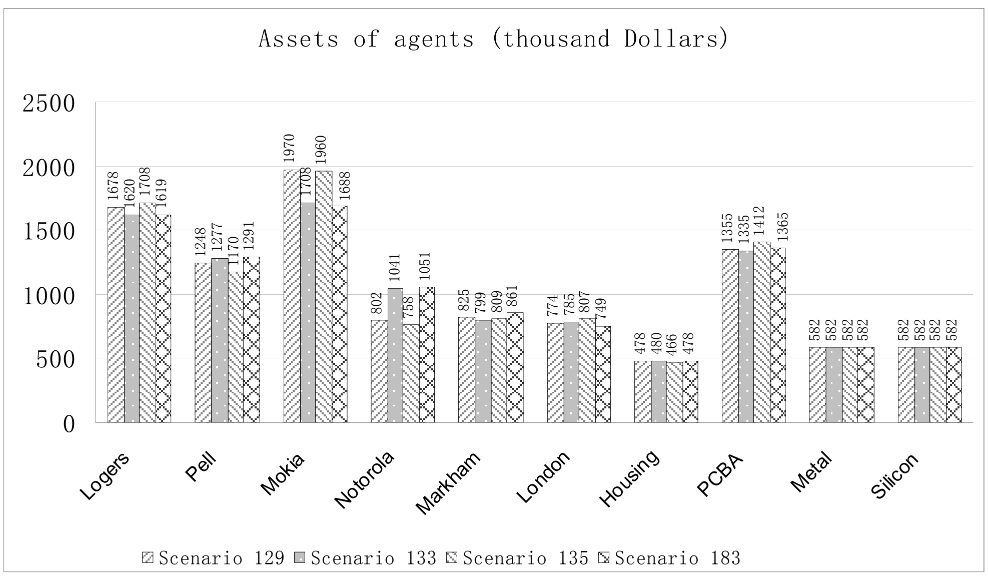
(d) Contracts offered to assemblers by Notorola

Notorola	Markham				London			Notorola's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 41	30	600	18000		27	600	16200	0.36
Scenario 42	23	600	13800		19	600	11400	0.26
Scenario 43	26	760	19760		21	760	15960	0.39
Scenario 44	25	760	19000		23	760	17480	0.39
Scenario 45	24	760	18240		22	760	16720	0.37
Scenario 46	22	760	16720		23	760	17480	0.36
Scenario 180	29	600	17400		25	600	15000	0.34
Scenario 181	19	600	11400		21	600	12600	0.26

The environment in Figure 8.17 is similar with that in Figure 8.15 except that Mokia and Notorola have an equal market share (50% each). The Order Amount Policy combinations which product holders adopted in the scenarios in Figure 8.17 are the same as those in the scenarios in Figure 8.15. Figure 8.17 shows that in the normal environment when product holders have equal market share, and market demand by customers is either Normal or High, there are no significant differences for all other agents when product holder agents change their Order Amount polices. For the product holder agents themselves, Mokia always earns more profit while Notorola loses some profit, especially when Notorola adopts the In Proportion policy. Figure 8.18 provides the retailers' performance on customer orders, and Table 8.4 shows



(a) Normal market demand by customers

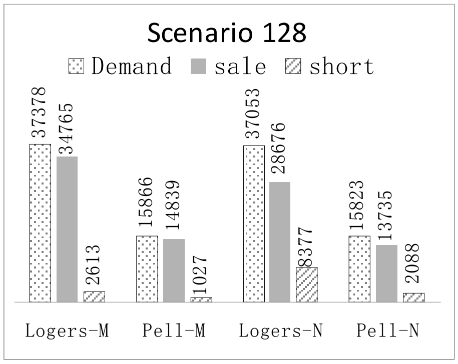


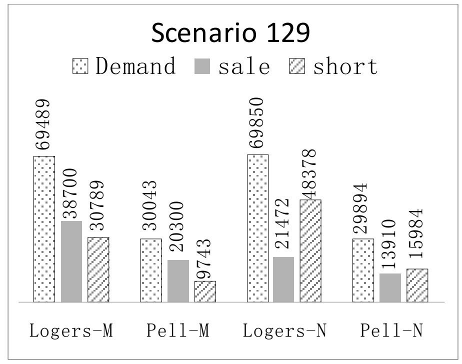
(b) High market demand by customers

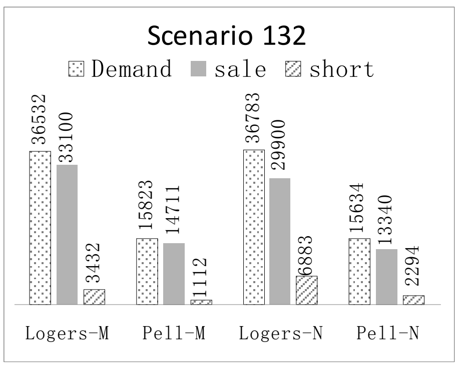
Figure 8.17 Supply chain performance when product holders change order amount policy in the normal environment (Both Mokia and Notorola have 50% market share)

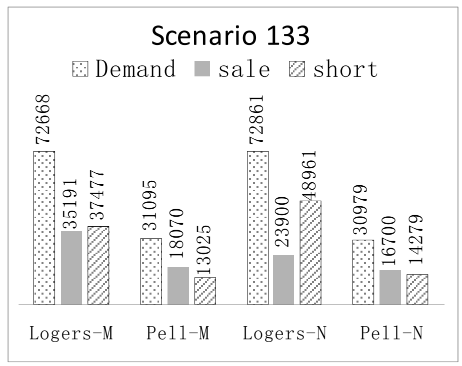
contract information of those scenarios. Mokia sold 19% more phones in Scenario 129 than Scenario 128; 11% more phones in Scenario 133 than Scenario 132; 15% more phones in Scenario 135 than Scenario 134; and 9% more phones in Scenario 183 than Scenario 182. Notorola had a 16% loss in sales in Scenario 129 compared to Scenario 128; a 6% loss in sales in Scenario 133 compared to Scenario 132; a 17%

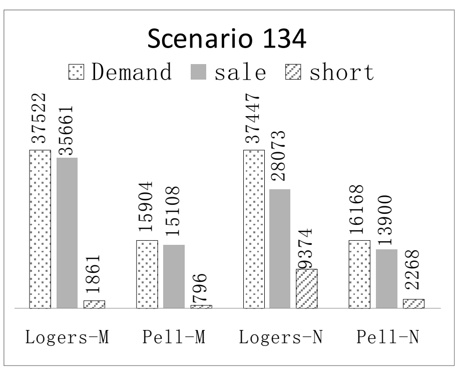
loss in sales in Scenario 135 compared to Scenario 134; and a 6% loss in sales in Scenario 183 compared to Scenario 182.

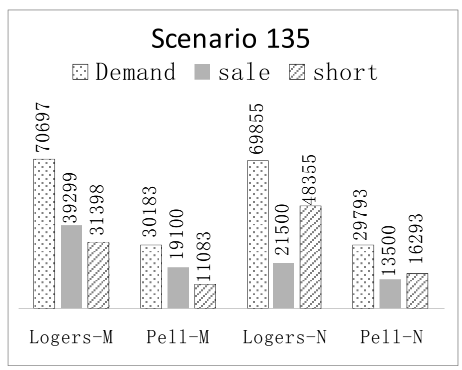












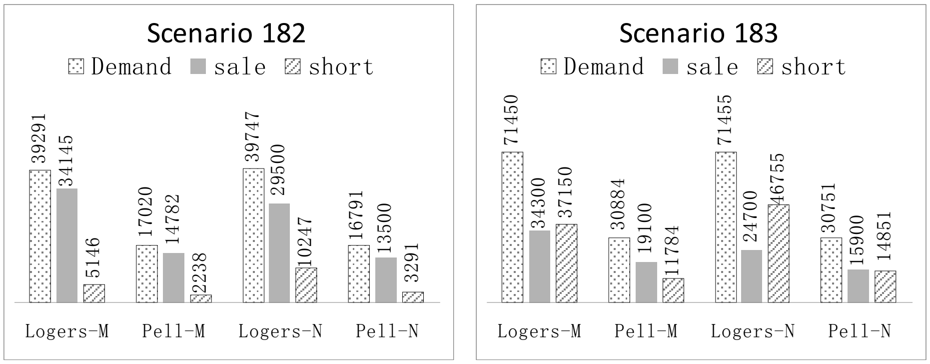


Figure 8.18 Retailers' performance for customer orders

Table 8.4 Contract information for Scenarios 128, 129, 132 - 135, 182 and 183

(a) Contracts received by Mokia from retailers

Mokia	Logers			Pell			Mokia's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units	Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 128	88	400	35200	37	400	14800	0.54
Scenario 129	96	400	38400	50	400	20000	0.62
Scenario 132	84	400	33600	37	400	14800	0.53
Scenario 133	88	400	35200	45	400	18000	0.57
Scenario 134	90	400	36000	38	400	15200	0.55
Scenario 135	99	400	39600	48	400	19200	0.63
Scenario 182	86	400	34400	37	400	14800	0.53
Scenario 183	86	400	34400	48	400	19200	0.57

(b) Contracts received by Notorola from retailers

Notorola	Logers			Pell			Notorola's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units	Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 128	72	400	28800	34	400	13600	0.46
Scenario 129	54	400	21600	35	400	14000	0.38
Scenario 132	75	400	30000	33	400	13200	0.47
Scenario 133	59	400	23600	41	400	16400	0.43
Scenario 134	70	400	28000	35	400	14000	0.45
Scenario 135	53	400	21200	33	400	13200	0.37
Scenario 182	74	400	29600	34	400	13600	0.47
Scenario 183	62	400	24800	40	400	16000	0.43

(c) Contracts offered to assemblers by Mokia

Mokia	Markham				London			Mokia's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 128	41	600	24600		44	600	26400	0.54
Scenario 129	51	600	30600		46	600	27600	0.62
Scenario 132	24	950	22800		28	950	26600	0.53
Scenario 133	29	950	27550		27	950	25650	0.57
Scenario 134	26	950	24700		28	950	26600	0.55
Scenario 135	32	950	30400		31	950	29450	0.57
Scenario 182	39	600	23400		44	600	26400	0.55
Scenario 183	48	600	28800		41	600	24600	0.57

(d) Contracts offered to assemblers by Notorola

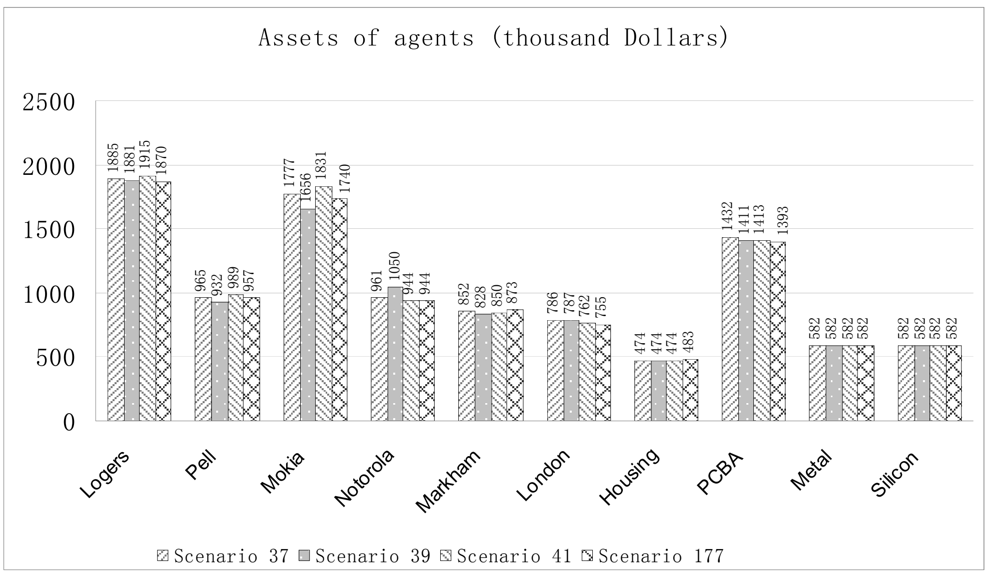
Notorola	Markham				London			Notorola's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 128	37	600	22200		35	600	21000	0.46
Scenario 129	29	600	17400		31	600	18600	0.38
Scenario 132	24	950	22800		23	950	21850	0.47
Scenario 133	20	950	19000		22	950	20900	0.43
Scenario 134	38	600	22800		33	600	19800	0.45
Scenario 135	21	950	19950		26	950	24700	0.43
Scenario 182	22	950	20900		21	950	19950	0.45
Scenario 183	62	400	24800		40	400	16000	0.43

Product Holder's Order Point Strategy Analysis

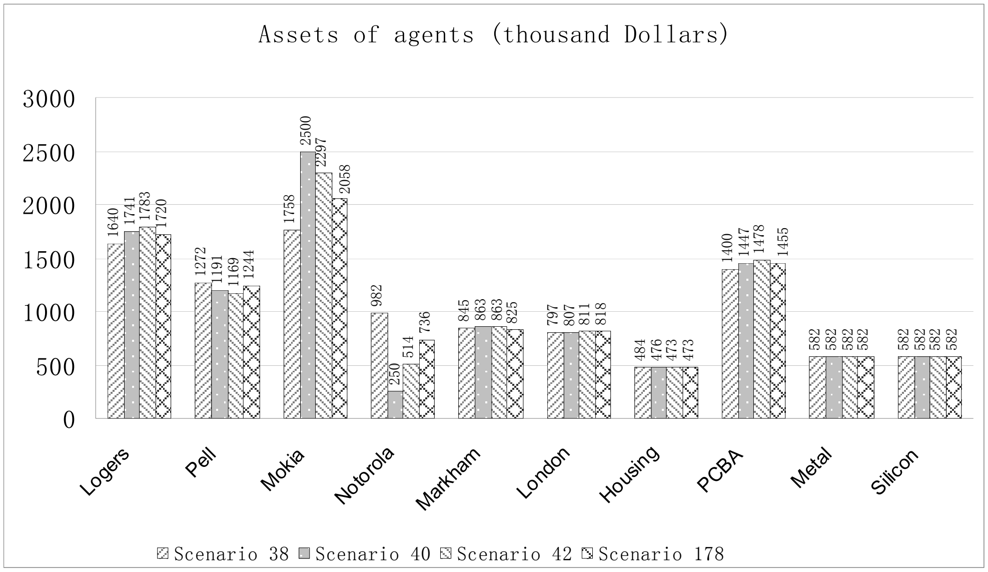
A product holder may adopt a different Order Point strategy to keep sufficient inventories to obtain more contracts from retailers. When the Positive strategy is adopted, more inventories are usually kept by product holders. The product holders face more inventory cost and risk that the entire inventory cannot be sold, causing the product holders to bear significant financial burdens. Figure 8.19 shows how a product holder's Order Point Strategy influences the entire supply chain. The environment in Figure 8.19 is as follows:

- customer adopts the Giving Up order policy;

- retailer agents adopt the Same Order Amount Policy and Conservative Order Point Strategy;
- product holder agents adopt the Same Order Amount and Stock-to-Order inventory policies;
- assembler and component agents adopt the Same Order Amount, Conservative Order Point, Normal production capacity, and Make-to-Stock inventory policies;
- material agents adopt the Normal production capacity, and Make-to-Stock inventory policies;
- Logers has 70% market share and Pell has 30%;
- Mokia has 60% market share, and Notorola has 40%.



(a) Normal market demand by customers



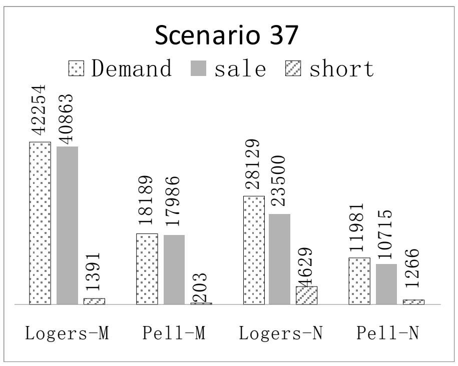
(b) High market demand by customers

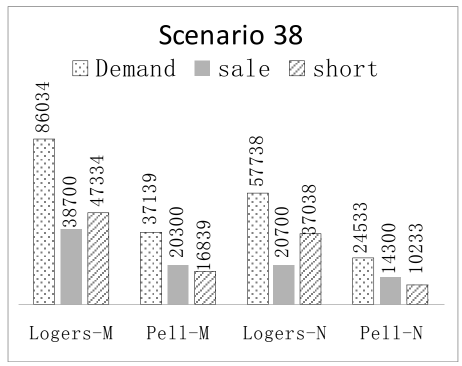
Figure 8.19 Supply chain performance when product holders change order point strategy in normal environment (Mokia has 60% and Notorola has 40% market share)

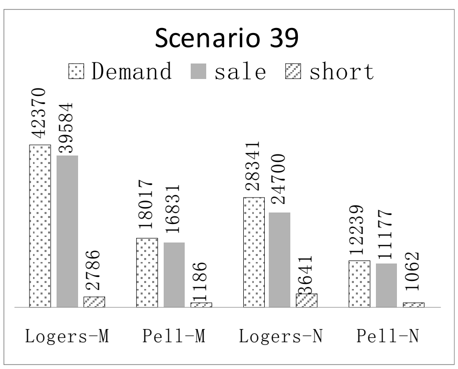
In Scenarios 37 and 38 Mokia and Notorola adopt the Conservative Order Point Strategy. In Scenarios 39 and 40 Mokia adopts the Positive strategy while Notorola adopts the Conservative strategy. In Scenarios 41 and 42 both Mokia and Notorola adopt the Positive strategy. In Scenarios 177 and 178 Mokia adopts the Conservative strategy while Notorola adopts the Positive strategy.

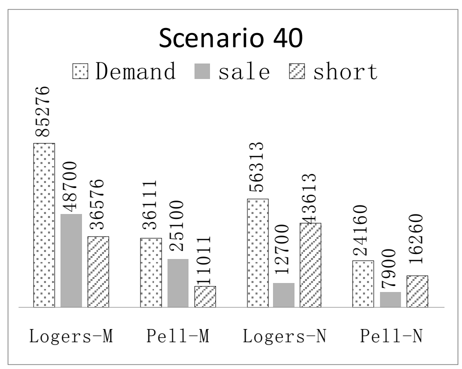
The results show that when customer demand is Normal, there are no obvious differences for any agent if product holders change their Order Point strategies. When customer demand is High, Pell and Mokia usually benefit from the High market demand, but Logers and Notorola lose some sales. When both product holders adopt the Positive Order Point Strategy, Mokia will gain the most profit while Notorola loses the most profit. Figure 8.20 provides the retailers' performance for customer orders, and Table 8.5 shows the contract information of those scenarios. Figure 8.20 shows that when customer demand is High, some customer orders to Logers will be lost due to the limited production capacity of the manufacturing agents. Logers lost 8% sales in Scenario 37 compared to Scenario 38; lost 4% sales in Scenario 39 compared to Scenario 40; lost 4% sales in Scenario 41 compared to 42; and lost 5% sales in

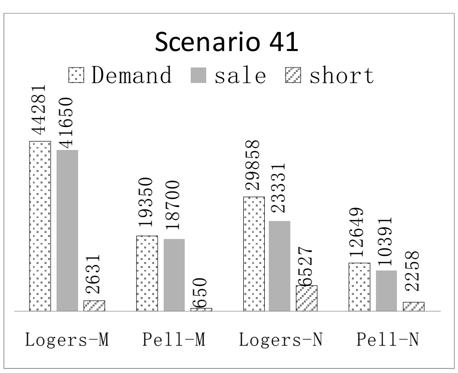
Scenario 177 compared to Scenario 178. Pell sold 20% more phones in Scenario 37 than Scenario 38; 18% more phones in Scenario 39 than Scenario 40; 12% more phones in Scenario 41 than Scenario 42; and earned 20% more phones in Scenario 177 than Scenario 178. Mokia sold 0.3% more phones in Scenario 37 than Scenario 38; 31% more phones in Scenario 39 than Scenario 40; 15% more phones in Scenario 41 than Scenario 42; and 11% more phones in Scenario 177 than Scenario 178. Notorola sold 2% more phones in Scenario 37 than Scenario 38; lost 43% sales in Scenario 39 compared to Scenario 40; lost 23% sales in Scenario 41 compared to Scenario 42; and lost 11% sales in Scenario 177 compared to Scenario 178.

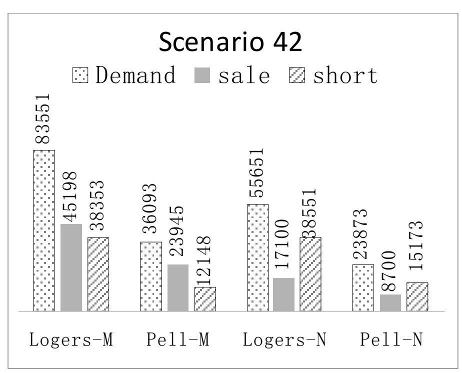












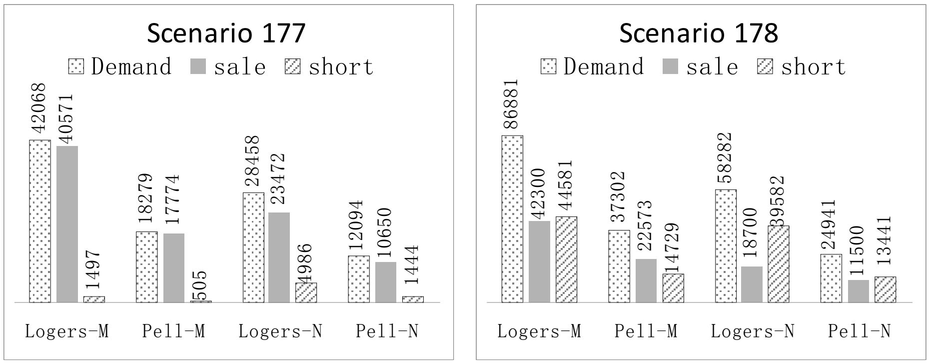


Figure 8.20 Retailers' performance for customer orders

Table 8.5 Contract information for Scenarios 37 to 42, and 177 to 178

(a) Contracts received by Mokia from retailers

Mokia	Logers			Pell			Mokia's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units	Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 37	103	400	41200	45	400	18000	0.63
Scenario 38	97	400	38800	50	400	20000	0.63
Scenario 39	100	400	40000	42	400	16800	0.61
Scenario 40	121	400	48400	62	400	24800	0.79
Scenario 41	104	400	41600	46	400	18400	0.64
Scenario 42	114	400	45600	60	400	24000	0.73
Scenario 177	102	400	40800	45	400	18000	0.63
Scenario 178	107	400	42800	57	400	22800	0.69

(b) Contracts received by Notorola from retailers

Notorola	Logers			Pell			Notorola's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units	Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 37	59	400	23600	27	400	10800	0.37
Scenario 38	52	400	20800	35	400	14000	0.37
Scenario 39	62	400	24800	28	400	11200	0.39
Scenario 40	31	400	12400	19	400	7600	0.21
Scenario 41	59	400	23600	26	400	10400	0.36
Scenario 42	42	400	16800	21	400	8400	0.27
Scenario 177	59	400	23600	27	400	10800	0.37
Scenario 178	46	400	18400	28	400	11200	0.31

(c) Contracts offered to assemblers by Mokia

Mokia	Markham				London			Mokia's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 37	51	600	30600		49	600	29400	0.63
Scenario 38	51	600	30600		48	600	28800	0.63
Scenario 39	47	600	28200		49	600	29400	0.61
Scenario 40	62	600	37200		60	600	36000	0.78
Scenario 41	52	600	31200		48	600	28800	0.64
Scenario 42	59	600	35400		58	600	34800	0.74
Scenario 177	51	600	30600		48	600	28800	0.63
Scenario 178	55	600	33000		54	600	32400	0.69

(d) Contracts offered to assemblers by Notorola

Notorola	Markham				London			Notorola's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 37	31	600	18600		27	600	16200	0.37
Scenario 38	30	600	18000		29	600	17400	0.37
Scenario 39	33	600	19800		28	600	16800	0.39
Scenario 40	19	600	11400		16	600	9600	0.22
Scenario 41	30	600	18000		27	600	16200	0.36
Scenario 42	23	600	13800		19	600	11400	0.26
Scenario 177	34	600	20400		24	600	14400	0.37
Scenario 178	24	600	14400		25	600	15000	0.31

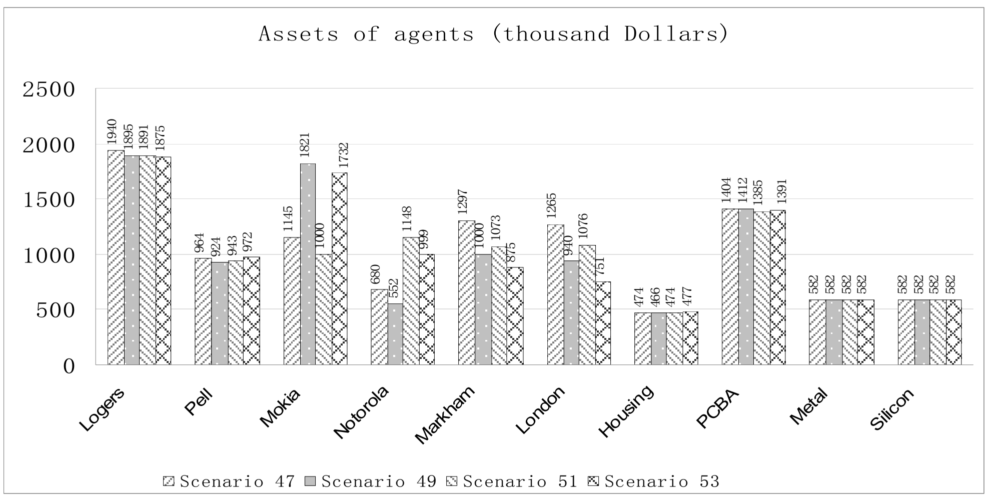
Product Holder's Inventory Strategy Analysis

To investigate how the product holder's inventory strategy influences the entire supply chain performance, two groups of scenarios were tested. The first group, shown in Figure 8.21, uses the following settings:

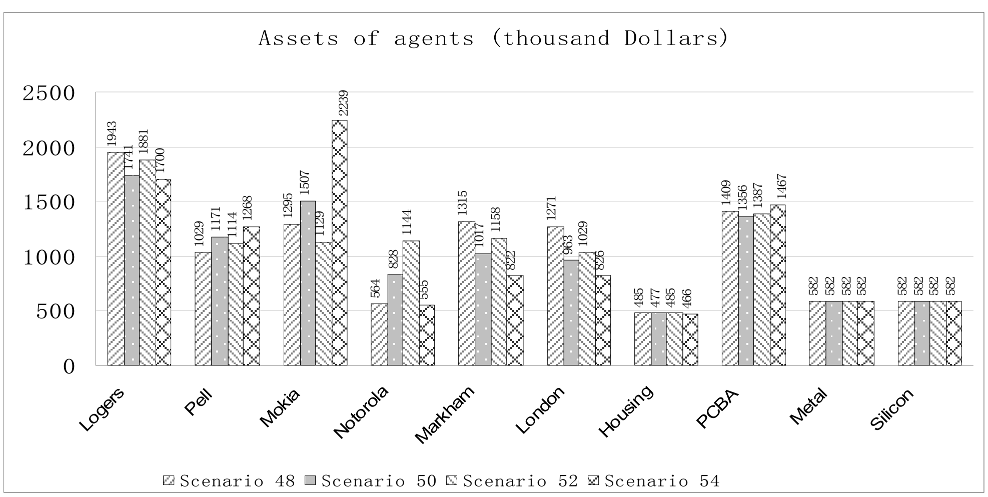
- customer adopts the Giving Up order policy;
- retailers adopt the Same Order Amount Policy and Conservative Order Point Strategy;
- product holder agents adopt the Same Order Amount Policy and Conservative Order Point Strategy;

- assembler and component agents adopt the Same Order Amount, Conservative Order Point, Normal production capacity, and Make-to-Stock inventory policies;
- material agents adopt the Normal production capacity, and Make-to-Stock inventory policies;
- Logers has 70% market share while Pell has 30%;
- Mokia has 60% market share and Notorola has 40%.

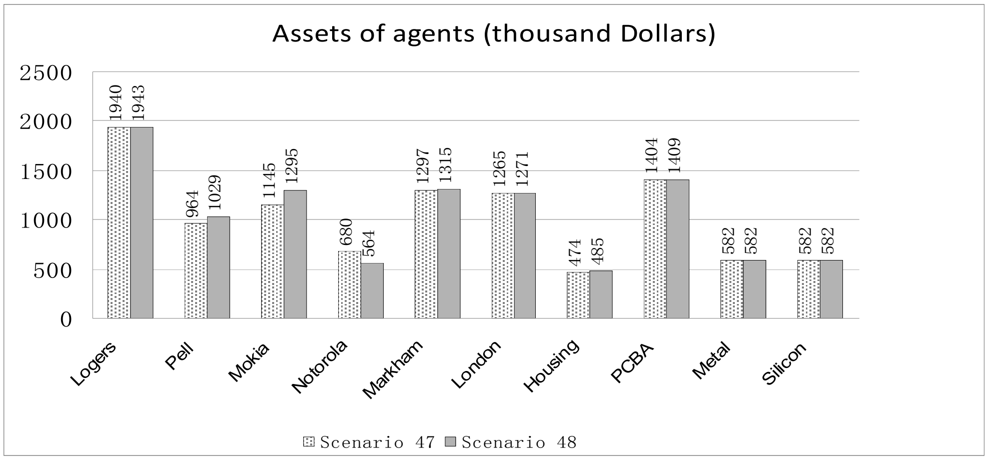
The second group, shown in Figure 8.23, is the same situation as the first group, except that Mokia and Notorola have equal market share (50% each).



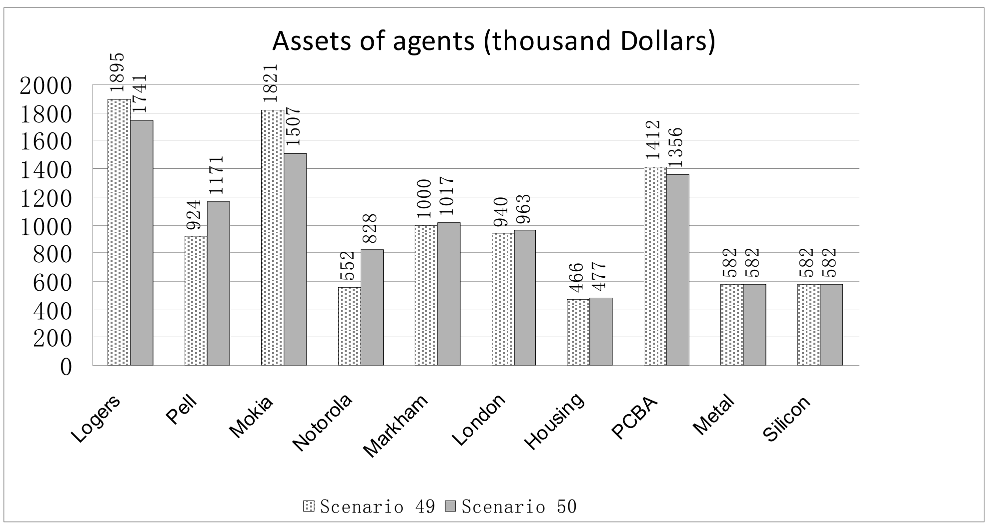
(a) Normal market demand by customers



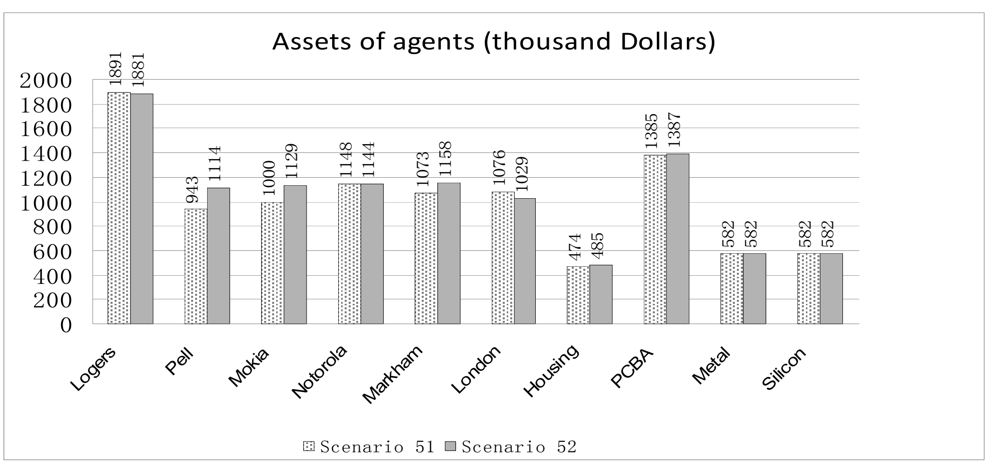
(b) High market demand by customers



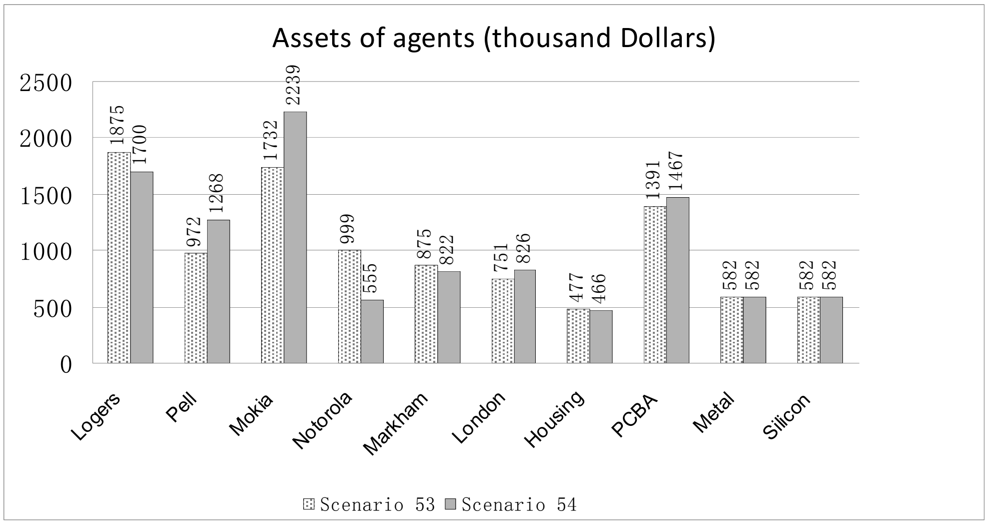
(c) Comparison of Scenario 47 with Scenario 48



(d) Comparison of Scenario 49 with Scenario 50



(e) Comparison of Scenario 51 with Scenario 52



(f) Comparison of Scenario 53 with Scenario 54

Figure 8.21 Supply chain performance when product holders change inventory strategies in normal environment (Mokia 60%, Notorola 40% market share)

Figure 8.21 shows a comparison of several scenarios using different inventory strategies. In Scenarios 47 and 48, both Mokia and Notorola adopt the Order-to-Order inventory strategy. In Scenarios 49 and 50 Mokia adopts the Stock-to-Order strategy while Notorola adopts the Order-to-Order strategy. In Scenarios 51 and 52 Mokia adopts the Order-to-Order strategy while Notorola adopts the Stock-to-Order strategy. In Scenarios 53 and 54 both Mokia and Notorola adopt the Stock-to-Order strategy. Figure 8.21 shows that there is no significant difference for most agents (retailer, component and material agents) when the product holder's inventory strategies are changed and customer demand is either Normal or High. For assembler agents the best product holders' inventory strategy is the Stock-to-Order Inventory Strategy. For the product holder agents themselves, the Order-to-Order strategy is best. Figure 8.22 shows the retailers' performance for these scenarios and Table 8.6 displays the contract information.

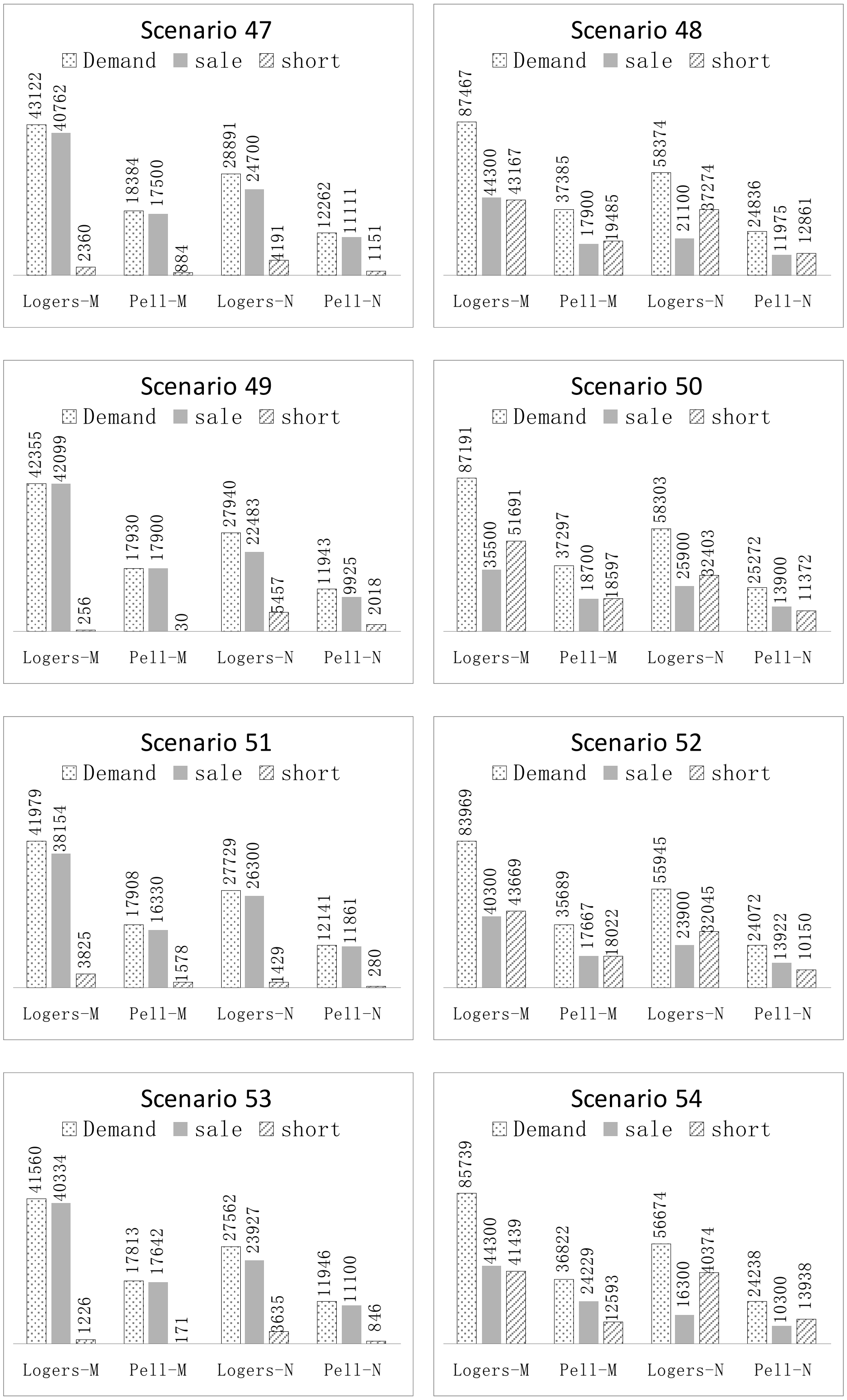


Figure 8.22 Retailers' performance for customer orders

Table 8.6 Contract information for Scenario 47 to Scenario 54

(a) Contracts received by Mokia from retailers

Mokia	Logers				Pell			Mokia's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 47	103	400	41200		43	400	17200	0.62
Scenario 48	110	400	44000		44	400	17600	0.65
Scenario 49	107	400	42800		45	400	18000	0.65
Scenario 50	88	400	35200		46	400	18400	0.58
Scenario 51	97	400	38800		41	400	16400	0.59
Scenario 52	101	400	40400		44	400	17600	0.60
Scenario 53	102	400	40800		45	400	18000	0.63
Scenario 54	112	400	44800		61	400	24400	0.73

(b) Contracts received by Notorola from retailers

Notorola	Logers				Pell			Notorola's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 47	62	400	24800		28	400	11200	0.38
Scenario 48	53	400	21200		30	400	12000	0.35
Scenario 49	56	400	22400		25	400	10000	0.35
Scenario 50	64	400	25600		35	400	14000	0.42
Scenario 51	66	400	26400		30	400	12000	0.41
Scenario 52	60	400	24000		35	400	14000	0.40
Scenario 53	60	400	24000		27	400	10800	0.37
Scenario 54	40	400	16000		25	400	10000	0.27

(c) Contracts offered to assemblers by Mokia

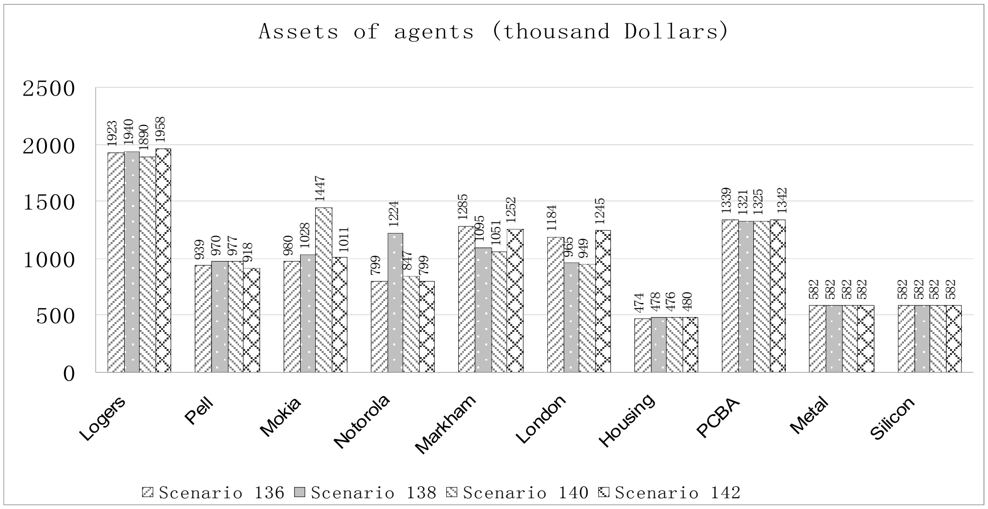
Mokia	Markham				London			Mokia's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 47	69	400	27600		77	400	30800	0.62
Scenario 48	78	400	31200		76	400	30400	0.65
Scenario 49	49	600	29400		53	600	31800	0.65
Scenario 50	46	600	27600		43	600	25800	0.57
Scenario 51	71	400	28400		67	400	26800	0.59
Scenario 52	76	400	30400		69	400	27600	0.61
Scenario 53	51	600	30600		47	600	28200	0.62
Scenario 54	57	600	34200		58	600	34800	0.73

(d) Contracts offered to assemblers by Notorola

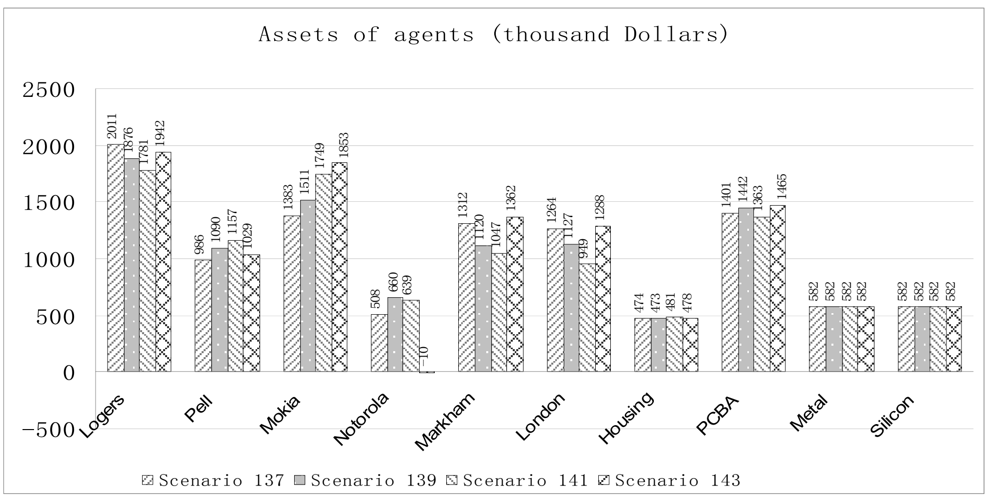
Notorola	Markham				London			Notorola's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 47	50	400	20000		40	400	16000	0.38
Scenario 48	42	400	16800		41	400	16400	0.35
Scenario 49	45	400	18000		36	400	14400	0.35
Scenario 50	49	400	19600		50	400	20000	0.43
Scenario 51	28	600	16800		36	600	21600	0.41
Scenario 52	33	600	19800		30	600	18000	0.39
Scenario 53	33	600	19800		26	600	15600	0.38
Scenario 54	21	600	12600		22	600	13200	0.27

Comparing High customer demand with Normal demand, Logers maintains sales or may lose a small amount of sales while Pell gains sales. Mokia usually gains some sales except in the situation where Mokia adopts the Stock-to-Order and Notorola adopts the Order-to-Order strategy. Notorola usually loses some sales unless Mokia adopts the Stock-to-Order strategy while Notorola adopts the Order-to-Order strategy.

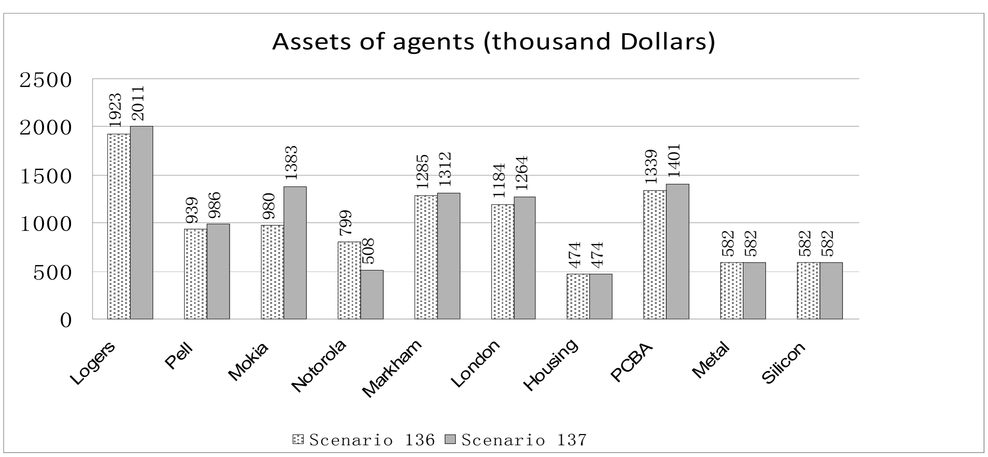
The following will examine the performance of each combination of product holder's inventory strategies. Logers kept the same sales in Scenarios 47 and 48; lost 5% sales in Scenario 49 compared to Scenario 50; maintained nearly the same sales in Scenarios 51 and Scenario 52, and lost 6% sales in Scenario 53 compared to Scenario 54. Pell earned 4% more sales in Scenario 47 than Scenario 48; 17% more sales in Scenario 49 than Scenario 50, earned 12% more sales in Scenario 51 than in Scenario 52; and 20% more sales in Scenario 53 than Scenario 54. Mokia earned 6.7% more sales in Scenario 47 than Scenario 48; lost 10% sales in Scenario 49 compared to Scenario 50; earned 6% more sales in Scenario 51 than Scenario 52; and earned 18% more sales in Scenario 53 than Scenario 54. Notorola lost 7.6% sales in Scenario 47 compared to Scenario 48; earned 23% more sales in Scenario 49 than Scenario 50; lost 1% sales in Scenario 51 compared to Scenario 52; and lost 24% sales in Scenario 53 compared to Scenario 54.



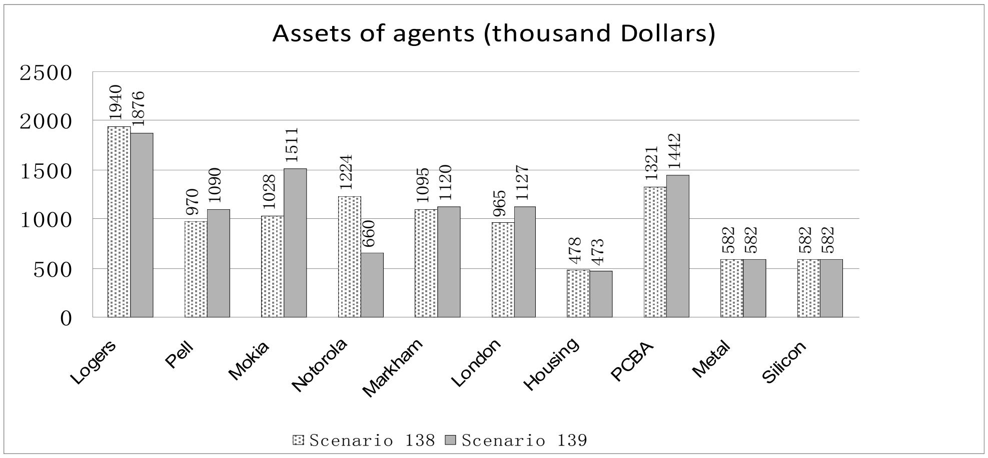
(a) Normal market demand by customers



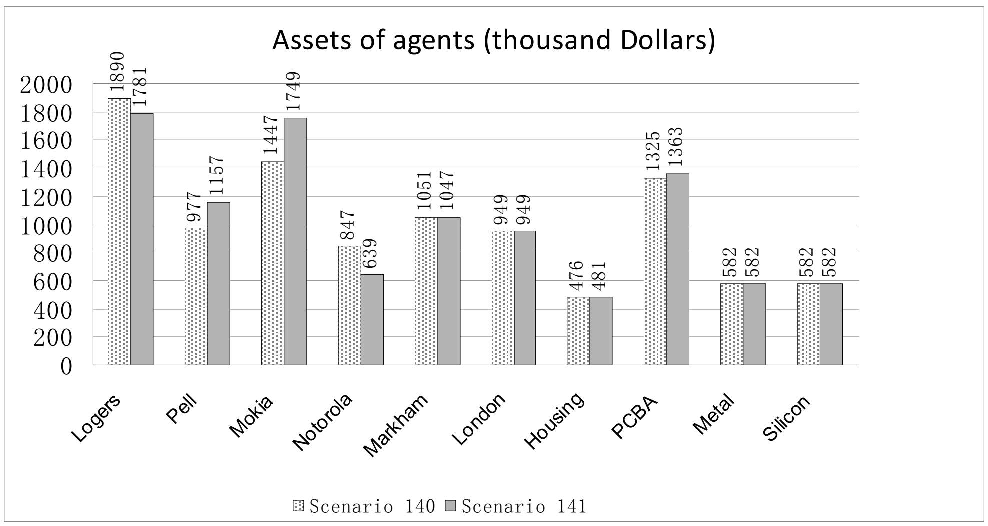
(b) High market demand by customers



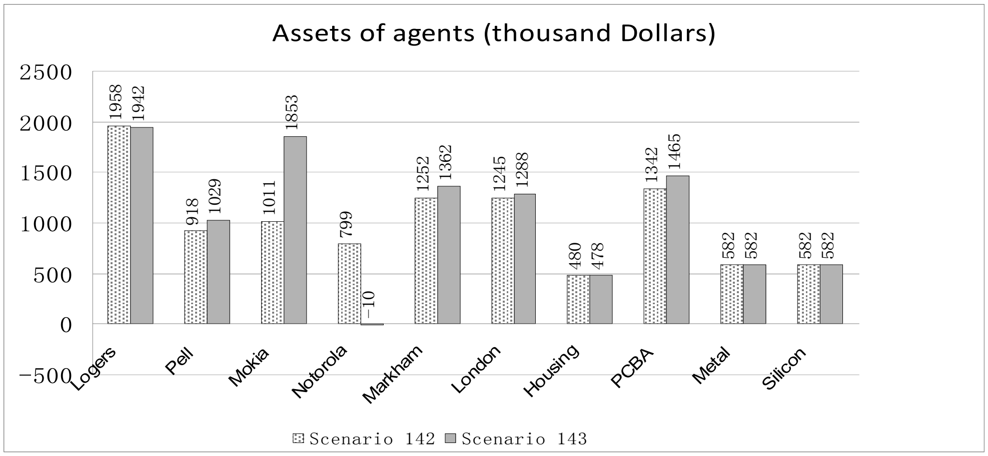
(c) Comparison of Scenario 136 with Scenario 137



(d) Comparison of Scenario 138 with Scenario 139



(e) Comparison of Scenario 140 with Scenario 141



(f) Comparison of Scenario 142 with Scenario 143

Figure 8.23 Supply chain performance when product holders change inventory strategies in normal environment (Both Mokia and Notorola have 50% market share)

Figure 8.23 shows a comparison of several scenarios with different product holder inventory strategies. In Scenarios 136 and 137 both Mokia and Notorola adopt the Order-to-Order inventory strategy. In Scenarios 138 and 139 Mokia adopts the Order-to-Order strategy while Notorola adopts the Stock-to-Order strategy. In Scenarios 140 and 141 Mokia adopts the Stock-to-Order strategy while Notorola adopts the Order-to-Order strategy. In Scenarios 142 and 143 both Mokia and Notorola adopt the Stock-to-Order strategy. Figure 8.23 shows that when market demand changes from Normal to High, Logers has very little change, Pell and Mokia always obtain more sales and Notorola always loses sales. Figure 8.24 provides details of retailers' performance for these scenarios, and Table 8.7 displays the contract information.

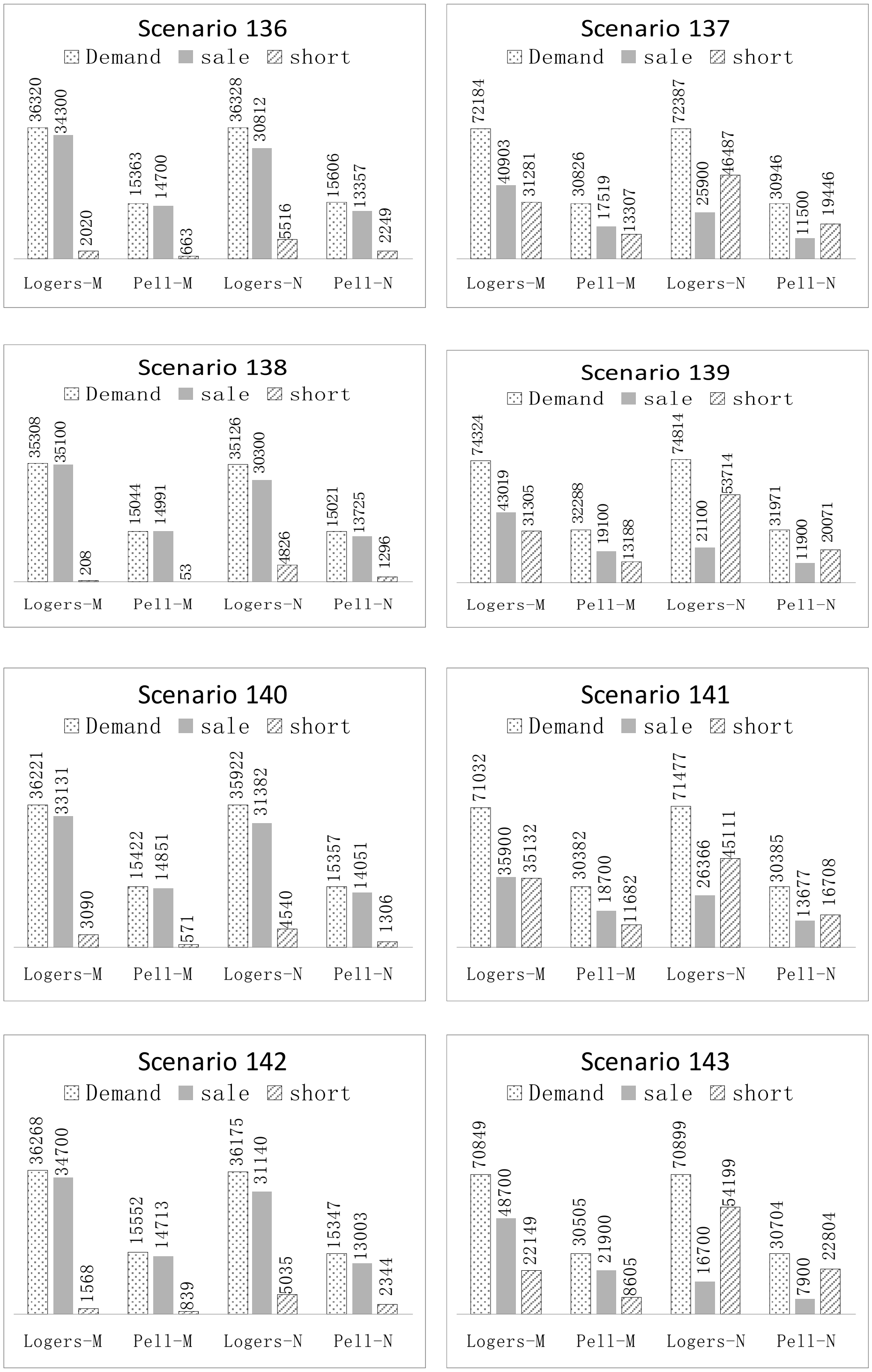


Figure 8.24 Retailers' performance for customer orders

Table 8.7 Contracts information for Scenario 136 to Scenario 143

(a) Contracts received by Mokia from retailers

Mokia	Logers				Pell			Mokia's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 136	85	400	34000		36	400	14400	0.52
Scenario 137	103	400	41200		44	400	17600	0.62
Scenario 138	88	400	35200		38	400	15200	0.53
Scenario 139	107	400	42800		48	400	19200	0.66
Scenario 140	83	400	33200		37	400	14800	0.51
Scenario 141	89	400	35600		46	400	18400	0.57
Scenario 142	88	400	35200		37	400	14800	0.53
Scenario 143	123	400	49200		55	400	22000	0.74

(b) Contracts received by Notorola from retailers

Notorola	Logers				Pell			Notorola's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 136	78	400	31200		33	400	13200	0.48
Scenario 137	64	400	25600		28	400	11200	0.38
Scenario 138	76	400	30400		34	400	13600	0.47
Scenario 139	52	400	20800		29	400	11600	0.34
Scenario 140	79	400	31600		35	400	14000	0.49
Scenario 141	67	400	26800		34	400	13600	0.43
Scenario 142	78	400	31200		32	400	12800	0.47
Scenario 143	43	400	17200		20	400	8000	0.26

(c) Contracts offered to assemblers by Mokia

Mokia	Markham				London			Mokia's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 136	66	400	26400		55	400	22000	0.52
Scenario 137	75	400	30000		72	400	28800	0.62
Scenario 138	67	400	26800		59	400	23600	0.54
Scenario 139	77	400	30800		78	400	31200	0.66
Scenario 140	42	600	25200		38	600	22800	0.51
Scenario 141	45	600	27000		45	600	27000	0.57
Scenario 142	62	400	24800		63	400	25200	0.53
Scenario 143	92	400	36800		86	400	34400	0.74

(d) Contracts offered to assemblers by Notorola

Notorola	Markham				London			Notorola's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 136	54	400	21600		57	400	22800	0.48
Scenario 137	46	400	18400		46	400	18400	0.38
Scenario 138	38	600	22800		35	600	21000	0.46
Scenario 139	26	600	15600		28	600	16800	0.34
Scenario 140	59	400	23600		55	400	22000	0.49
Scenario 141	55	400	22000		46	400	18400	0.43
Scenario 142	56	400	22400		54	400	21600	0.47
Scenario 143	31	400	12400		32	400	12800	0.26

The simulation results show that when market demand is High, Mokia will earn more market share while Notorola will lose some market share. Logers usually loses some sales while Pell always earns more sales. The following will examine the performance of each combination of product holder's inventory strategies. Logers earned 2.6% more sales in Scenario 137 than Scenario 136; lost 2% sales in Scenario 139 compared to Scenario 138; lost 3% sales in Scenario 141 compared to Scenario 140; and lost 0.7% sales in Scenario 143 compared to Scenario 142. Pell earned 3.4% more sales in Scenario 137 than Scenario 136; 8% more sales in Scenario 139 than Scenario 138; 12% more sales in Scenario 141 than Scenario 140; and 7.5% sales in Scenario 143 than Scenario 142. Mokia earned 19% more sales in Scenario 137 than Scenario 136; 24% more sales in Scenario 139 than Scenario 138; 14% more sales in Scenario 141 than Scenario 140; and 43% more sales in Scenario 143 than Scenario 142. Notorola lost 15% sales in Scenario 137 compared to Scenario 136; lost 25% sales in Scenario 139 compared to Scenario 138; lost 12% sales in Scenario 141 compared to Scenario 140; and lost 44% sales in Scenario 143 compared to Scenario 142.

8.5 Assembler Agent Analysis

Assembler factors that influence the performance of the whole supply chain include its assembling quality, production capacity, assembling cost, inventory strategy, product Order Amount Policy, Order Point Strategy, etc. In this system, production capacity, inventory strategy, Order Amount Policy, and Order Point Strategy will be considered.

Like the product holder agent, inventory strategy has three possible values:

0 – Make-to-Order: the assembler agent keeps no inventory. When a request-for-quotation (RFQ) is received from a product holder, the assembler will send an RFQ to the component agents to determine if the components are available. If all component agents can satisfy the RFQs, the assembler will accept the product holder's RFQ. After the product holder changes the RFQ to a contract, the assembler will transfer its RFQs to contracts. When the components are available, the phone will be assembled to fulfill the contract.

1 – Make-to-Stock: an assembler produces stock to maintain a certain inventory level. When the assembler receives an RFQ from a product holder, the assembler first checks the inventory. If the inventory is no less than the order amount, the RFQ will be accepted. If the inventory is insufficient the RFQ will be rejected.

2 – Changing inventory policy iteratively: an assembler will change its inventory policy every half year.

Order Amount Policy has two options:

0 – In Proportion;

1 – Same.

Order Point Strategy has two options:

0 – Conservative;

1 – Positive.

Production Capacity has three possible values:

0 – Normal: an assembler's production capacity can meet Normal customer demand (150 units per day);

1 – Maximum: an assembler has the maximum production capacity (two times Normal capacity – 300 units per day); and

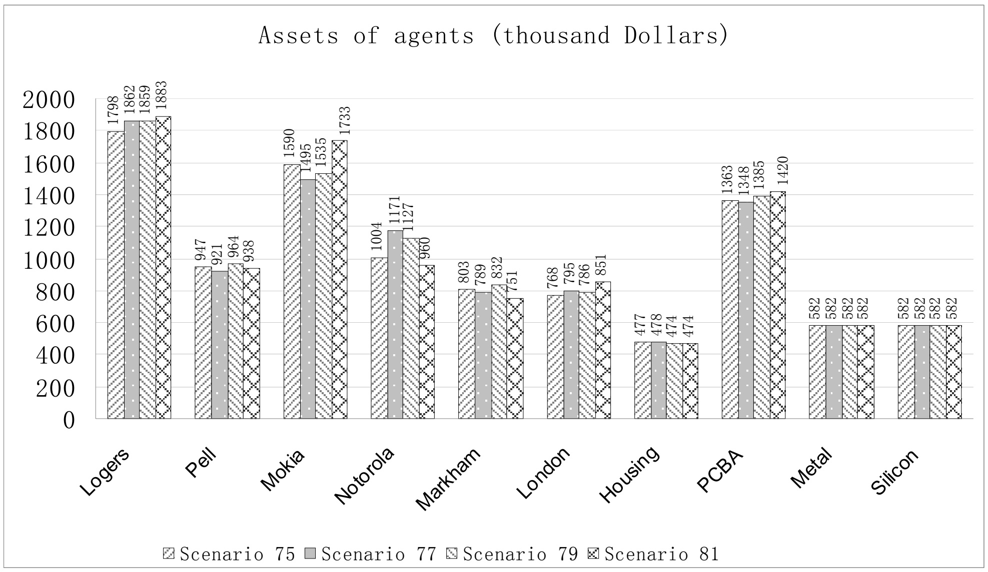
2 – Minimum: the assembler only has half Normal production capacity (75 units per day)

Assembler's Order Amount Policy Analysis

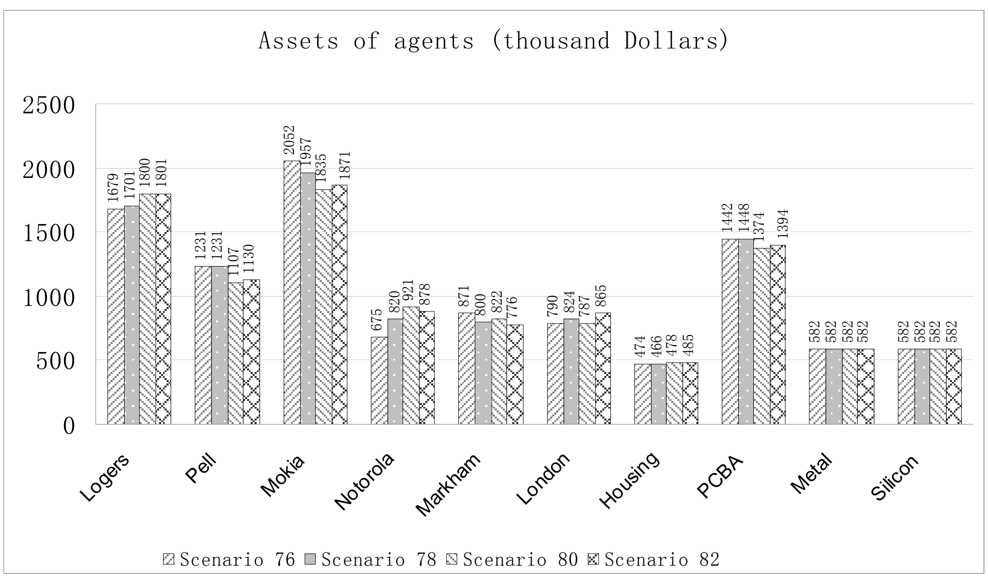
The two assemblers compete for mobile phone components from the component agents. They also compete for orders from product holder agents. An assembler may adopt a different Order Amount Policy in order to seize more resources and earn more profit. Figure 8.25 shows the overall performance of the entire supply chain when assemblers adopt different order amount policies. The settings for these scenarios are as follows:

- customer agent adopts the Giving Up order policy;
- retailers adopt the Same Order Amount Policy and Conservative Order Point Strategy;
- product holder agents adopt the Same Order Amount Policy, Conservative Order Point Strategy, and Stock-to-Order strategy;
- assembler agents adopt the Conservative Order Point, Normal production capacity, and Make-to-Stock inventory policies;
- component agents adopt the Same Order Amount, Conservative Order Point, Normal production capacity, and Make-to-Stock inventory policies;
- material agents adopt Normal production capacity, and Make-to-Stock inventory policies;
- Mokia has 60% market share and Notorola has 40%.

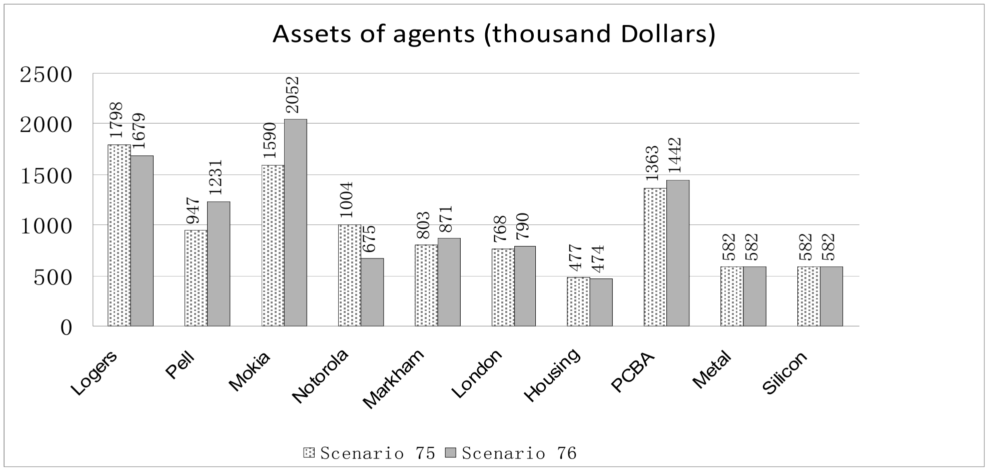
In Scenarios 75 and 76 both Markham and London adopt the In Proportion policy. In Scenarios 77 and 78 Markham adopts the In Proportion policy while London adopts the Same Order Amount Policy. In Scenarios 79 and 80 both Markham and London adopt the Same Order Amount Policy. In Scenario 81 and 82 Markham adopts the Same Order Amount Policy while London adopts the In Proportion Order Amount Policy.



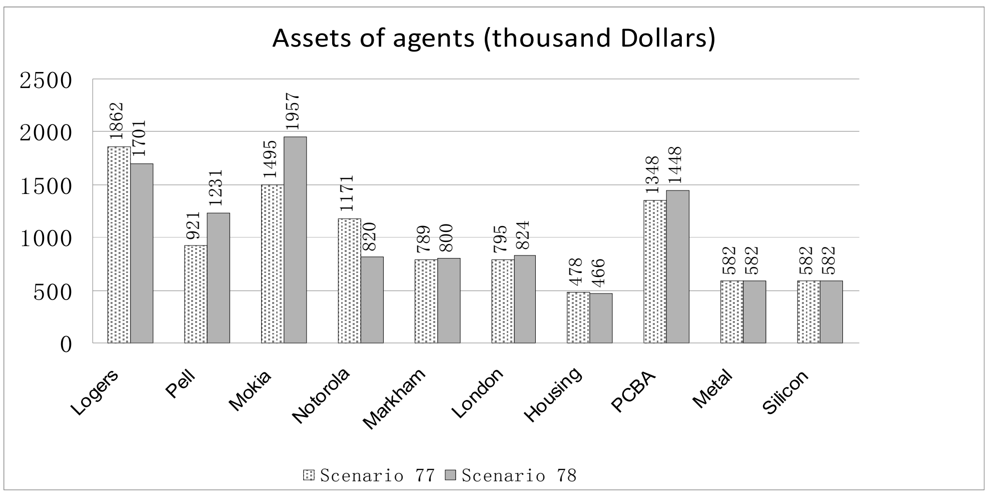
(a) Normal market demand by customers



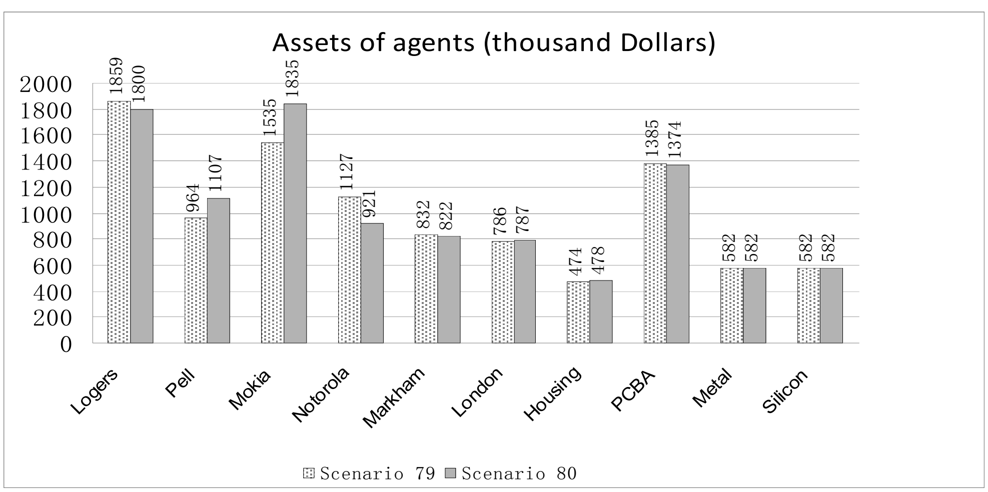
(b) High market demand by customers



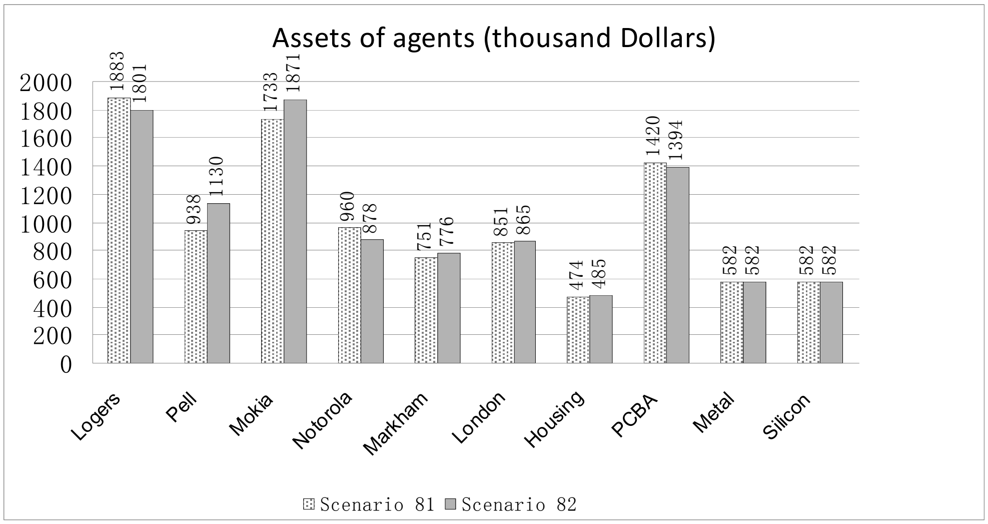
(c) Comparison of Scenario 75 with Scenario 76



(d) Comparison of Scenario 77 with Scenario 78



(e) Comparison of Scenario 79 with Scenario 80



(f) Comparison of Scenario 81 with Scenario 82

Figure 8.25 Supply chain performance when assemblers change order amount policies in normal environment

The results in Figure 8.25 show that when market demand is Normal and an assembler changes its order amount policy, there is no significant change for all agents. When market demand is High, Logers and Notorola always lose some profit, while Pell and Mokia always gain some profit. Table 8.8 displays the contract summary of each of the retailers and product holders.

Table 8.8 Contract information for Scenario 75 to Scenario 82

(a) Contracts received by Mokia from retailers

Mokia	Logers				Pell			Mokia's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 75	96	400	38400		44	400	17600	0.61
Scenario 76	103	400	41200		55	400	22000	0.67
Scenario 77	106	400	42400		58	400	23200	0.70
Scenario 78	95	400	38000		43	400	17200	0.59
Scenario 79	95	400	38000		41	400	16400	0.59
Scenario 80	100	400	40000		50	400	20000	0.64
Scenario 81	102	400	40800		45	400	18000	0.63
Scenario 82	103	400	41200		50	400	20000	0.65

(b) Contracts received by Notorola from retailers

Notorola	Logers				Pell			Notorola's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 75	61	400	24400		27	400	10800	0.39
Scenario 76	49	400	19600		29	400	11600	0.33
Scenario 77	45	400	18000		26	400	10400	0.30
Scenario 78	67	400	26800		29	400	11600	0.41
Scenario 79	66	400	26400		29	400	11600	0.41
Scenario 80	56	400	22400		28	400	11200	0.36
Scenario 81	61	400	24400		25	400	10000	0.37
Scenario 82	54	400	21600		29	400	11600	0.35

(c) Contracts offered to assemblers by Mokia

Mokia	Markham				London			Mokia's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 75	46	600	27600		47	600	28200	0.61
Scenario 76	54	600	32400		52	600	31200	0.67
Scenario 77	58	600	34800		51	600	30600	0.69
Scenario 78	50	600	30000		43	600	25800	0.59
Scenario 79	46	600	27600		45	600	27000	0.58
Scenario 80	49	600	29400		51	600	30600	0.64
Scenario 81	47	600	28200		52	600	31200	0.63
Scenario 82	49	600	29400		53	600	31800	0.65

(d) Contracts offered to assemblers by Notorola

Notorola	Markham				London			Notorola's Market Share
	Number of Contract	Units of Phone in Each Contract	Total Units		Number of Contract	Units of Phone in Each Contract	Total Units	
Scenario 75	31	600	18600		28	600	16800	0.39
Scenario 76	22	600	13200		30	600	18000	0.33
Scenario 77	23	600	13800		25	600	15000	0.31
Scenario 78	29	600	17400		36	600	21600	0.41
Scenario 79	30	600	18000		35	600	21000	0.42
Scenario 80	30	600	18000		27	600	16200	0.36
Scenario 81	24	600	14400		33	600	19800	0.37
Scenario 82	25	600	15000		31	600	18600	0.35

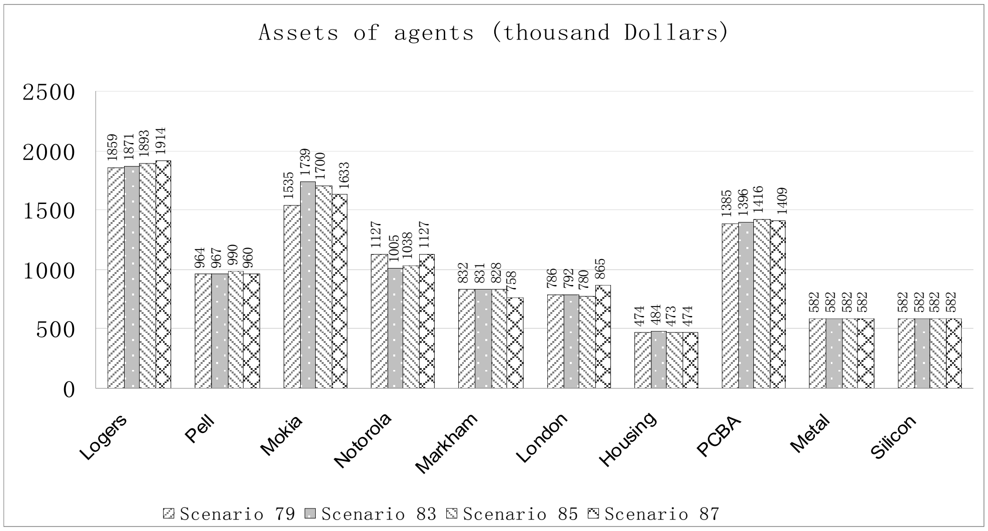
Assembler's Order Point Strategy Analysis

Figure 8.26 shows the overall performance of the supply chain when the assemblers' order point strategies change. The settings for these scenarios are:

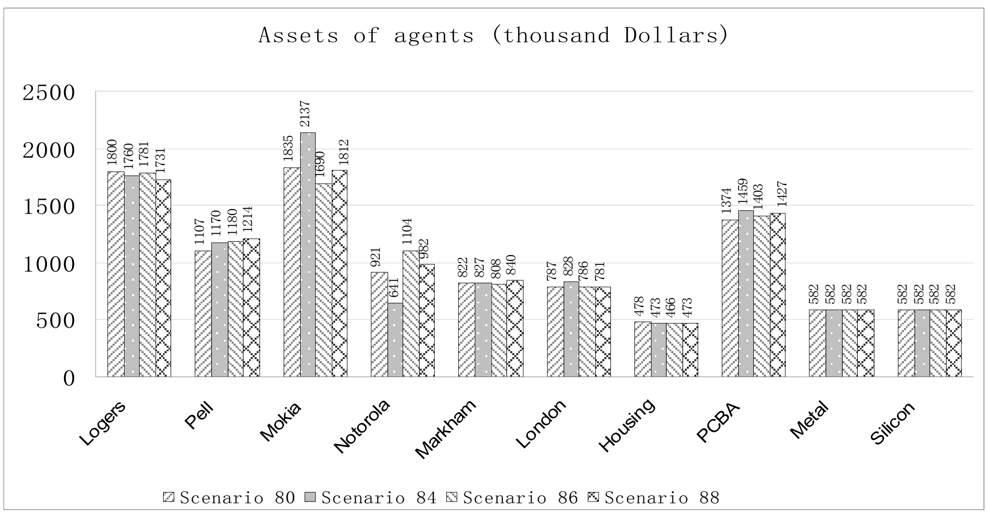
- customer agent adopts the Giving Up order policy;
- retailers adopt the Same Order Amount Policy and Conservative Order Point Strategy;
- product holder agents adopt the Same Order Amount Policy, Conservative Order Point Strategy, and Stock-to-Order strategy;
- assembler agents adopt the Same Order Amount Policy, Normal production capacity, and Make-to-Stock inventory policies;
- component agents adopt the Same Order Amount, Conservative Order Point, Normal production capacity, and Make-to-Stock inventory policies;
- material agents adopt the Normal production capacity, and Make-to-Stock inventory policies;
- Mokia has 60% market share, and Notorola has 40%.

In Scenarios 79 and 80 both Markham and London adopt the Same Order Amount Policy. In Scenarios 83 and 84 all assemblers adopt the Conservative strategy. In Scenarios 85 and 86 Markham adopts the Positive strategy while London adopts the Conservative strategy. In Scenarios 87 and 88 all assemblers adopt Positive strategy.

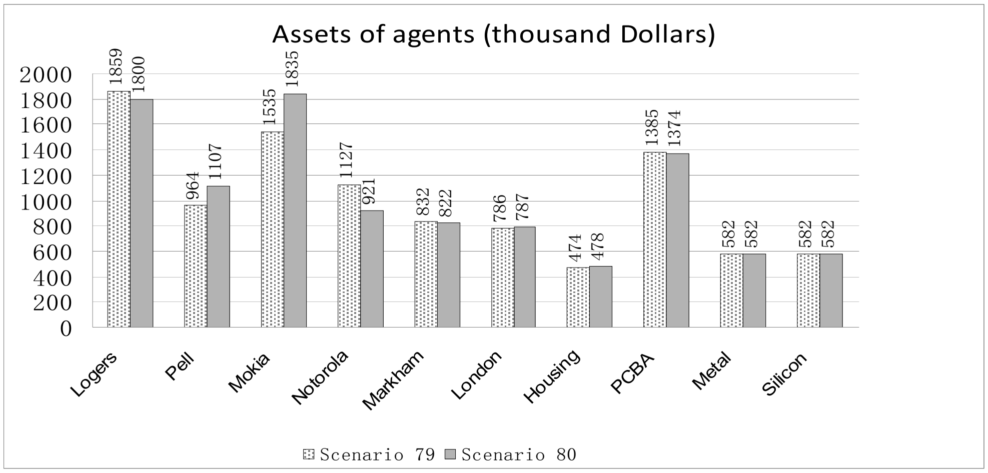
The results indicate that when market demand by customers is Normal, there is no significant change to any agent's profit when he Order Point Strategy changes. When market demand is High, Logers and Mokia usually lose some sales while Pell and Notorola gain same sales.



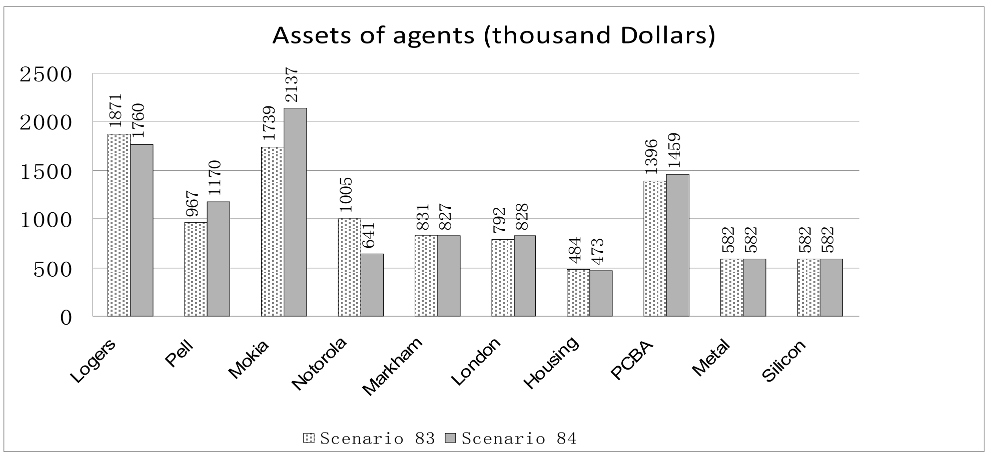
(a) Normal market demand by customers



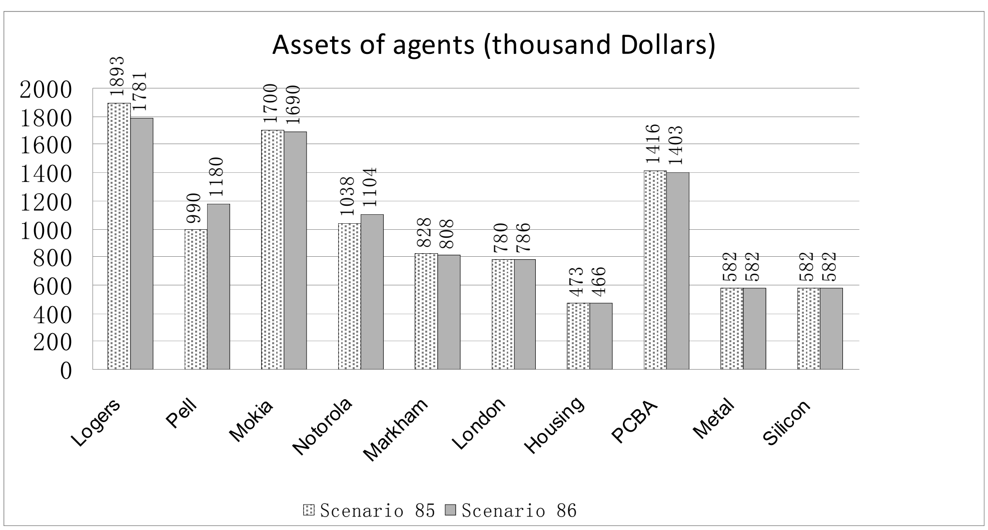
(b) High market demand by customers



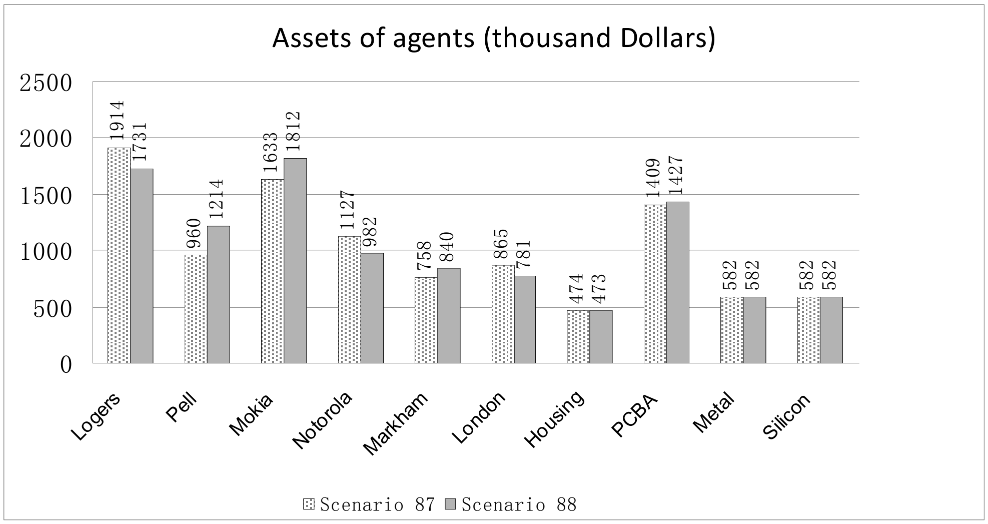
(c) Comparison of Scenario 79 with Scenario 80



(d) Comparison of Scenario 83 with Scenario 84



(e) Comparison of Scenario 85 with Scenario 86



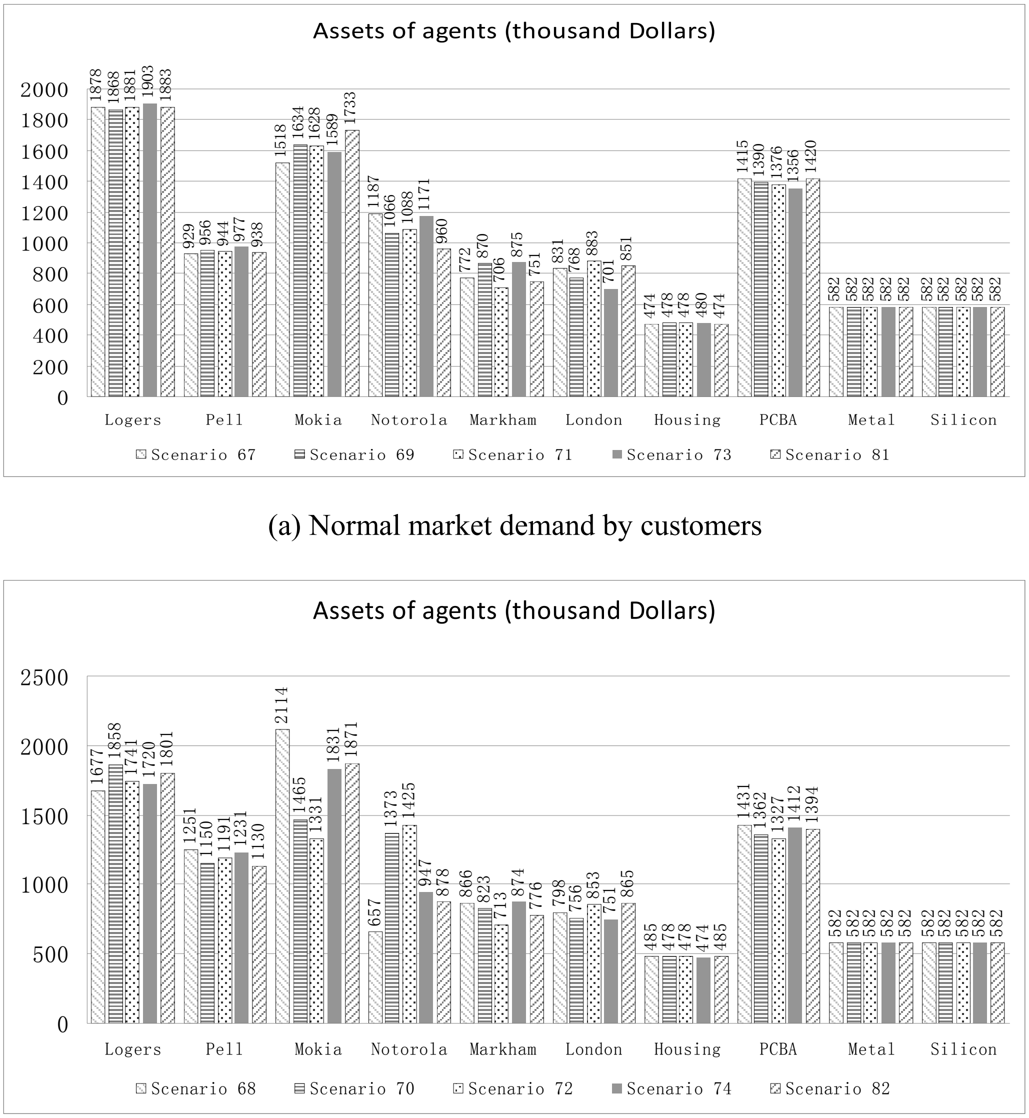
(f) Comparison of Scenario 87 with Scenario 88

Figure 8.26 Supply chain performance when assemblers change order point strategies in normal environment

Figure 8.26 shows that in Normal market demand the results are similar when assemblers change their Order Point Strategy as when they change their Order Amount policy (Figure 8.25); there is no significant difference for all agents. When market demand is High, Logers and Notorola usually lose some profit, while Pell and Mokia gain some profit.

Assembler's Production Capacity Analysis

Figure 8.27 shows the overall performance when assemblers adopt different production capacities. The settings for this group of scenarios are normal except for assemblers' production capacities. In Scenarios 67 and 68 Markham has Normal production capacity while London has Maximum Production Capacity (300 units per day). In Scenarios 69 and 70 Markham has Maximum Production Capacity while London has Normal production capacity. In Scenarios 71 and 72 Markham has Minimum production capacity (75 units per day) while London has Normal production capacity. In Scenarios 73 and 74 Markham has Normal production capacity while London has Minimum production capacity. In Scenarios 81 and 82 all assemblers have normal production capacity (every assembler produces 150 units per day).



(a) Normal market demand by customers

(b) High market demand by customers

Figure 8.27 Supply chain performance when assemblers change production capacities in normal environment

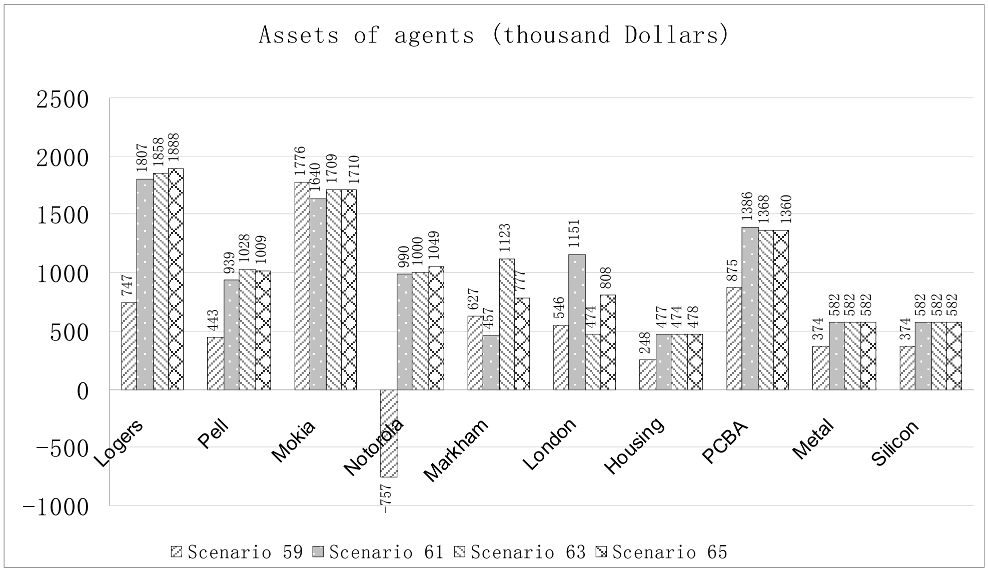
Figure 8.27 shows that normally there are no significant changes for each agent's assets when market demand by customers is Normal. When market demand by customers is High, changing assemblers' production capacity will normally result in Logers losing some sales and Pell gaining more sales. The profits of the Product holders' depend on the combination of the assemblers' production capacities. Although an assembler has Maximum Production Capacity, the performance of the whole chain will not change as production is limited by component and material agents.

Assembler's Inventory Strategy Analysis

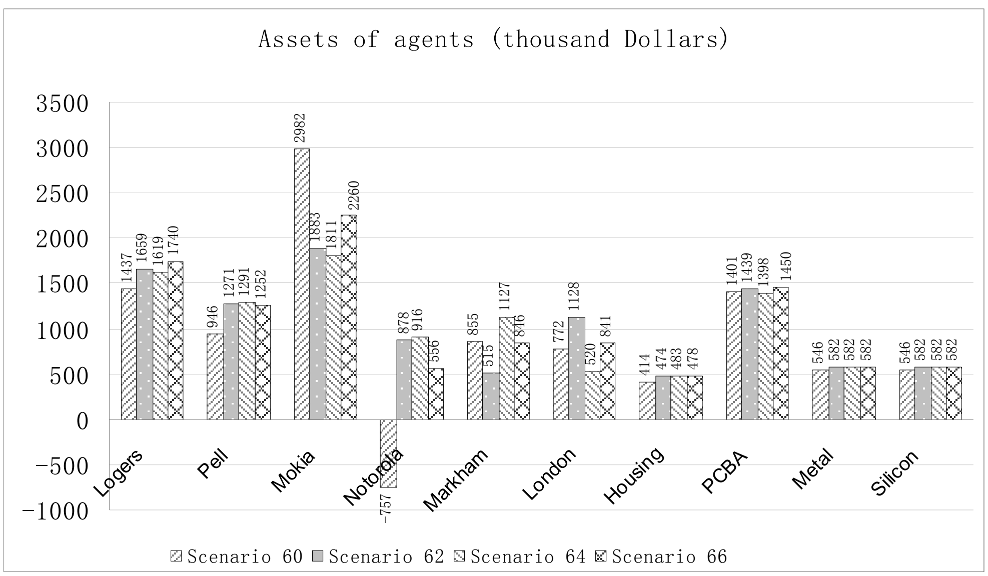
Figure 8.28 displays the overall performance of the whole supply chain under different combinations of assemblers' inventory strategies. The settings for this group of scenarios are normal. In Scenarios 59 and 60 all assemblers adopt the Make-to-Order strategy. In Scenarios 61 and 62 Markham adopts the Make-to-Order strategy while London adopts the Make-to-Stock strategy. In Scenarios 63 and 64 Markham adopts the Make-to-Stock while London adopts the Make-to-Order strategies. In Scenarios 65 and 66 all assemblers adopt the Make-to-Stock strategy.

Figure 8.28 indicates that when customer demand is Normal and all assemblers adopt the Make-to-Order strategy, the whole supply chain performance is very poor except for Mokia. Retailers have only 40% profits and Notorola has negative assets (bankruptcy). The component agents' profits are reduced approximately 45% and material agents' profits are reduced 35%. The assembler agents' profits are also lower than average. In other situations, the profits for all agents except assemblers will be almost the same. In situations where assemblers adopt differing inventory strategies, the assembler who adopts the Make-to-Stock strategy will get more profit. In scenarios with High market demand by customers, the simulation results are similar to scenarios with Normal market demand. If all of assemblers adopt the Make-to-Order strategy, retailers' assets will be reduced approximately 15%, component and material agents' assets will decrease approximately 5%, Notorola will be bankrupt, and Mokia will gain 70% more assets. This results because of the long lead time of assemblers' production. Although assemblers often have no work to do Notorola has a smaller market share and has difficulty getting contracts from the assemblers. When assemblers adopt differing inventory strategies, the assembler who adopts the

Make-to-Stock strategy will gain more profit while the assembler who adopts the Make-to-Order strategy will lose some profit. Other agents will not be affected.



(a) Normal market demand by customers



(b) High market demand by customers

Figure 8.28 Supply chain performance when assemblers change inventory strategies in normal environment

8.6 Component Agent Analysis

Component agent factors that influence the performance of the whole supply chain are similar with assembler factors. They may include production quality, production capacity, production cost, inventory strategy, product Order Amount Policy, Order Point Strategy, etc. In this system, production capacity, inventory strategy, Order Amount Policy, and Order Point Strategy will be considered.

Inventory strategy has three possible values:

0 – Make-to-Order;

1 – Make-to-Stock;

2 – Changing inventory policy iteratively.

Order Amount Policy has two options:

0 – In Proportion;

1 – Same.

Order Point Strategy has two options:

0 – Conservative;

1 – Positive.

Production Capacity has three possible values:

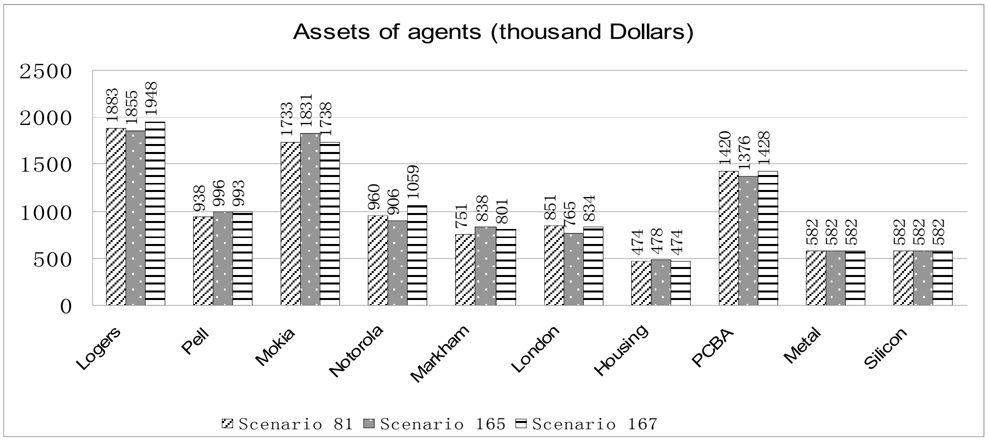
0 – Normal: 200 units per day;

1 – Maximum: two times Normal capacity – 400 units per day;

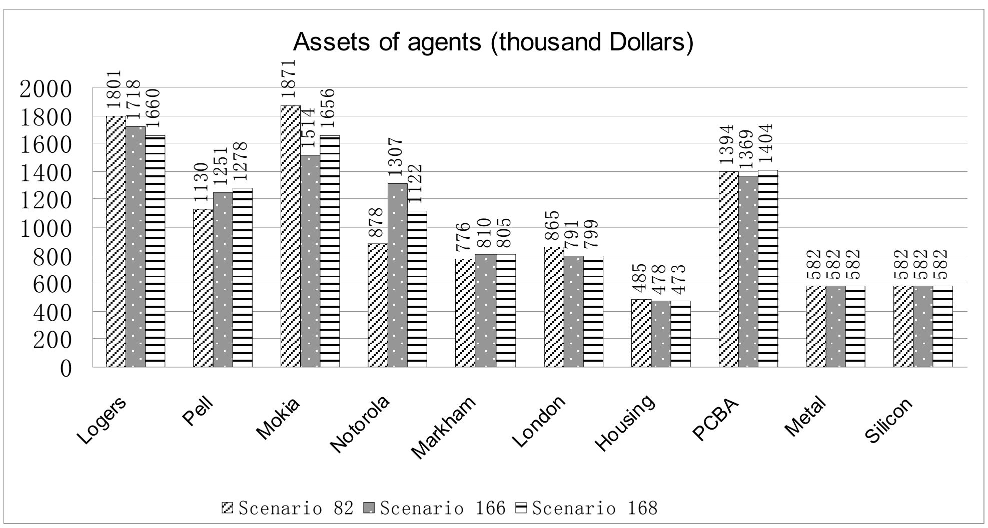
2 – Minimum: 100 units per day.

Component Agent's Order Amount Policy Analysis

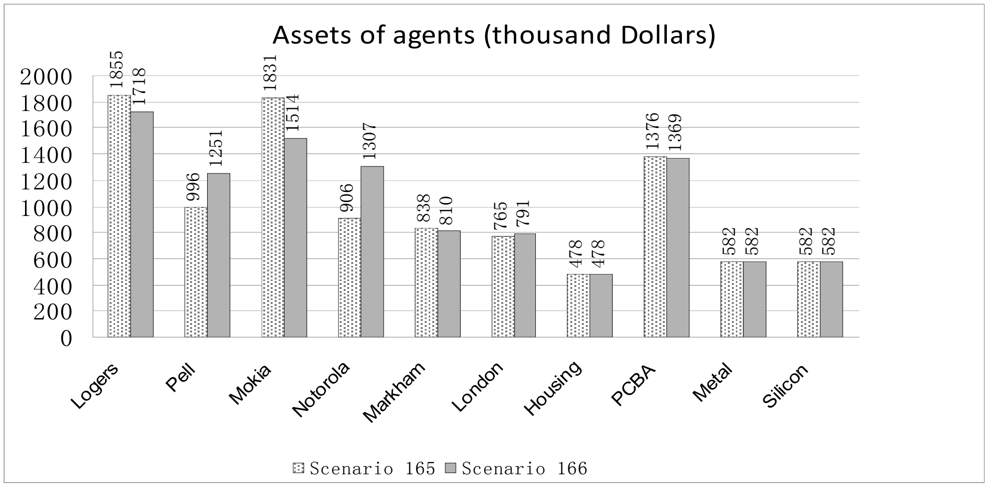
Figure 8.29 shows the overall performance of the supply chain when component agents change their order amount policies in normal environment. In Scenarios 81 and 82 all of component agents adopt the Same Order Amount Policy. In Scenarios 165 and 166 all component agents adopt the In Proportion policy. In Scenarios 167 and 168 Housing agent adopts the In Proportion policy while PCBA adopts the Same Order Amount Policy. The results indicate that there are no significant differences for any agent's asset when component agents change their order amount policies and market demand by customers is Normal. If market demand by customers is High and both component agents adopt the Same Order Amount Policy, Logers and Notorola always lose some profit, while Pell and Mokia will gain some profit. When other order amount policy combinations are adopted, Logers and Mokia always lose some profit, while Pell and Notorola will gain some profit.



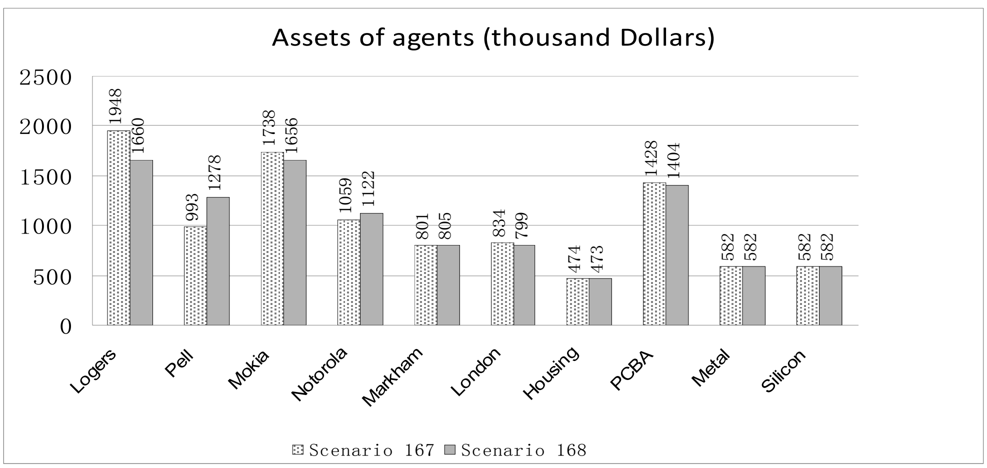
(a) Normal market demand by customers



(b) High market demand by customers



(c) Comparison of Scenario 165 with Scenario 166



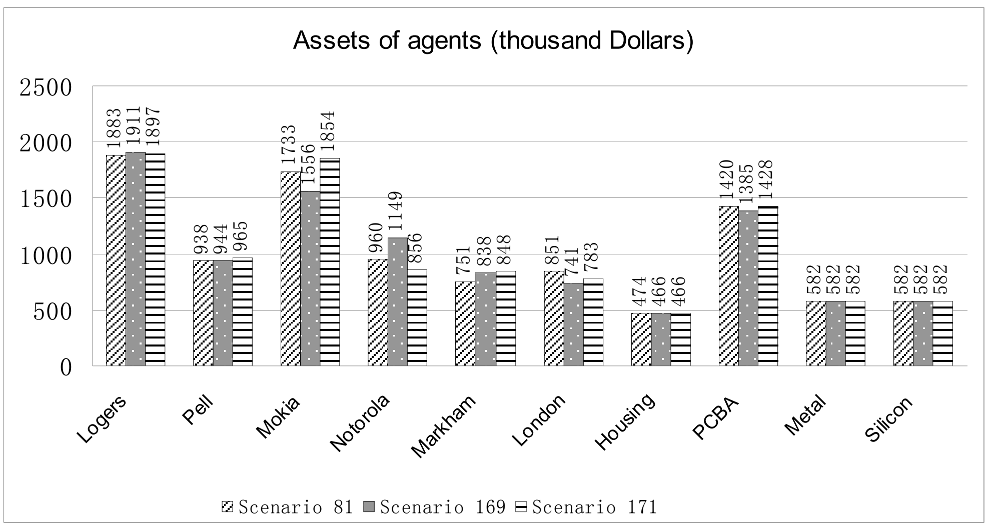
(d) Comparison of Scenario 167 with Scenario 168

Figure 8.29 Supply chain performance when component agents change order amount policies in normal environment

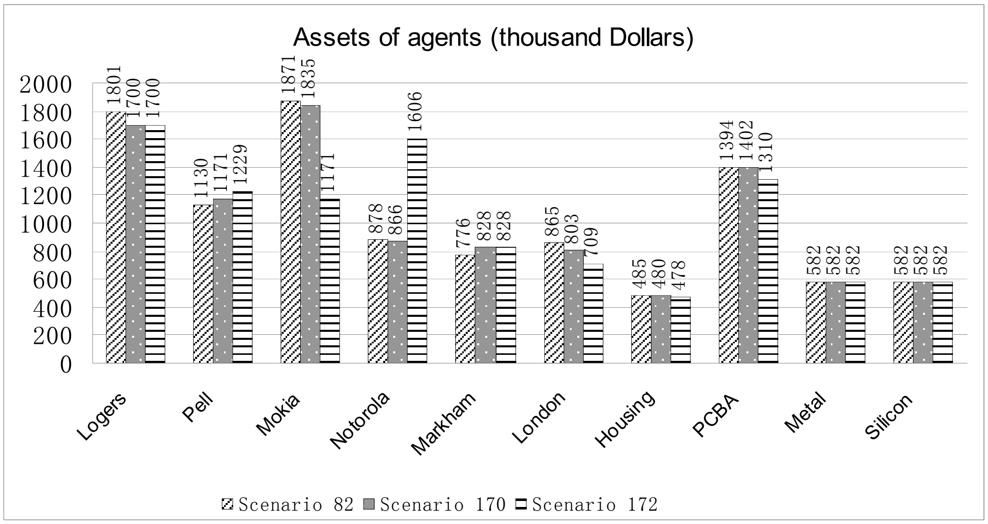
Component Agent's Order Point Strategy Analysis

Figure 8.30 shows the overall performance of the supply chain when component agents change their order point strategies in normal environment. In Scenarios 81 and 82 all component agents adopt the Conservative Order Point Strategy. In Scenarios 169 and 170 all component agents adopt the Positive strategy. In Scenarios 171 and 172 Housing agent adopts the Positive strategy while the PCBA agent adopts the Conservative Order Point strategy. The results indicate that when market demand is

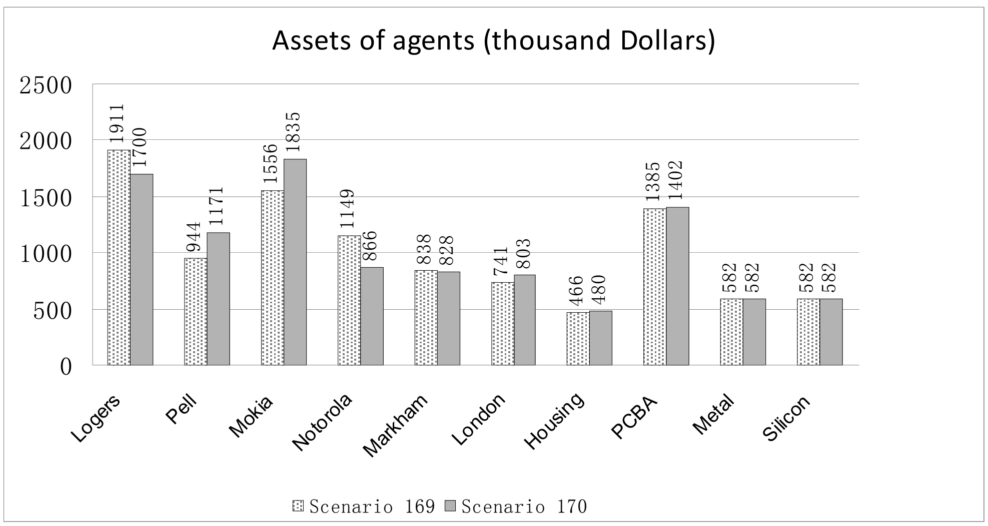
Normal and if both component agents adopt the Positive order amount strategy, Mokia will lose some sales while Notorola will gain more sales. When market demand is High and both component agents adopt the Conservative strategy, Logers and Notorola will lose some sales (approximately 5%), while Pell and Mokia will gain more sales (approximately 10%). If both component agents adopt the Positive strategy, Logers will lose 10% of sales, Pell will gain 25% more sales, Mokia will gain 18% more assets, and Notorola will lose 25% assets. When component agents adopt different order point strategies, Logers will lose 10% sales, Pell will gain 25% more sales, Mokia will lose 35% assets, and Notorola will gain 85% more assets.



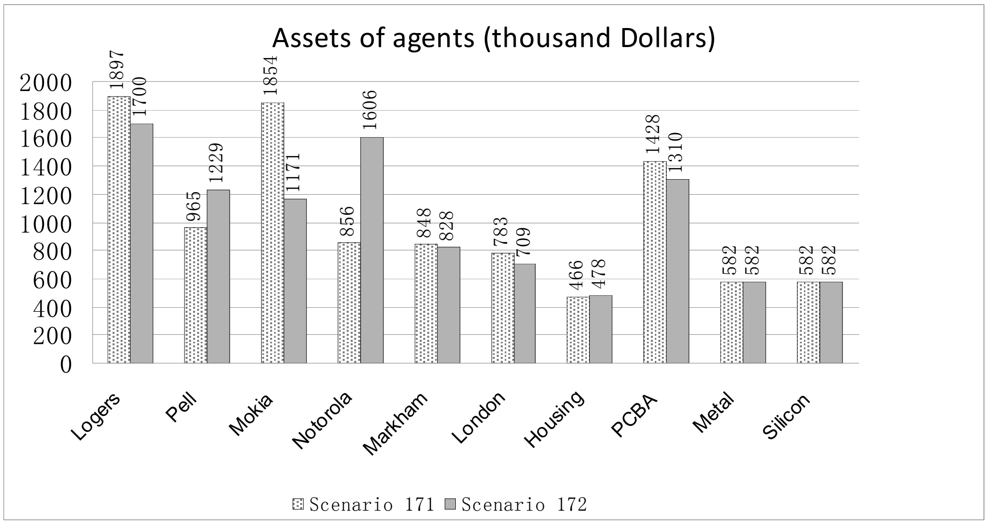
(a) Normal market demand by customers



(b) High market demand by customers



(c) Comparison of Scenario 169 with Scenario 170

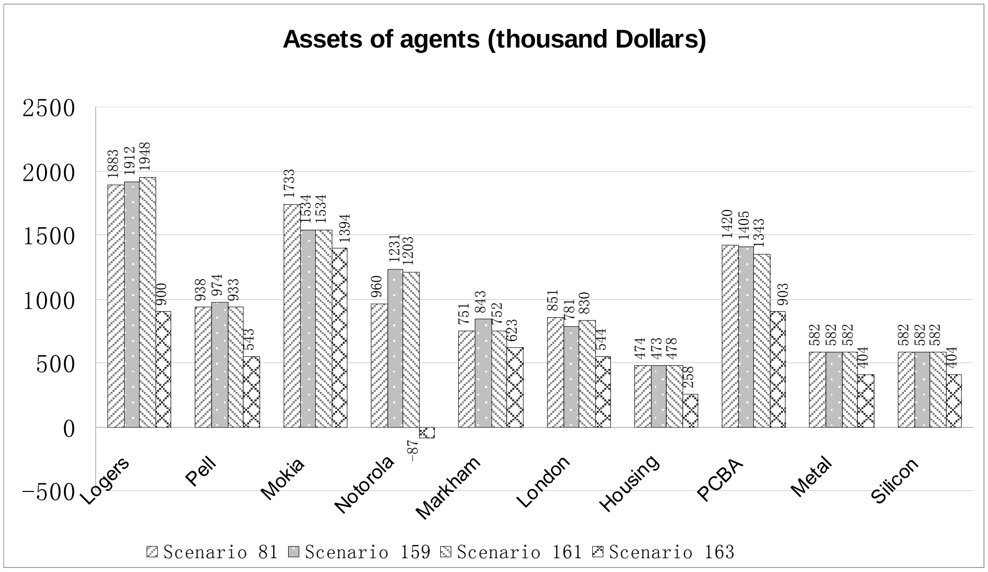


(d) Comparison of Scenario 171 with Scenario 172

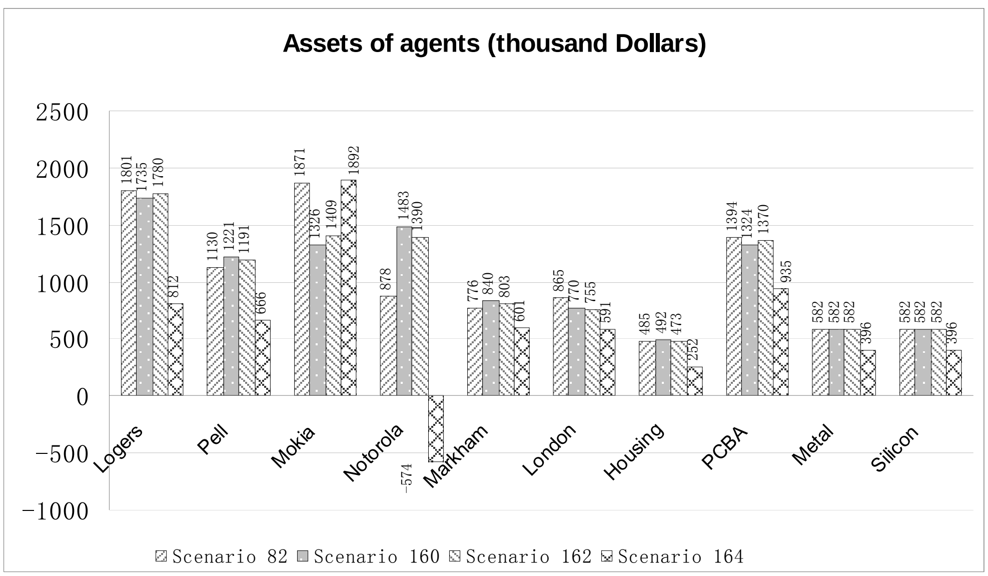
Figure 8.30 Supply chain performance when component agents change order point strategies in normal environment

Component Agent's Production Capacity Analysis

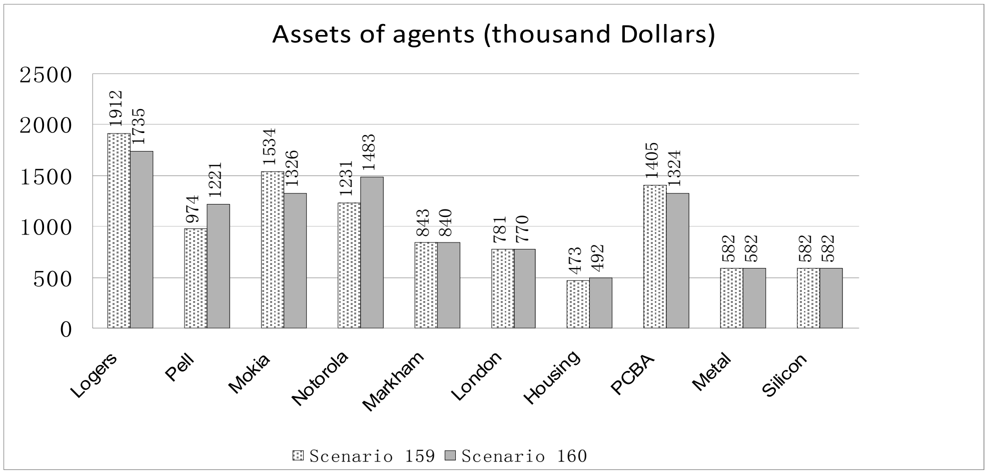
Figure 8.31 shows the overall performance of the supply chain when component agents change their production capacities in normal environment. In Scenarios 81 and 82 all component agents have Normal Production Capacities. In Scenarios 159 and 160 all component agents have Maximum Production Capacity. In Scenarios 161 and 162 Housing agent has Maximum Capacity while the PCBA agent has Normal Production Capacity; In Scenarios 163 and 164 the Housing agent has Minimum Production Capacity while the PCBA agent has Normal Production Capacity. The results indicate that provided no component agent' production capacity is limited, there are no significant differences for any agent's assets. When at least one component agent's production capacity is Minimum, all agents' profits are reduced, except the Mokia agent. The Notorola agent will end up in bankruptcy. The results when customer demand is High are similar to Normal customer demand.



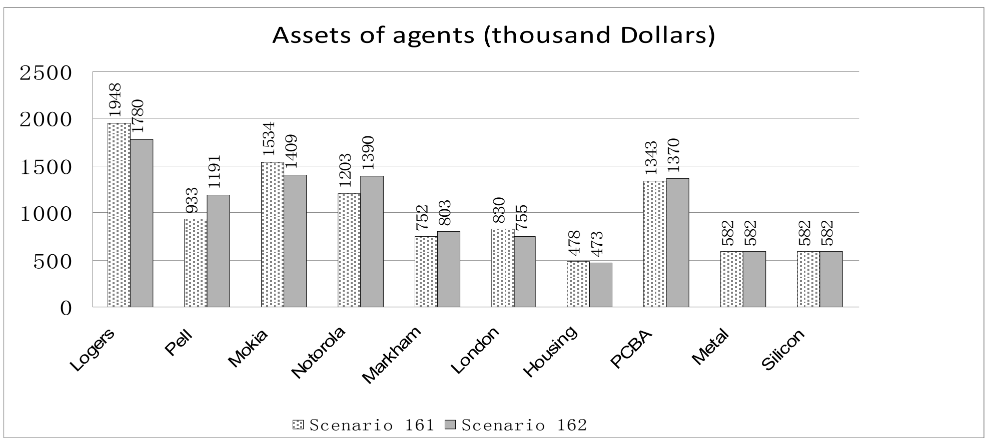
(a) Normal market demand by customers



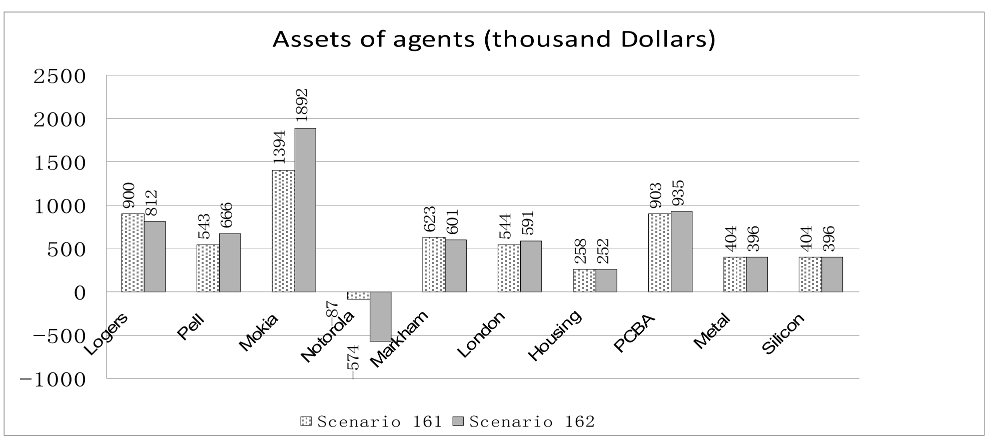
(b) High market demand by customers



(c) Comparison of Scenario 159 with Scenario 160



(d) Comparison of Scenario 161 with Scenario 162

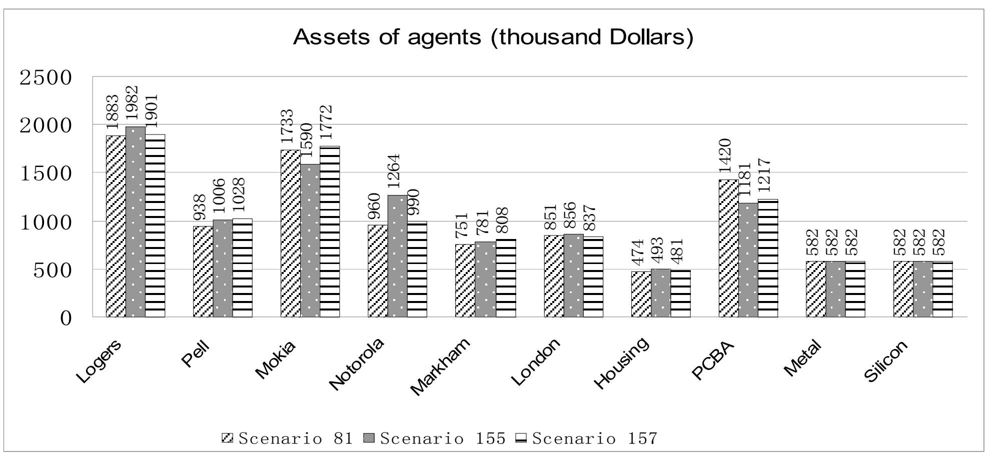


(e) Comparison of Scenario 163 with Scenario 164

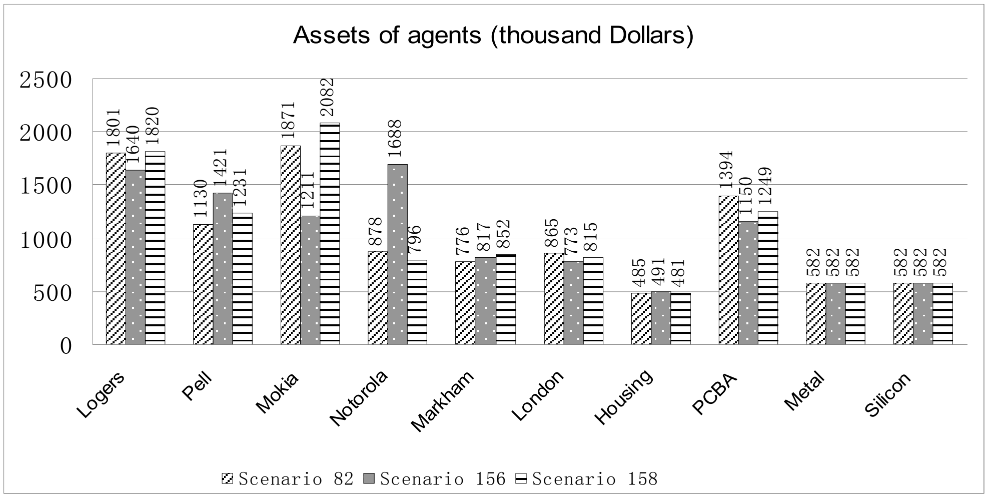
Figure 8.31 Supply chain performance when component agents change production capacities in normal environment

Component Agent's Inventory Strategy Analysis

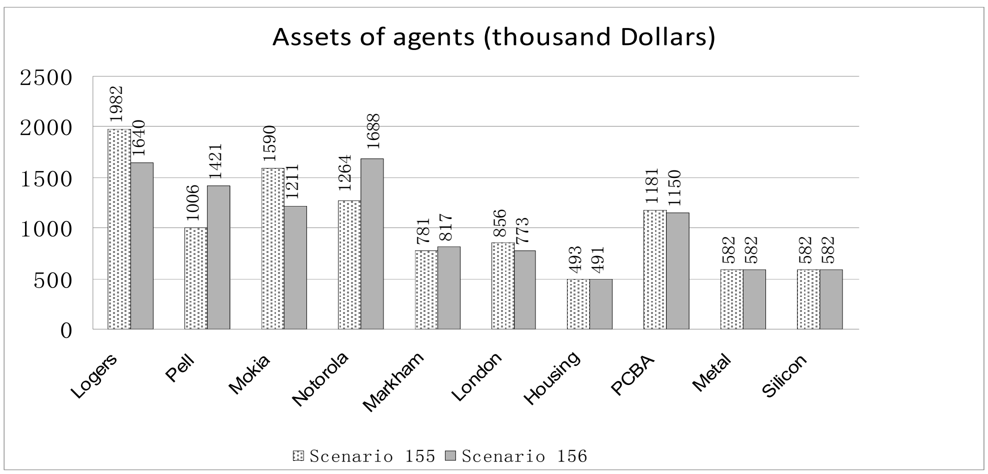
Figure 8.32 shows the overall performance of the supply chain when component agents change their inventory strategies in normal environment. In Scenarios 81 and 82 all component agents adopt the Make-to-Stock strategy. In Scenarios 155 and 156 all component agents adopt the Make-to-Order strategy. In Scenarios 157 and 158 Housing agent adopts the Make-to-Stock strategy while the PCBA agent adopts the Make-to-Order strategy. The results indicate that there are no significant differences for any agent's assets when component agents change their inventory strategies and market demand by customers is Normal. If market demand by customers is High, Logers always loses some sales and Pell always gain more sales. If both of component



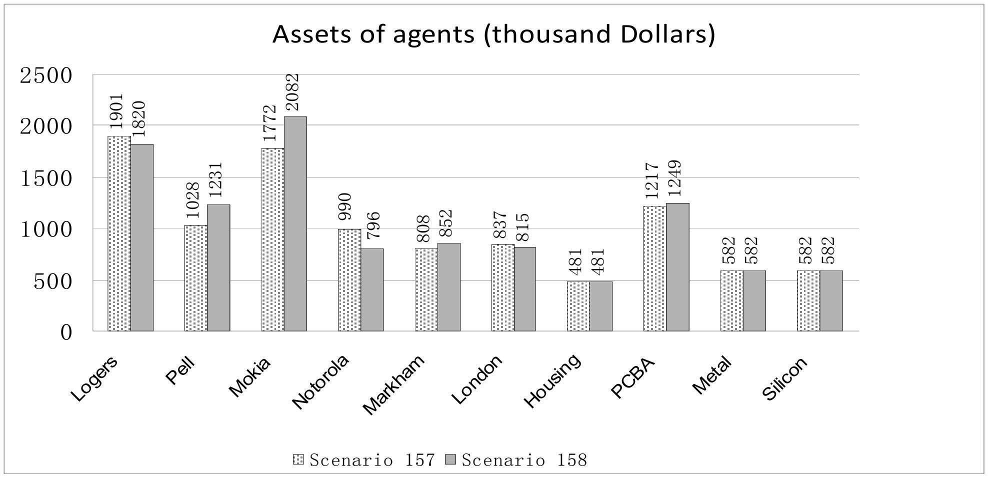
(a) Normal market demand by customers



(b) High market demand by customers



(c) Comparison of Scenario 155 with Scenario



(d) Comparison of Scenario 157 with Scenario 158

Figure 8.32 Supply chain performance when components change inventory strategies in normal environment

agents adopt the Make-to-Order strategy, Mokia will lose more profit while Notorola will gain more benefit. If component agents adopt differing inventory strategies, Mokia will gain some profit while Notorola will lose some profit.

8.7 Raw Material Agent Analysis

Raw material agent factors that influence the performance of the whole supply chain include production quality, production capacity, production cost, inventory strategy, etc. In this system, production capacity and inventory strategy will be considered.

Inventory strategy has three possible values:

0 – Make-to-Order;

1 – Make-to-Stock;

2 – Changing inventory policy iteratively which the starting policy will be determined by the system randomly.

Production Capacity has three possible values:

0 – Normal: 300 units per day;

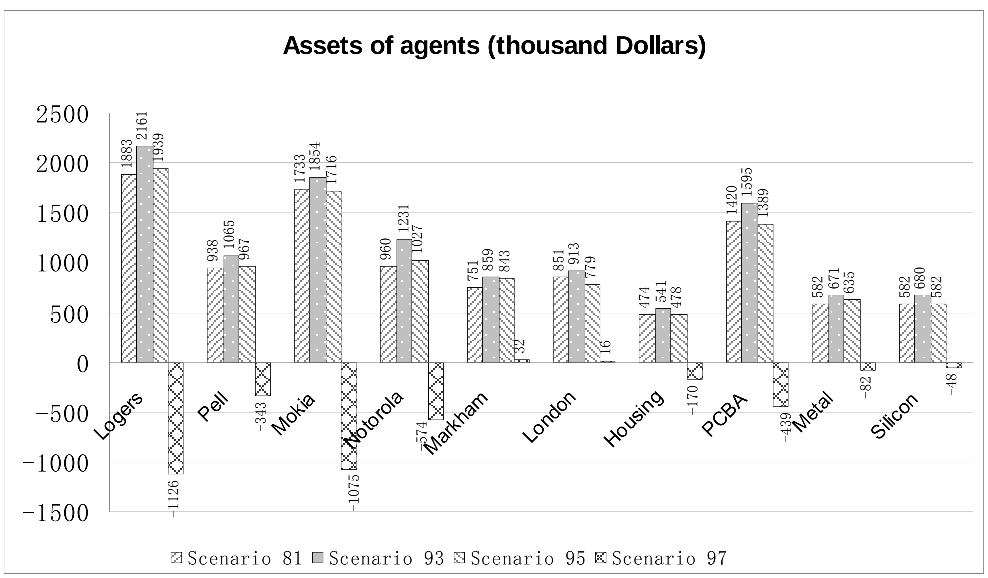
1 – Maximum: two times Normal capacity – 600 units per day; and

2 – Minimum: 150 units per day.

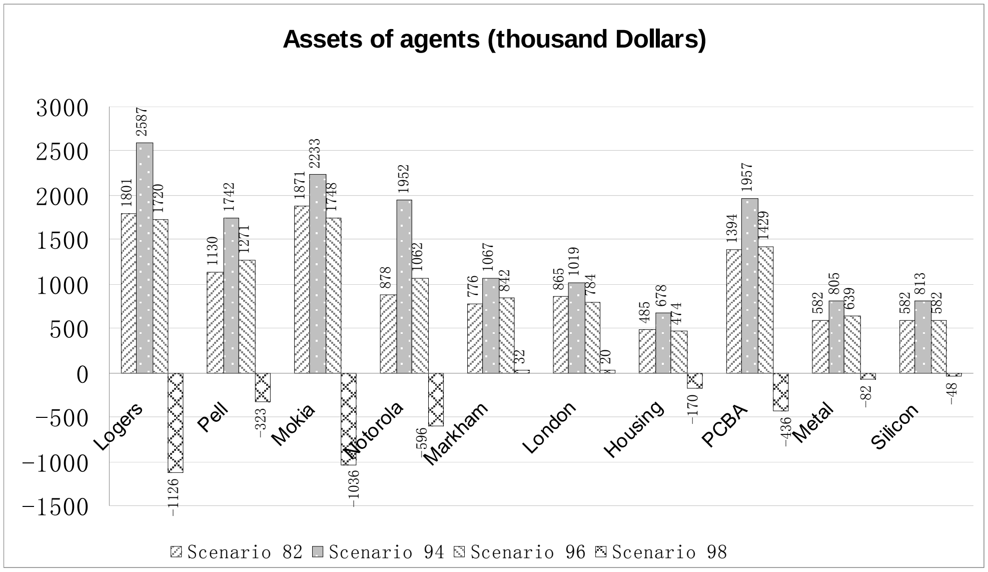
Raw Material Agent's Production Capacity Analysis

Figure 8.33 shows the supply chain overall performance when raw material agents changes their production capacities in normal environment. In Scenarios 81 and 82, all raw material agents have Normal Production Capacities. In Scenarios 93 and 94, all raw material agents have Maximum Production Capacity. In Scenarios 95 and 96, the Metal agent has Maximum Capacity while the Silicon agent has Normal Production Capacity. In Scenarios 97 and 98, the Metal agent has Minimum Production Capacity while the Silicon agent has Normal Production Capacity.

The results indicate that when market demand by customers is Normal and at least one raw material agent has Normal Production Capacity and no agent has Minimum capacity, there are no changes to an agent's final assets. If all raw material agents have Maximum Production Capacities, all agents will gain a little more profit. If at least one material agent has Minimum Production Capacity, all agents will end up in bankruptcy. The performance of the whole supply chain has similar results when market demand by customers is High.



(a) Normal market demand by customers

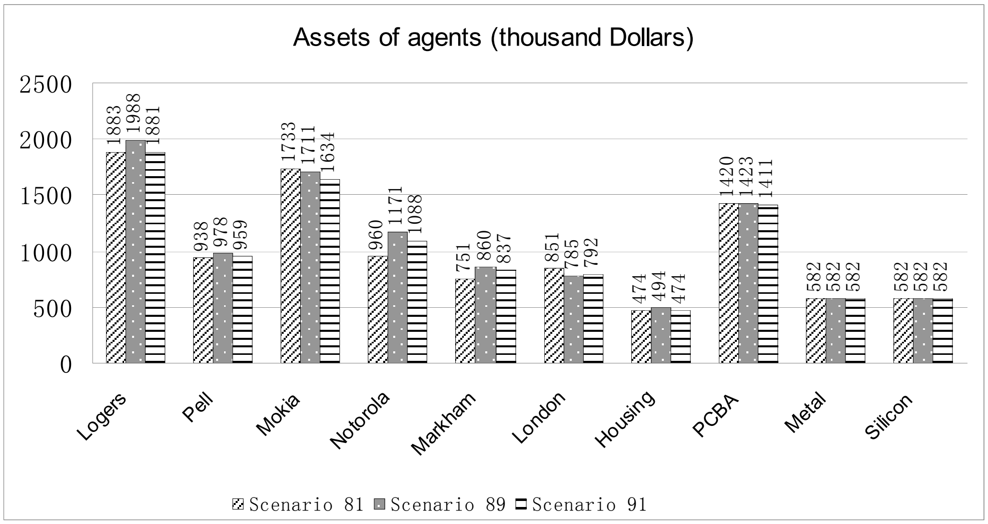


(b) High market demand by customers

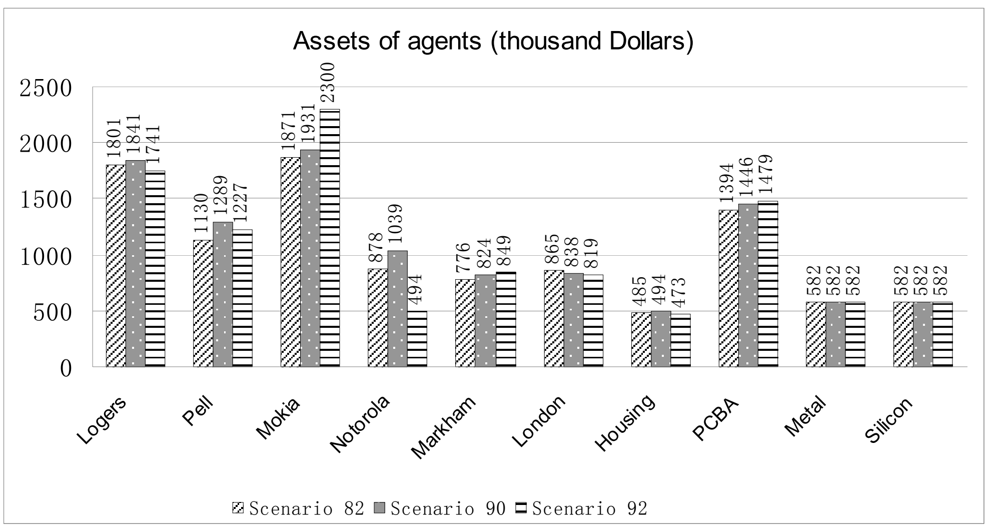
Figure 8.33 Supply chain performance when raw material agents change production capacities in normal environment

Raw Material Agent's Inventory Strategy Analysis

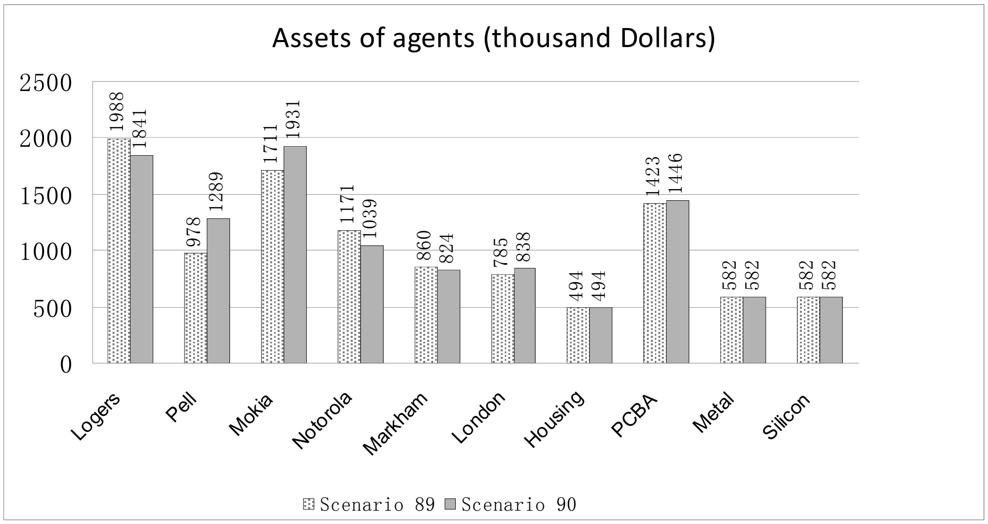
Figure 8.34 shows the overall performance of the supply chain when component agents change their inventory strategies in the normal environment. In Scenarios 81 and 82, all raw material agents adopt the Make-to-Stock strategy. In Scenarios 89 and 90, all raw material agents adopt the Make-to-Order strategy. In Scenarios 91 and 92, the Metal agent adopts the Make-to-Order strategy while the Silicon agent adopts the Make-to-Stock strategy. The results indicate that there are no significant differences for any agents' assets when raw material agents change their inventory strategies and market demand by customers is Normal. When market demand is High, Pell will always gain more benefit. If material agents adopt differing inventory strategies, Mokia will gain more market share while Notorola will lose some sales.



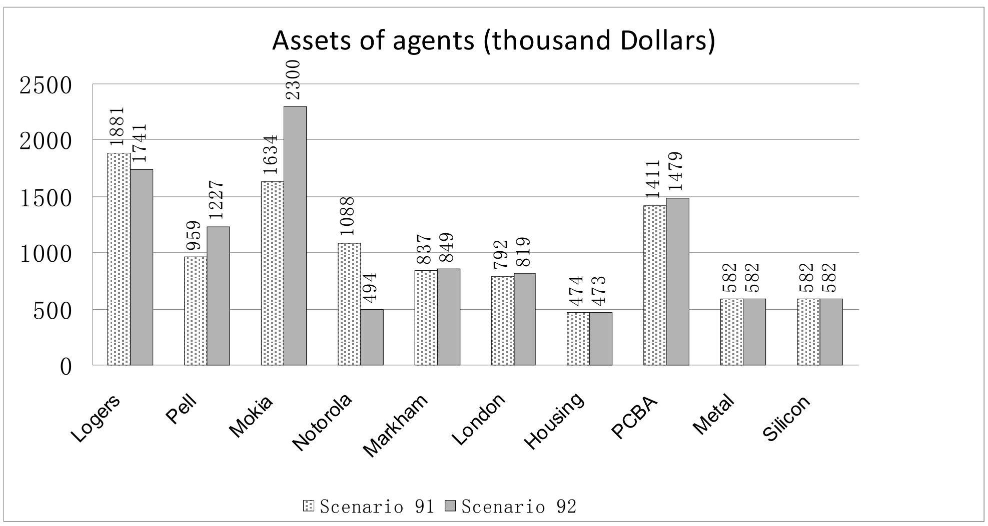
(a) Normal market memand by customers



(b) High market demand by customers



(c) Comparison of Scenario 89 with Scenario 90



(d) Comparison of Scenario 91 with Scenario 92

Figure 8.34 Supply chain performance when raw material agents change inventory strategies in normal environment

8.8 Discussions

The results of this mobile phone simulation system have shown some facts and revealed some phenomena. If market demand by customers is Low, all agents will get little profits. If market demand by customers is High, all agents will still get little benefit unless at least one of the manufacturing agents can increase its production capacity. Usually accumulating unfulfilled customer's orders is good for the entire supply chain except when at least one manufacturing agent has Minimum production capacity because then all agents will not benefit. A retailer agent may gain more profit if it collects unfulfilled customer orders. It is suitable for a retailer to adopt the Positive Order Point Strategy (which means increasing the inventory level) if the resource is scarce. If market demand by customers is High while one or more manufacturing agents have limited production, a retailer may adopt the Same Order Amount Policy in order to get the most benefit. If all manufacturing agents have maximum production capacities, the In Proportion Order Amount Policy is the first choice for retailers.

For a product holder agent, when market demand by customers is High, keeping Maximum inventory (which means adopting the Stock-to-Order strategy) is a wise decision. If the market demand by customers is Low, the Order-to-Order strategy should be adopted to reduce inventory cost. If one or more manufacturing agents have limited production capacity, a product holder agent may adopt the Same Order Amount Policy and the Positive Order Point Strategy. If component agents have limited supplies, an assembler should adopt the Make-to-Stock strategy, Same Order Amount Policy and Positive Order Point Strategy when market demand by customers is Normal or High. If a raw material agent has a production capacity limitation and market demand by customers is Normal or High, assembler and component agents should adopt the Make-to-Stock strategy, Same Order Amount Policy and Positive Order Point Strategy. Product holder agents should adopt the Stock-to-Order strategy, Same Order Amount Policy and Positive Order Point Strategy.

Chapter 9 Conclusions and Future Work

9.1 Conclusions

Each entity in a supply chain has its own characteristics and business strategies. A successful supply chain model must include most of the activities among all partners to examine many business strategies. The intelligent agent-based supply chain simulation system designed here has considered not only many business activities, but has also included knowledge management issues. Although the simulation model only has six layers, it can be extended to more layers with no difficulty, as necessary. Information and message exchanging is very fast (real time) and low cost because it relies on new communication media – the Internet. In this system, new analysis and application systems, such as SAP BI/BO/FI/CO/MM/SD, PeopleSoft HCM/HRMS/ERP/CRM, and Microsoft Dynamics ERP, can be integrated. A knowledge-based decision support engine will provide the system's intellectual ability.

The prototype mobile phone simulation system designed and implemented in this research has partially achieved the functions and objectives of an intelligent agent-based supply chain simulation system. Because of time limitation, some functions have not been implemented in the system. Even so, the simulation results have revealed many valuable operational strategies. For example, if market demand by customers is High, retailers should share this information with all of the supply chain partners. Therefore, the manufacturing companies (assemblers, semi-product manufactures, component/element manufactures, and raw material providers) can increase their production capacities, and all of supply chain partners will gain more profit. For inventory strategy, if the market demand is very low, Order-to-Order strategy is the best choice for product holders and retailers, and Make-to-Order strategy is the first option for the manufacturing companies.

The main contributions of this dissertation include:

1. A supply chain focused enterprise architecture model is presented. The model considers all aspects of an enterprise, from external to internal factors, from soft to hard factors, from uncontrollable to manageable factors, and from equipment to knowledge factors. The architecture divides an enterprise into four elements: enterprise organization, business processing activities, workplace and properties, and management and technologies. The strengths and weaknesses of an enterprise can be identified by analyzing each of these elements. The proposed enterprise architecture stresses knowledge management as an important factor in the development of an enterprise.
2. An intelligent agent-based supply chain simulation system model is designed. The simulation system is based on the supply chain focused enterprise architecture model. In this system, an agent has five components: interface; task distribution; business processing activities, knowledge management and decision support; and information storage. The supply chain simulation system can be used to simulate and evaluate strategies for business processing activities and management.
3. A generic prototype mobile phone simulation system is designed, developed, implemented, and validated. The system has six layers: one customer agent, two retailer agents, two product holder agents, two assembler agents, two component agents, and two raw material agents. The system can be used to test 32 factors that may affect the performance of the entire supply chain including: customer demand, customer behavior, retailer's inventory strategy, product holder's inventory strategy, assembler's production strategy and inventory strategy. Many techniques, methodologies and human behaviors in supply chain management can be studied using this simulation system. Comparing with the Beer game and TAC-SCM simulation systems in the literature, the system developed in this dissertation has six layers while the Beer game has four layers (retailer, whole seller, distributor, and factory) and the TAC-SCM system has three (consumer, assembler, and component).

4. A large number of scenarios were tested in different environments, and each factor's influence on the entire supply chain was analyzed. Through this system, a user can determine the best strategies and policies for an agent in a given situation.
5. The generic supply chain simulation system developed can be used in a number of ways, including: as an analysis tool for an entity in a supply chain from the entity's perspective; as a tool for studying supply chain coordination and integration from the perspective of an entire supply chain, or portion of it; as a tool to design supply chains by answering "what-if" questions.

9.2 Future Work

As mentioned in the previous section, the designed and implemented mobile phone simulation system has not accomplished some objectives and functions. One of the future work is to fulfill those functions. Enhancement could include using Microsoft BizTalk server as a way to implement business communication and negotiation; integrating a demand forecasting module from other ERP systems (such as SAP and PeopleSoft); and developing a production scheduling and planning module (instead of using the First-Due-First production policy). Accomplishing those functions will enhance the proposed intelligent agent-based supply chain simulation system.

Appendix A

Simulation Scenarios Tested in Chapter 8

DC	CB	OA	OP	SS	PS	PC
1-Normal	0- Giving Up	0-In Proportion	0-Conservative	0-OTO	0-MTO	0-Normal
2-High	1- Accumulating	1-Same	1-Positive	1-STO	1-MTS	1-Maximum
3-Low				2-Change Iteratively	2-Change Iteratively	2-Minimum

Scenario	Customer		Logers		Pell		Mokia			Notorola			Markham				London				Housing				PCBA				Metal		Silicon	
	DC	CB	OA	OP	OA	OP	OA	OP	SS	OA	OP	SS	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	PS	PC
Scenarios 1 to 98 Logers has 70% market share, Mokia has 60% market share																																
1	1	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
2	2	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
3	3	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
4	1	0	1	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
5	2	0	1	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
6	3	0	1	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
7	1	0	0	0	1	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
8	2	0	0	0	1	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
9	3	0	0	0	1	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0

Scenario	Customer		Logers		Pell		Mokia			Notorola			Markham				London				Housing				PCBA				Metal		Silicon	
	DC	CB	OA	OP	OA	OP	OA	OP	SS	OA	OP	SS	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	PS	PC
10	1	0	1	0	1	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
11	2	0	1	0	1	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
12	3	0	1	0	1	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
13	1	1	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
14	2	1	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
15	3	1	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
16	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
17	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
18	3	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
19	1	0	1	0	1	0	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
20	2	0	1	0	1	0	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
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22	1	1	1	1	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
23	2	1	1	1	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
24	3	1	1	1	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
25	1	0	0	0	0	0	1	0	1	1	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
26	2	0	0	0	0	0	1	0	1	1	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
27	3	0	0	0	0	0	1	0	1	1	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
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30	2	0	1	1	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
31	1	0	1	0	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
32	2	0	1	0	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Scenario	Customer		Logers		Pell		Mokia			Notorola			Markham				London				Housing				PCBA				Metal		Silicon	
	DC	CB	OA	OP	OA	OP	OA	OP	SS	OA	OP	SS	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	PS	PC
33	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
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35	1	0	1	1	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
36	2	0	1	1	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
37	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
38	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
39	1	0	1	0	1	0	1	1	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
40	2	0	1	0	1	0	1	1	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
41	1	0	1	0	1	0	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
42	2	0	1	0	1	0	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
43	1	0	1	0	1	0	0	1	1	0	1	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
44	2	0	1	0	1	0	0	1	1	0	1	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
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47	1	0	1	0	1	0	1	0	0	1	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
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49	1	0	1	0	1	0	1	0	1	1	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
50	2	0	1	0	1	0	1	0	1	1	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
51	1	0	1	0	1	0	1	0	0	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
52	2	0	1	0	1	0	1	0	0	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
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54	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Scenario	Customer		Logers		Pell		Mokia			Notorola			Markham				London				Housing				PCBA				Metal		Silicon	
	DC	CB	OA	OP	OA	OP	OA	OP	SS	OA	OP	SS	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	PS	PC
55	1	0	1	0	1	0	1	0	2	1	0	2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
56	2	0	1	0	1	0	1	0	2	1	0	2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
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61	1	0	1	0	1	0	1	0	1	1	0	1	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
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69	1	0	1	0	1	0	1	0	1	1	0	1	1	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
70	2	0	1	0	1	0	1	0	1	1	0	1	1	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
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74	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	2	1	0	1	0	1	0	1	0	1	0	1	0	1	0
75	1	0	1	0	1	0	1	0	1	1	0	1	1	0	0	0	1	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0
76	2	0	1	0	1	0	1	0	1	1	0	1	1	0	0	0	1	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0

Scenario	Customer		Logers		Pell		Mokia			Notorola			Markham				London				Housing				PCBA				Metal		Silicon	
	DC	CB	OA	OP	OA	OP	OA	OP	SS	OA	OP	SS	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	PS	PC
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78	2	0	1	0	1	0	1	0	1	1	0	1	1	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
79	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
80	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
81	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0
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84	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
85	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	1	1	0	1	0	1	0	1	0	1	0	1	0
86	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	1	1	0	1	0	1	0	1	0	1	0	1	0
87	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
88	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
89	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	0	0	0	0
90	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	0	0	0	0
91	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	0	0	1	0
92	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	0	0	1	0
93	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1	1
94	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1	1
95	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1	0
96	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1	0
97	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	2	1	0
98	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	2	1	0

Scenario	Customer		Logers		Pell		Mokia			Notorola			Markham				London				Housing				PCBA				Metal		Silicon	
	DC	CB	OA	OP	OA	OP	OA	OP	SS	OA	OP	SS	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	PS	PC
Scenarios 100 to 127, Logers and Pell have equal market share																																
100	1	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
101	2	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
102	3	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
103	1	0	1	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
104	2	0	1	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
105	3	0	1	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
106	1	0	0	0	1	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
107	2	0	0	0	1	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
108	3	0	0	0	1	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
109	1	0	1	0	1	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
110	2	0	1	0	1	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
111	3	0	1	0	1	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0
112	1	0	0	0	0	0	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
113	2	0	0	0	0	0	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
114	1	0	0	0	1	0	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
115	2	0	0	0	1	0	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
116	1	0	1	1	1	1	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
117	2	0	1	1	1	1	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
118	1	0	1	0	1	0	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
119	2	0	1	0	1	0	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
120	1	0	1	0	1	1	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1

Scenario	Customer		Logers		Pell		Mokia			Notorola			Markham				London				Housing				PCBA				Metal		Silicon	
	DC	CB	OA	OP	OA	OP	OA	OP	SS	OA	OP	SS	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	PS	PC
121	2	0	1	0	1	1	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
122	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
123	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
124	1	0	1	1	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
125	2	0	1	1	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
126	1	0	1	1	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
127	2	0	1	1	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
Scenarios 128 to 145, Mokia and Notorola have equal market share																																
128	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
129	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
130	1	0	1	1	1	1	1	1	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
131	2	0	1	1	1	1	1	1	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
132	1	0	1	0	1	0	0	0	1	0	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
133	2	0	1	0	1	0	0	0	1	0	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
134	1	0	1	0	1	0	0	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
135	2	0	1	0	1	0	0	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
136	1	0	1	0	1	0	1	0	0	1	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
137	2	0	1	0	1	0	1	0	0	1	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
138	1	0	1	0	1	0	1	0	0	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
139	2	0	1	0	1	0	1	0	0	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
140	1	0	1	0	1	0	1	0	1	1	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
141	2	0	1	0	1	0	1	0	1	1	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Scenario	Customer		Logers		Pell		Mokia			Notorola			Markham				London				Housing				PCBA				Metal		Silicon	
	DC	CB	OA	OP	OA	OP	OA	OP	SS	OA	OP	SS	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	PS	PC
142	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
143	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
144	1	0	1	0	0	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
145	2	0	1	0	0	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
Scenarios 146 to 149 Logers has 70% market share, Mokia has 60% market share																																
146	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
147	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
148	1	0	1	0	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
149	2	0	1	0	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
Scenarios 150 to 153 Logers and Pell have equal market share																																
150	1	0	1	0	1	1	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
151	2	0	1	0	1	1	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1
152	1	0	1	0	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
153	2	0	1	0	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
Scenarios 155 to 181 Logers has 70% market share, Mokia has 60% market share																																
155	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	0	0	1	0	0	0	1	0	1	0	1	0
156	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	0	0	1	0	0	0	1	0	1	0	1	0
157	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	0	0	1	0	1	0	1	0
158	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	0	0	1	0	1	0	1	0
159	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	1	1	0	1	1	1	0	1	0	1	0
160	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	1	1	0	1	1	1	0	1	0	1	0
161	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	1	1	0	1	0	1	0	1	0	1	0

Scenario	Customer		Logers		Pell		Mokia			Notorola			Markham				London				Housing				PCBA				Metal		Silicon	
	DC	CB	OA	OP	OA	OP	OA	OP	SS	OA	OP	SS	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	PS	PC
162	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	1	1	0	1	0	1	0	1	0	1	0
163	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	2	1	0	1	0	1	0	1	0	1	0
164	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	2	1	0	1	0	1	0	1	0	1	0
165	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	0	0	1	0	0	0	1	0	1	0
166	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	0	0	1	0	0	0	1	0	1	0
167	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	0	0	1	0	1	0	1	0	1	0
168	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	0	0	1	0	1	0	1	0	1	0
169	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	1	1	0	1	1	1	0	1	0
170	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	1	1	0	1	1	1	0	1	0
171	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	1	1	0	1	0	1	0	1	0
172	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	1	1	0	1	0	1	0	1	0
173	1	0	1	0	1	0	1	0	1	1	0	1	1	2	1	0	1	2	1	0	1	0	1	0	1	0	1	0	1	0	1	0
174	2	0	1	0	1	0	1	0	1	1	0	1	1	2	1	0	1	2	1	0	1	0	1	0	1	0	1	0	1	0	1	0
177	1	0	1	0	1	0	1	0	1	1	1	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
178	2	0	1	0	1	0	1	0	1	1	1	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
180	1	0	1	0	1	0	0	1	1	1	1	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
181	2	0	1	0	1	0	0	1	1	1	1	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
Scenarios 182 and 183, Mokia and Notorola have equal market share																																
182	1	0	1	0	1	0	1	0	1	0	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
183	2	0	1	0	1	0	1	0	1	0	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
Scenarios 190 to 199 Logers has 70% market share, Mokia has 60% market share																																
190	1	1	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0

Scenario	Customer		Logers		Pell		Mokia			Notorola			Markham				London				Housing				PCBA				Metal		Silicon	
	DC	CB	OA	OP	OA	OP	OA	OP	SS	OA	OP	SS	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	PS	PC
191	1	1	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0
192	1	1	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0
193	1	1	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0
194	1	1	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0
195	1	1	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0
196	1	1	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0
197	1	1	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0
198	1	1	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0
199	1	1	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0
Scenarios 201 to 210 Logers has 70% market share, Mokia has 60% market share																																
201	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
202	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
203	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
204	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
205	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
206	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
207	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
208	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
209	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
210	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
Scenarios 212 to 221 Logers and Pell have equal market share, Mokia and Notorola have equal market share																																
212	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Scenario	Customer		Logers		Pell		Mokia			Notorola			Markham				London				Housing				PCBA				Metal		Silicon	
	DC	CB	OA	OP	OA	OP	OA	OP	SS	OA	OP	SS	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	OA	OP	PS	PC	PS	PC
213	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
214	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
215	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
216	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
217	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
218	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
219	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
220	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
221	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenarios 222 to 227 Logers has 70% market share, Mokia has 60% market share																																
222	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1	1
223	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1	1
224	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1	0
225	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	1	0
226	1	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	2	1	0
227	2	0	1	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	2	1	0

Appendix B

Final Assets of Agents for Tested Scenarios in Chapter 8 (in Thousands Dollars)

Scenario	Logers	Pell	Mokia	Notorola	Markham	London	Housing	PCBA	Metal	Silicon
1	1741	876	1518	998	762	831	484	1356	582	582
2	1919	973	2829	-97	871	867	473	1551	582	582
3	335	265	309	224	511	427	210	642	335	335
4	1737	962	1749	819	764	870	474	1423	582	582
5	1719	1152	1909	787	867	768	466	1420	582	582
6	431	286	354	249	471	493	220	668	349	349
7	1750	972	1786	861	838	790	474	1406	582	582
8	1897	974	2249	473	823	854	485	1446	582	582
9	377	275	349	263	517	418	220	670	343	343
10	1777	943	1714	847	853	782	481	1389	582	582
11	1760	1129	2509	207	843	861	474	1506	582	582
12	361	273	335	264	541	418	224	685	356	356
13	1734	908	1621	903	811	758	471	1342	582	582
14	1872	979	2204	479	886	763	466	1460	582	582
15	366	281	366	255	455	494	220	675	353	353
16	1898	964	1628	1125	817	768	474	1379	582	582
17	1720	1271	1172	1649	749	801	478	1321	582	582
18	449	309	367	278	494	432	200	618	329	329
19	2082	990	1738	1209	984	739	534	1574	667	667
20	3680	2096	3671	1958	1305	1355	902	2650	1049	1049
21	503	306	405	294	517	465	220	671	366	366
22	1899	993	1749	1043	842	797	485	1378	582	582
23	1680	1249	2235	554	834	831	483	1436	582	582
24	375	266	367	262	523	395	198	612	331	331
25	1699	1035	1498	1095	744	835	477	1342	582	582
26	1571	1273	2328	340	816	838	473	1480	582	582
27	408	294	361	276	391	514	214	654	336	336
29	1903	1027	1732	1082	780	835	485	1388	582	582
30	1698	1251	2202	577	863	778	466	1457	582	582
31	1861	970	1754	967	799	823	483	1393	582	582
32	1498	1469	1753	1041	780	820	466	1410	582	582
33	1885	966	1694	1066	769	837	473	1416	582	582
34	1781	1176	1995	799	839	798	473	1448	582	582
35	1946	883	1694	1022	784	823	477	1372	582	582
36	2023	968	2362	454	817	864	478	1456	582	582
37	1885	965	1777	961	852	786	474	1432	582	582
38	1640	1272	1758	982	845	797	484	1400	582	582
39	1881	932	1656	1050	828	787	474	1411	582	582
40	1741	1191	2500	250	863	807	476	1447	582	582

Scenario	Logers	Pell	Mokia	Notorola	Markham	London	Housing	PCBA	Metal	Silicon
41	1915	989	1831	944	850	762	474	1413	582	582
42	1783	1169	2297	514	863	811	473	1478	582	582
43	1847	967	1637	1040	849	769	473	1416	582	582
44	1639	1271	1699	1041	872	761	478	1380	582	582
45	1821	984	1754	977	811	820	473	1421	582	582
46	1639	1292	1833	920	799	842	474	1432	582	582
47	1940	964	1145	680	1297	1265	474	1404	582	582
48	1943	1029	1295	564	1315	1271	485	1409	582	582
49	1895	924	1821	552	1000	940	466	1412	582	582
50	1741	1171	1507	828	1017	963	477	1356	582	582
51	1891	943	1000	1148	1073	1076	474	1385	582	582
52	1881	1114	1129	1144	1158	1029	485	1387	582	582
53	1875	972	1732	999	875	751	477	1391	582	582
54	1700	1268	2239	555	822	826	466	1467	582	582
55	1903	933	1185	1048	1135	910	466	1381	582	582
56	1691	1117	1268	915	1052	1032	478	1378	582	582
57	1877	989	1716	857	904	899	474	1422	582	582
58	1783	1150	2764	-95	962	851	466	1527	582	582
59	747	443	1776	-757	627	546	248	875	374	374
60	1437	946	2982	-757	855	772	414	1401	546	546
61	1807	939	1640	990	457	1151	477	1386	582	582
62	1659	1271	1883	878	515	1128	474	1439	582	582
63	1858	1028	1709	1000	1123	474	474	1368	582	582
64	1619	1291	1811	916	1127	520	483	1398	582	582
65	1888	1009	1710	1049	777	808	478	1360	582	582
66	1740	1252	2260	556	846	841	478	1450	582	582
67	1878	929	1518	1187	772	831	474	1415	582	582
68	1677	1251	2114	657	866	798	485	1431	582	582
69	1868	956	1634	1066	870	768	478	1390	582	582
70	1858	1150	1465	1373	823	756	478	1362	582	582
71	1881	944	1628	1088	706	883	478	1376	582	582
72	1741	1191	1331	1425	713	853	478	1327	582	582
73	1903	977	1589	1171	875	701	480	1356	582	582
74	1720	1231	1831	947	874	751	474	1412	582	582
75	1798	947	1590	1004	803	768	477	1363	582	582
76	1679	1231	2052	675	871	790	474	1442	582	582
77	1862	921	1495	1171	789	795	478	1348	582	582
78	1701	1231	1957	820	800	824	466	1448	582	582
79	1859	964	1535	1127	832	786	474	1385	582	582
80	1800	1107	1835	921	822	787	478	1374	582	582
81	1883	938	1733	960	751	851	474	1420	582	582
82	1801	1130	1871	878	776	865	485	1394	582	582
83	1871	967	1739	1005	831	792	484	1396	582	582
84	1760	1170	2137	641	827	828	473	1459	582	582
85	1893	990	1700	1038	828	780	473	1416	582	582
86	1781	1180	1690	1104	808	786	466	1403	582	582
87	1914	960	1633	1127	758	865	474	1409	582	582

Scenario	Logers	Pell	Mokia	Notorola	Markham	London	Housing	PCBA	Metal	Silicon
88	1731	1214	1812	982	840	781	473	1427	582	582
89	1988	978	1711	1171	860	785	494	1423	582	582
90	1841	1289	1931	1039	824	838	494	1446	582	582
91	1881	959	1634	1088	837	792	474	1411	582	582
92	1741	1227	2300	494	849	819	473	1479	582	582
93	2161	1065	1854	1231	859	913	541	1595	671	680
94	2587	1742	2233	1952	1067	1019	678	1957	805	813
95	1939	967	1716	1027	843	779	478	1389	635	582
96	1720	1271	1748	1062	842	784	474	1429	639	582
97	-1126	-343	-1075	-574	32	16	-170	-439	-82	-48
98	-1126	-323	-1036	-596	32	20	-170	-436	-82	-48
100	1373	1394	1539	1115	773	835	473	1405	582	582
101	1448	1376	1800	854	844	806	474	1428	582	582
102	386	364	367	301	467	511	225	678	365	365
103	1342	1365	1760	819	798	825	466	1416	582	582
104	1374	1428	1920	725	844	769	481	1386	582	582
105	330	323	308	306	473	482	224	677	355	355
106	1315	1353	1675	894	721	853	470	1376	582	582
107	1424	1415	2093	580	833	814	466	1464	582	582
108	330	346	359	264	477	496	227	687	356	356
109	1354	1395	1671	991	852	736	484	1359	582	582
110	1395	1435	1924	737	822	810	483	1381	582	582
111	324	327	307	265	554	401	218	660	349	349
112	1566	1581	1802	1234	929	823	543	1596	684	684
113	3308	3371	3865	2677	1538	1396	1029	2982	1157	1157
114	1557	1583	1823	1243	834	921	548	1614	693	693
115	3359	3262	3721	2798	1472	1423	1026	2960	1161	1161
116	1680	1635	1943	1369	917	920	582	1705	727	727
117	3562	3583	3868	3170	1557	1503	1096	3138	1218	1218
118	1549	1539	1717	1232	964	774	534	1568	668	668
119	3543	3547	3935	3026	1563	1495	1085	3119	1218	1218
120	1631	1674	1898	1308	913	916	568	1670	708	708
121	3244	3795	3837	3065	1495	1530	1077	3092	1210	1210
122	1473	1390	1534	1187	817	793	478	1371	582	582
123	1556	1410	1875	919	833	791	473	1435	582	582
124	1409	1433	1529	1231	804	802	474	1371	582	582
125	1657	1355	2013	820	841	774	466	1430	582	582
126	1462	1422	1655	1100	781	831	473	1420	582	582
127	1392	1597	1348	1485	809	778	485	1349	582	582
128	1838	962	1535	1147	792	796	474	1387	582	582
129	1678	1248	1970	802	825	774	478	1355	582	582
130	1868	943	1369	1347	750	811	481	1336	582	582
131	1751	1188	2033	761	801	804	466	1418	582	582
132	1819	934	1434	1190	768	818	481	1347	582	582
133	1620	1277	1708	1041	799	785	480	1335	582	582
134	1851	984	1592	1131	775	786	478	1338	582	582
135	1708	1170	1960	758	809	807	466	1412	582	582

Scenario	Logers	Pell	Mokia	Notorola	Markham	London	Housing	PCBA	Metal	Silicon
136	1923	939	980	799	1285	1184	474	1339	582	582
137	2011	986	1383	508	1312	1264	474	1401	582	582
138	1940	970	1028	1224	1095	965	478	1321	582	582
139	1876	1090	1511	660	1120	1127	473	1442	582	582
140	1890	977	1447	847	1051	949	476	1325	582	582
141	1781	1157	1749	639	1047	949	481	1363	582	582
142	1958	918	1011	799	1252	1245	480	1342	582	582
143	1942	1029	1853	-10	1362	1288	478	1465	582	582
144	1892	944	1536	1156	791	773	478	1320	582	582
145	1801	1157	1939	872	787	808	480	1368	582	582
146	1910	991	1594	1187	855	744	478	1370	582	582
147	1761	1218	1870	946	835	797	474	1406	582	582
148	1848	1025	1567	1187	774	806	466	1381	582	582
149	1457	1494	1837	941	853	769	483	1403	582	582
150	1530	1561	1800	1248	835	911	543	1596	699	699
151	3199	3894	3996	2988	1563	1495	1091	3146	1210	1210
152	1344	1418	1689	989	770	823	474	1365	582	582
153	1213	1724	2423	372	858	804	466	1486	582	582
155	1982	1006	1590	1264	781	856	493	1181	582	582
156	1640	1421	1211	1688	817	773	491	1150	582	582
157	1901	1028	1772	990	808	837	481	1217	582	582
158	1820	1231	2082	796	852	815	481	1249	582	582
159	1912	974	1534	1231	843	781	473	1405	582	582
160	1735	1221	1326	1483	840	770	492	1324	582	582
161	1948	933	1534	1203	752	830	478	1343	582	582
162	1780	1191	1409	1390	803	755	473	1370	582	582
163	900	543	1394	-87	623	544	258	903	404	404
164	812	666	1892	-574	601	591	252	935	396	396
165	1855	996	1831	906	838	765	478	1376	582	582
167	1948	993	1738	1059	801	834	474	1428	582	582
168	1660	1278	1656	1122	805	799	473	1404	582	582
169	1911	944	1556	1149	838	741	466	1385	582	582
170	1700	1171	1835	866	828	803	480	1402	582	582
171	1897	965	1854	856	848	783	466	1428	582	582
172	1700	1229	1171	1606	828	709	478	1310	582	582
173	1826	965	1490	1181	805	755	473	1377	582	582
174	1637	1228	1528	1182	788	788	475	1384	582	582
175	1804	980	1547	1121	768	822	476	1371	582	582
176	1741	1238	2252	548	848	823	485	1439	582	582
177	1870	957	1740	944	873	755	483	1393	582	582
178	1720	1244	2058	736	825	818	473	1455	582	582
180	1873	925	1835	823	836	821	478	1415	582	582
181	1797	1116	2300	454	868	794	478	1438	582	582
182	1850	948	1497	1174	734	836	474	1373	582	582
183	1619	1291	1688	1051	861	749	478	1365	582	582
190	1918	987	1098	696	769	-11	392	1228	582	582
191	1928	961	1032	778	584	186	405	1222	582	582

Scenario	Logers	Pell	Mokia	Notorola	Markham	London	Housing	PCBA	Metal	Silicon
192	1920	972	1016	778	657	111	407	1206	582	582
193	1924	979	935	875	653	104	400	1207	582	582
194	1939	949	1049	761	764	2	406	1216	582	582
195	1799	1046	1194	567	759	38	399	1256	582	582
196	1870	1005	903	891	711	46	400	1222	582	582
197	1894	1036	1097	729	753	37	401	1252	582	582
198	1900	1036	967	859	580	200	407	1201	582	582
199	1940	996	936	890	698	71	400	1232	582	582
201	1861	1030	1049	777	145	633	405	1222	582	582
202	1919	968	1048	746	-18	794	401	1243	582	582
203	1904	938	918	859	17	741	400	1240	582	582
204	1853	968	855	891	-7	728	399	1193	582	582
205	1800	1088	1016	762	102	643	400	1197	582	582
206	1816	1065	1097	697	169	621	401	1262	582	582
207	1888	987	1049	729	56	693	403	1209	582	582
208	1779	1028	887	843	9	714	398	1206	582	582
209	1880	992	1016	762	56	687	400	1197	582	582
210	1889	966	951	827	32	698	392	1208	582	582
212	1424	1487	923	921	408	341	412	966	578	578
213	1496	1478	923	960	418	365	422	982	582	582
214	1441	1482	923	941	268	492	416	977	581	581
215	1492	1461	923	940	549	223	421	984	579	579
216	1411	1533	943	902	412	349	416	976	582	582
217	1458	1487	923	940	413	344	418	976	580	580
218	1419	1470	942	883	477	276	412	968	574	574
219	1485	1459	904	940	357	398	416	972	582	582
220	1485	1449	924	921	377	381	416	972	582	582
221	1461	1513	904	960	334	441	421	980	580	580
222	1455	1441	1711	1066	818	768	478	1359	582	582
223	1413	1536	2326	453	791	879	483	1454	582	582
224	1471	1430	1739	1021	737	864	479	1362	582	618
225	1576	1426	2135	698	805	818	465	1441	582	620
226	333	284	544	-90	385	455	156	469	250	279
227	426	337	884	-293	453	418	160	525	250	296

Appendix C

Summary Results of Tested Scenarios in Chapter 8

Note: LM Demand – Market demand in Logers for Mokia phones
LM Sale – the sales amount of Logers for Mokia phones
LM Shortage – the shortage of Mokia phones in Logers
LM Contract – the total contracts from Logers to Mokia
LM Amount – the order amount in an LM contract
LN Demand – Market demand in Logers for Notorola phones
LN Sales – the sales amount of Logers for Notorola phones
LN Shortage –the shortage of Notorola phones in Logers
LN Contract –the total contracts from Logers to Notorola
LN Amount –the order amount in an LN contract
PM Demand – Market demand in Pell for Mokia phones

Scenario	LM Demand	LM Sale	LM Shortage	LM Contract	LM Amount	LN Demand	LN Sale	LN Shortage	LN Contract	LN Amount	PM Demand
1	41287	37483	3804	48	798	27321	24080	3241	61	399	17660
2	88534	55935	32599	70	798	59148	9078	50070	22	399	38162
3	20697	20433	264	27	798	13426	13426	0	34	399	8894
4	44207	40358	3849	102	400	29399	21100	8299	52	400	19019
5	90211	41100	49111	102	400	60425	19900	40525	49	400	38612
6	21556	21556	0	55	400	14089	14089	0	36	400	9052
7	43038	40386	2652	51	798	28904	21481	7423	55	399	19076
8	85162	47928	37234	61	798	56638	16659	39979	41	399	36684
9	21170	20909	261	27	798	13844	13844	0	35	399	8999
10	44865	40300	4565	102	400	30093	21900	8193	55	400	19396
11	93424	49500	43924	124	400	61752	12300	49452	30	400	40213
12	20598	20598	0	53	400	13862	13751	111	35	400	9093
13	41193	38826	2367	49	798	27356	22644	4712	57	399	17670
14	86366	47382	38984	60	798	57348	16659	40689	41	399	36740
15	20776	20776	0	27	798	13913	13782	131	35	399	9095
16	42632	38764	3868	97	400	28275	25942	2333	65	400	18202
17	83718	30700	53018	77	400	55684	30300	25384	76	400	35765
18	21502	21502	0	55	400	14504	14503	1	37	400	9327
19	41454	41048	406	104	400	27919	27222	697	68	400	17541
20	87721	65608	22113	165	400	57878	34300	23578	86	400	37403
21	22983	22335	648	57	400	15412	14700	712	37	400	9619

Scenario	LM Demand	LM Sale	LM Shortage	LM Contract	LM Amount	LN Demand	LN Sale	LN Shortage	LN Contract	LN Amount	PM Demand
22	42604	40506	2098	103	400	28201	24304	3897	62	400	18002
23	86281	43500	42781	108	400	57334	16766	40568	43	400	36718
24	20764	20764	0	55	400	13980	13980	0	36	400	8985
25	43560	35412	8148	45	798	29238	25243	3995	64	399	18892
26	82883	43392	39491	54	798	55287	14664	40623	36	399	35367
27	21373	21186	187	27	798	14144	14136	8	36	399	9210
29	43549	40179	3370	102	400	29059	24713	4346	63	400	18762
30	84834	43063	41771	108	400	56814	17500	39314	43	400	36365
31	41656	40518	1138	102	400	27647	23375	4272	59	400	17781
32	86819	34300	52519	86	400	57925	22300	35625	55	400	37273
33	41494	39701	1793	101	400	27567	24724	2843	62	400	17929
34	82261	42300	39961	107	400	55576	19900	35676	49	400	35599
35	43443	40559	2884	104	400	28792	25081	3711	63	400	18591
36	86955	51095	35860	129	400	58301	15900	42401	39	400	37106
37	42254	40863	1391	103	400	28129	23500	4629	59	400	18189
38	86034	38700	47334	97	400	57738	20700	37038	52	400	37139
39	42370	39584	2786	100	400	28341	24700	3641	62	400	18017
40	85276	48700	36576	121	400	56313	12700	43613	31	400	36111
41	44281	41650	2631	104	400	29858	23331	6527	59	400	19350
42	83551	45198	38353	114	400	55651	17100	38551	42	400	36093
43	45410	38579	6831	98	400	30359	25100	5259	62	400	19548
44	89101	37900	51201	95	400	59037	21500	37537	53	400	38492
45	43347	40110	3237	102	400	28806	23135	5671	58	400	18607
46	89539	39100	50439	98	400	59482	20300	39182	51	400	38451
47	43122	40762	2360	103	400	28891	24700	4191	62	400	18384
48	87467	44300	43167	110	400	58374	21100	37274	53	400	37385
49	42355	42099	256	107	400	27940	22483	5457	56	400	17930
50	87191	35500	51691	88	400	58303	25900	32403	64	400	37297
51	41979	38154	3825	97	400	27729	26300	1429	66	400	17908
52	83969	40300	43669	101	400	55945	23900	32045	60	400	35689
53	41560	40334	1226	102	400	27562	23927	3635	60	400	17813
54	85739	44300	41439	112	400	56674	16300	40374	40	400	36822
55	43428	36868	6560	93	400	28785	27851	934	70	400	18336
56	84238	37900	46338	95	400	56018	22529	33489	56	400	35776
57	42328	39858	2470	101	400	28374	24300	4074	60	400	18319
58	84223	52397	31826	132	400	55810	9900	45910	24	400	35699
59	46300	41465	4835	104	400	30942	300	30642	0	0	19882
60	85940	55100	30840	139	400	56859	300	56559	0	0	36682
61	46074	39018	7056	99	400	31168	23783	7385	60	400	20004
62	83185	39100	44085	99	400	55588	20700	34888	51	400	35570

Scenario	LM Demand	LM Sale	LM Shortage	LM Contract	LM Amount	LN Demand	LN Sale	LN Shortage	LN Contract	LN Amount	PM Demand
63	42555	39900	2655	100	400	28193	23900	4293	59	400	18420
64	87014	38300	48714	97	400	58721	20700	38021	52	400	37569
65	42505	39719	2786	99	400	28229	24700	3529	63	400	18389
66	85719	44700	41019	112	400	57608	16700	40908	41	400	36780
67	44062	37419	6643	95	400	29584	26834	2750	68	400	18826
68	85950	42700	43250	106	400	57447	17535	39912	44	400	36622
69	42594	39081	3513	99	400	28592	24993	3599	63	400	18238
70	90788	35100	55688	87	400	61220	28637	32583	72	400	39077
71	42585	38729	3856	97	400	28465	25629	2836	65	400	18377
72	88478	32700	55778	82	400	58901	28700	30201	71	400	37767
73	44669	38300	6369	95	400	29774	26422	3352	67	400	19125
74	84895	39500	45395	98	400	56868	21500	35368	54	400	36467
75	42514	38300	4214	96	400	28403	24342	4061	61	400	18165
76	84914	41900	43014	106	400	57298	18300	38998	45	400	36694
77	41815	37478	4337	95	400	27719	26440	1279	66	400	17912
78	82853	40793	42060	103	400	55274	19900	35374	49	400	35815
79	41526	37500	4026	95	400	27699	26300	1399	67	400	17949
80	85090	40300	44790	100	400	56002	22280	33722	56	400	36078
81	44443	40311	4132	102	400	29305	24089	5216	61	400	18811
82	88992	41100	47892	103	400	59509	21500	38009	54	400	38179
83	41454	40337	1117	102	400	27729	23859	3870	60	400	17854
84	86626	43500	43126	110	400	57655	18300	39355	45	400	36909
85	42372	40190	2182	102	400	28445	24300	4145	60	400	18210
86	87543	37900	49643	96	400	58067	24300	33767	60	400	37396
87	42180	39370	2810	100	400	27892	25595	2297	65	400	17967
88	88766	38142	50624	96	400	59147	23100	36047	57	400	38146
89	40866	40096	770	101	400	27441	26417	1024	66	400	17690
90	84977	40700	44277	101	400	56631	22700	33931	56	400	36638
91	41880	38791	3089	98	400	28158	25500	2658	64	400	17953
92	90028	45900	44128	116	400	59963	15500	44463	38	400	38638
93	43305	42336	969	107	400	28529	27500	1029	69	400	18439
94	86852	43900	42952	109	400	58017	34366	23651	86	400	37805
95	42127	40700	1427	103	400	27929	24700	3229	62	400	18088
96	87727	37900	49827	95	400	58158	23100	35058	57	400	37593
97	42536	1900	40636	4	400	28416	2700	25716	6	400	18125
98	88518	2300	86218	5	400	58645	2300	56345	5	400	37682
100	30357	27090	3267	48	570	20333	18432	1901	39	475	30293
101	61522	29940	31582	53	570	41136	16925	24211	36	475	61472
102	15636	15636	0	28	570	10356	10356	0	23	475	15413
103	30797	28939	1858	73	400	20735	15900	4835	39	400	31185

Scenario	LM Demand	LM Sale	LM Shortage	LM Contract	LM Amount	LN Demand	LN Sale	LN Shortage	LN Contract	LN Amount	PM Demand
104	59222	30700	28522	76	400	39588	14700	24888	37	400	59444
105	15246	14779	467	38	400	10157	10157	0	26	400	15264
106	31697	28326	3371	50	570	21340	16110	5230	35	475	31918
107	60997	32790	28207	58	570	40449	13600	26849	28	475	60507
108	15038	15038	0	27	570	9942	9942	0	22	475	15228
109	29761	28507	1254	72	400	20071	16660	3411	42	400	30213
110	60608	31100	29508	78	400	40317	14700	25617	36	400	60650
111	14923	14724	199	38	400	10052	10052	0	26	400	14938
112	31227	29610	1617	53	570	20862	19787	1075	43	475	31484
113	61135	51600	9535	91	570	40547	32125	8422	68	475	60280
114	29825	29696	129	53	570	19891	19477	414	42	475	30238
115	66346	50135	16211	89	570	44315	34806	9509	74	475	66764
116	31488	30886	602	79	400	21179	20869	310	54	400	31206
117	65861	50342	15519	127	400	43496	38545	4951	97	400	65824
118	29338	29100	238	74	400	19894	19806	88	50	400	29413
119	62901	51140	11761	128	400	41679	37354	4325	94	400	62228
120	30927	30340	587	77	400	20657	20326	331	52	400	31129
121	61128	45500	15628	115	400	41182	36969	4213	93	400	61467
122	30722	27900	2822	70	400	20426	19500	926	49	400	30441
123	61369	32300	29069	82	400	40990	16700	24290	41	400	61585
124	30856	26761	4095	67	400	20525	19584	941	50	400	30899
125	61914	35100	26814	87	400	41168	15900	25268	39	400	61705
126	30712	28282	2430	72	400	20438	19017	1421	47	400	30633
127	59887	24300	35587	61	400	40222	21530	18692	54	400	60097
128	37378	34765	2613	88	400	37053	28676	8377	72	400	15866
129	69489	38700	30789	96	400	69850	21472	48378	54	400	30043
130	38433	31809	6624	81	400	38263	32336	5927	82	400	16422
131	70774	38536	32238	98	400	70399	23100	47299	57	400	30347
132	36532	33100	3432	84	400	36783	29900	6883	75	400	15823
133	72668	35191	37477	88	400	72861	23900	48961	59	400	31095
134	37522	35661	1861	90	400	37447	28073	9374	70	400	15904
135	70697	39299	31398	99	400	69855	21500	48355	53	400	30183
136	36320	34300	2020	85	400	36328	30812	5516	78	400	15363
137	72184	40903	31281	103	400	72387	25900	46487	64	400	30826
138	35308	35100	208	88	400	35126	30300	4826	76	400	15044
139	74324	43019	31305	107	400	74814	21100	53714	52	400	32288
140	36221	33131	3090	83	400	35922	31382	4540	79	400	15422
141	71032	35900	35132	89	400	71477	26366	45111	67	400	30382
142	36268	34700	1568	88	400	36175	31140	5035	78	400	15552
143	70849	48700	22149	123	400	70899	16700	54199	43	400	30505

Scenario	LM Demand	LM Sale	LM Shortage	LM Contract	LM Amount	LN Demand	LN Sale	LN Shortage	LN Contract	LN Amount	PM Demand
144	35316	34965	351	88	400	35321	29500	5821	74	400	15273
145	71910	38700	33210	96	400	72504	23983	48521	60	400	30695
146	43817	38196	5621	97	400	29293	26724	2569	67	400	18970
147	88659	40300	48359	100	400	58377	21500	36877	54	400	37671
148	42297	37100	5197	92	400	28318	26523	1795	67	400	18160
149	87467	35900	51567	90	400	57930	19900	38030	49	400	37359
150	30022	29165	857	74	400	20048	19489	559	49	400	30277
151	62224	45946	16278	116	400	41654	35726	5928	90	400	62970
152	30025	27934	2091	71	400	19859	16997	2862	43	400	29774
153	59975	31500	28475	79	400	40342	10700	29642	26	400	60317
155	45214	38300	6914	95	400	29896	27900	1996	70	400	19315
156	87211	29100	58111	74	400	57859	30300	27559	76	400	37264
157	44245	41100	3145	103	400	29196	23500	5696	59	400	18937
158	87321	43074	44247	108	400	58286	19900	38386	49	400	37282
159	43485	37620	5865	95	400	29112	27316	1796	69	400	18800
160	89644	33410	56234	84	400	59829	27900	31929	70	400	38159
161	41964	38103	3861	96	400	28137	27500	637	69	400	17785
162	84293	34300	49993	85	400	55394	27900	27494	70	400	36087
163	41834	35681	6153	89	400	27983	9194	18789	23	400	17981
164	84077	40765	43312	102	400	55734	2300	53434	5	400	35865
165	42100	41891	209	105	400	28163	21900	6263	55	400	18118
166	86126	35500	50626	90	400	57215	25528	31687	64	400	36911
167	42991	40110	2881	101	400	29082	25500	3582	63	400	18800
168	86502	35500	51002	90	400	57311	24300	33011	60	400	37405
169	41514	38165	3349	96	400	27512	26700	812	67	400	17686
170	86016	39900	46116	99	400	57643	20700	36943	52	400	36852
171	43314	42264	1050	107	400	29432	22300	7132	55	400	18825
172	84375	29900	54475	76	400	56688	30700	25988	76	400	36540
173	42248	36565	5683	92	400	28453	26692	1761	66	400	18134
174	85834	35077	50757	87	400	56872	24300	32572	60	400	36913
175	41942	37156	4786	94	400	28112	25638	2474	65	400	18124
176	87988	44300	43688	110	400	58584	17100	41484	43	400	37620
177	42068	40571	1497	102	400	28458	23472	4986	59	400	18279
178	86881	42300	44581	107	400	58282	18700	39582	46	400	37302
180	43907	42197	1710	106	400	29208	21900	7308	55	400	18570
181	83647	46300	37347	116	400	56015	16242	39773	40	400	35985
182	39291	34145	5146	86	400	39747	29500	10247	74	400	17020
183	71450	34300	37150	86	400	71455	24700	46755	62	400	30884
190	42567	39853	2714	99	400	28217	25100	3117	62	400	18363
191	41715	38903	2812	98	400	27920	26350	1570	66	400	17814

Scenario	LM Demand	LM Sale	LM Shortage	LM Contract	LM Amount	LN Demand	LN Sale	LN Shortage	LN Contract	LN Amount	PM Demand
192	42882	39100	3782	98	400	28222	25900	2322	65	400	18320
193	41682	37100	4582	93	400	27852	28023	-171	70	400	18097
194	43283	39900	3383	100	400	29051	25544	3507	64	400	18672
195	41769	40300	1469	102	400	28169	22300	5869	56	400	17965
196	45817	35317	10500	89	400	30425	28700	1725	72	400	19738
197	43174	39100	4074	98	400	28579	25403	3176	63	400	18637
198	46405	37100	9305	92	400	30762	27500	3262	69	400	19699
199	43813	37100	6713	92	400	29393	28300	1093	70	400	18740
201	44345	37978	6367	95	400	29731	25900	3831	65	400	18944
202	42072	39900	2172	100	400	28332	25143	3189	63	400	18205
203	43131	37032	6099	93	400	28461	27697	764	69	400	18543
204	41585	35167	6418	88	400	27965	28585	-620	71	400	17904
205	43847	38300	5547	96	400	29287	24300	4987	60	400	18815
206	43105	38645	4460	97	400	29000	24300	4700	61	400	18367
207	43177	38094	5083	95	400	28750	26300	2450	66	400	18533
208	42591	35555	7036	90	400	28162	26700	1462	67	400	18275
209	43160	38300	4860	95	400	28620	25900	2720	65	400	18456
210	44595	36957	7638	92	400	29964	27461	2503	68	400	19062
212	24977	23760	1217	50	475	24940	22765	2175	48	475	25241
213	25073	23597	1476	50	475	25123	24361	762	51	475	24977
214	25204	23195	2009	49	475	25191	23689	1502	50	475	25378
215	24895	24309	586	51	475	24677	23583	1094	50	475	24471
216	24703	23575	1128	50	475	24813	22659	2154	48	475	24789
217	25557	23575	1982	49	475	25521	23592	1929	50	475	25647
218	26267	23316	2951	49	475	25820	23051	2769	48	475	26067
219	26537	23575	2962	49	475	26732	24050	2682	50	475	26559
220	25269	23575	1694	49	475	25187	24050	1137	50	475	25165
221	26404	23575	2829	50	475	26256	23575	2681	49	475	26718
222	31403	29100	2303	72	400	20993	17994	2999	46	400	31255
223	60722	34269	26453	86	400	40517	11900	28617	29	400	60765
224	30474	29500	974	75	400	20629	17859	2770	45	400	30615
225	59692	34700	24992	86	400	39877	14700	25177	36	400	59508
226	30177	17697	12480	45	400	20249	7100	13149	17	400	30443
227	58354	21100	37254	53	400	39266	5500	33766	13	400	58198

Note:

PM Sale – the sales amount of Pell for Mokia phones
PM Shortage – the shortage of Mokia phones in Pell
PM Contract – the total contracts from Pell to Mokia
PM Amount – the order amount in a PM contract
PN Demand – Market demand in Pell for Notorola phones
PN Sale – the sales amount of Pell for Notorola phones
PN Shortage – the shortage of Notorola phones in Pell
PN Contract – the total contracts from Pell to Notorola
PN Amount – the order amount in a PN contract
MM Contract – the total contracts from Mokia to Markham
MM Amount – the order amount in an MM contract

Scenario	PM Sale	PM Shortage	PM Contract	PM Amount	PN Demand	PN Sale	PN Shortage	PN Contract	PN Amount	MM Contract	MM Amount
1	16035	1625	47	342	11832	10834	998	63	171	22	1140
2	24134	14028	70	342	25583	4575	21008	25	171	35	1140
3	8894	0	27	342	5905	5905	0	34	171	16	1140
4	17926	1093	53	342	12816	10618	2198	61	171	25	1140
5	21025	17587	61	342	25774	11244	14530	64	171	27	1140
6	9052	0	27	342	6089	6089	0	35	171	15	1140
7	18420	656	46	400	12490	10390	2100	26	400	28	1140
8	20456	16228	51	400	24045	8300	15745	20	400	29	1140
9	8999	0	23	400	5988	5988	0	15	400	15	1140
10	17900	1496	45	400	12638	10231	2407	26	400	27	1140
11	24300	15913	61	400	26701	7500	19201	18	400	32	1140
12	9093	0	23	400	5923	5923	0	15	400	16	1140
13	16804	866	49	342	12004	10684	1320	62	171	25	1140
14	20478	16262	60	342	24653	8337	16316	47	171	31	1140
15	9095	0	27	342	6054	6054	0	35	171	12	1140
16	17123	1079	43	400	12282	11500	782	29	400	47	600
17	16700	19065	42	400	23831	17900	5931	44	400	36	600
18	9327	0	24	400	6282	6282	0	16	400	28	600
19	17500	41	44	400	11782	11607	175	29	400	58	600
20	31100	6303	78	400	24854	19853	5001	49	400	83	600
21	9329	290	24	400	6516	6307	209	16	400	28	600
22	17731	271	44	400	12178	11432	746	28	400	50	600
23	25100	11618	62	400	24282	9120	15162	23	400	56	600
24	8985	0	23	400	5921	5921	0	15	400	28	600
25	18216	676	54	342	12632	11757	875	68	171	41	600
26	26976	8391	79	342	23789	7653	16136	43	171	57	600
27	9210	0	27	342	6148	6148	0	36	171	24	600
29	17900	862	44	400	12621	11900	721	29	400	46	600

Scenario	PM Sale	PM Shortage	PM Contract	PM Amount	PN Demand	PN Sale	PN Shortage	PN Contract	PN Amount	MM Contract	MM Amount
30	24700	11665	62	400	24214	9500	14714	23	400	59	600
31	17771	10	45	400	11926	11017	909	28	400	48	600
32	24622	12651	62	400	25103	13900	11203	34	400	49	600
33	17588	341	44	400	11924	11129	795	28	400	44	600
34	21253	14346	53	400	23290	11500	11790	28	400	53	600
35	16324	2267	41	400	12519	10687	1832	26	400	47	600
36	19900	17206	50	400	25040	8700	16340	21	400	58	600
37	17986	203	45	400	11981	10715	1266	27	400	51	600
38	20300	16839	50	400	24533	14300	10233	35	400	51	600
39	16831	1186	42	400	12239	11177	1062	28	400	47	600
40	25100	11011	62	400	24160	7900	16260	19	400	62	600
41	18700	650	46	400	12649	10391	2258	26	400	52	600
42	23945	12148	60	400	23873	8700	15173	21	400	59	600
43	17500	2048	44	400	13084	11100	1984	27	400	25	1140
44	19900	18592	50	400	25634	14700	10934	36	400	27	1140
45	17965	642	45	400	12445	11111	1334	28	400	47	600
46	21500	16951	54	400	25459	13500	11959	33	400	49	600
47	17500	884	43	400	12262	11111	1151	28	400	69	400
48	17900	19485	44	400	24836	11975	12861	30	400	78	400
49	17900	30	45	400	11943	9925	2018	25	400	49	600
50	18700	18597	46	400	25272	13900	11372	35	400	46	600
51	16330	1578	41	400	12141	11861	280	30	400	71	400
52	17667	18022	44	400	24072	13922	10150	35	400	76	400
53	17642	171	45	400	11946	11100	846	27	400	51	600
54	24229	12593	61	400	24238	10300	13938	25	400	57	600
55	15787	2549	40	400	12502	12184	318	30	400	62	600
56	17900	17876	45	400	24194	13691	10503	34	400	60	600
57	18038	281	45	400	12215	11115	1100	28	400	50	600
58	26300	9399	66	400	23775	5900	17875	14	400	68	600
59	17900	1982	45	400	13250	300	12950	0	0	53	600
60	27933	8749	70	400	24316	300	24016	0	0	72	600
61	17354	2650	44	400	13194	10780	2414	27	400	38	600
62	22300	13270	56	400	23756	12300	11456	30	400	43	600
63	18300	120	46	400	12104	11500	604	28	400	56	600
64	21900	15669	55	400	24927	13100	11827	32	400	56	600
65	17987	402	45	400	12274	11500	774	29	400	45	600
66	24300	12480	61	400	24394	9900	14494	24	400	57	600
67	16452	2374	42	400	12694	11513	1181	29	400	45	600
68	23500	13122	58	400	24371	10700	13671	27	400	57	600
69	17011	1227	43	400	12172	11405	767	29	400	51	600
70	18300	20777	45	400	26167	13900	12267	35	400	45	600

Scenario	PM Sale	PM Shortage	PM Contract	PM Amount	PN Demand	PN Sale	PN Shortage	PN Contract	PN Amount	MM Contract	MM Amount
71	17119	1258	43	400	12164	11100	1064	28	400	40	600
72	17900	19867	45	400	25306	15100	10206	37	400	39	600
73	17246	1879	43	400	12746	11651	1095	29	400	49	600
74	21100	15367	52	400	24526	12700	11826	32	400	53	600
75	17500	665	44	400	12079	10700	1379	27	400	46	600
76	23100	13594	58	400	24373	10700	13673	26	400	58	600
77	16095	1817	41	400	11963	11679	284	29	400	46	600
78	21900	13915	55	400	23503	11900	11603	29	400	54	600
79	17082	867	43	400	12031	11460	571	29	400	50	600
80	20300	15778	50	400	24446	11113	13333	28	400	49	600
81	17836	975	45	400	12591	10226	2365	25	400	47	600
82	20300	17879	50	400	25326	11500	13826	29	400	49	600
83	17606	248	44	400	11942	11052	890	28	400	51	600
84	22746	14163	57	400	24832	9900	14932	24	400	55	600
85	17230	980	43	400	12030	11879	151	29	400	50	600
86	19722	17674	50	400	25066	13100	11966	32	400	47	600
87	16967	1000	43	400	11982	11576	406	29	400	45	600
88	21623	16523	54	400	25201	11900	13301	29	400	52	600
89	17118	572	43	400	11796	11792	4	30	400	49	600
90	21522	15116	54	400	24218	13500	10718	33	400	49	600
91	17245	708	44	400	11994	11289	705	28	400	45	600
92	23842	14796	60	400	25668	9900	15768	24	400	59	600
93	18276	163	46	400	12491	12279	212	31	400	49	600
94	24473	13332	61	400	24828	19500	5328	49	400	59	600
95	17500	588	44	400	11767	11100	667	28	400	50	600
96	21100	16493	52	400	24963	13500	11463	33	400	52	600
97	1100	17025	2	400	11931	1500	10431	3	400	2	600
98	1500	36182	3	400	25250	1500	23750	3	400	2	600
100	27135	3158	48	570	20223	18825	1398	39	475	24	1140
101	29940	31532	53	570	41351	15500	25851	33	475	27	1140
102	15346	67	28	570	10328	10279	49	23	475	14	1140
103	29407	1778	53	570	20388	15975	4413	33	475	24	1140
104	31650	27794	55	570	39380	14852	24528	32	475	27	1140
105	14694	570	27	570	10151	10151	0	22	475	14	1140
106	28375	3543	71	400	21271	16700	4571	43	400	23	1140
107	32700	27807	83	400	40239	13500	26739	33	400	29	1140
108	15228	0	39	400	9981	9981	0	26	400	12	1140
109	28491	1722	71	400	20341	17486	2855	44	400	27	1140
110	31100	29550	79	400	40905	15500	25405	38	400	28	1140
111	14756	182	38	400	10068	10068	0	26	400	17	1140
112	29940	1544	53	570	20951	19631	1320	42	475	52	600

Scenario	PM Sale	PM Shortage	PM Contract	PM Amount	PN Demand	PN Sale	PN Shortage	PN Contract	PN Amount	MM Contract	MM Amount
113	48828	11452	86	570	40707	36278	4429	76	475	84	600
114	29942	296	76	400	19874	19807	67	50	400	51	600
115	47347	19417	119	400	44194	35500	8694	89	400	82	600
116	30460	746	78	400	20797	20417	380	52	400	53	600
117	49922	15902	125	400	43797	39366	4431	100	400	85	600
118	29100	313	74	400	19753	19642	111	50	400	57	600
119	50700	11528	127	400	42000	37794	4206	95	400	86	600
120	30859	270	79	400	20704	20607	97	53	400	52	600
121	54585	6882	137	400	41178	38876	2302	98	400	86	600
122	26321	4120	67	400	20246	19500	746	50	400	44	600
123	29020	32565	73	400	41113	17100	24013	42	400	54	600
124	27500	3399	68	400	20781	19171	1610	49	400	47	600
125	29100	32605	72	400	41393	15900	25493	39	400	55	600
126	28133	2500	72	400	20404	18300	2104	45	400	46	600
127	26700	33397	67	400	40193	23100	17093	57	400	43	600
128	14839	1027	37	400	15823	13735	2088	34	400	41	600
129	20300	9743	50	400	29894	13910	15984	35	400	51	600
130	14343	2079	36	400	16095	13865	2230	35	400	38	600
131	21122	9225	53	400	30246	11900	18346	29	400	50	600
132	14711	1112	37	400	15634	13340	2294	33	400	24	950
133	18070	13025	45	400	30979	16700	14279	41	400	29	950
134	15108	796	38	400	16168	13900	2268	35	400	26	950
135	19100	11083	48	400	29793	13500	16293	33	400	32	950
136	14700	663	36	400	15606	13357	2249	33	400	66	400
137	17519	13307	44	400	30946	11500	19446	28	400	75	400
138	14991	53	38	400	15021	13725	1296	34	400	67	400
139	19100	13188	48	400	31971	11900	20071	29	400	77	400
140	14851	571	37	400	15357	14051	1306	35	400	42	600
141	18700	11682	46	400	30385	13677	16708	34	400	45	600
142	14713	839	37	400	15347	13003	2344	32	400	62	400
143	21900	8605	55	400	30704	7900	22804	20	400	92	400
144	14957	316	53	285	15020	13224	1796	77	171	41	600
145	19540	11155	68	285	31062	12832	18230	75	171	48	600
146	17230	1740	43	400	12463	11900	563	30	400	49	600
147	20886	16785	52	400	25304	12700	12604	32	400	53	600
148	17837	323	45	400	12133	12057	76	30	400	44	600
149	24700	12659	63	400	24942	14300	10642	35	400	52	600
150	29674	603	76	400	20117	19714	403	51	400	48	600
151	56911	6059	144	400	41697	38504	3193	97	400	87	600
152	29143	631	73	400	19822	17355	2467	45	400	46	600
153	40132	20185	101	400	39801	12300	27501	30	400	63	600

Scenario	PM Sale	PM Shortage	PM Contract	PM Amount	PN Demand	PN Sale	PN Shortage	PN Contract	PN Amount	MM Contract	MM Amount
155	17187	2128	43	400	12952	12315	637	31	400	46	600
156	19100	18164	48	400	25031	18490	6541	46	400	42	600
157	18300	637	46	400	12382	11500	882	29	400	49	600
158	22300	14982	56	400	25249	11500	13749	28	400	55	600
159	16700	2100	42	400	12510	12070	440	30	400	48	600
160	16809	21350	42	400	25718	16887	8831	42	400	45	600
161	16183	1602	41	400	12020	11785	235	29	400	44	600
162	17900	18187	44	400	24045	15100	8945	38	400	44	600
163	15892	2089	40	400	11958	4300	7658	11	400	44	600
164	20700	15165	51	400	23980	1900	22080	4	400	51	600
165	18079	39	45	400	12152	11190	962	28	400	51	600
166	18700	18211	47	400	24397	15500	8897	39	400	45	600
167	18067	733	46	400	12176	11100	1076	27	400	49	600
168	21281	16124	53	400	24665	13500	11165	33	400	49	600
169	16652	1034	42	400	11728	11500	228	29	400	49	600
170	20700	16152	51	400	24711	11900	12811	30	400	51	600
171	18324	501	46	400	12480	10300	2180	25	400	54	600
172	17132	19408	43	400	24125	16700	7425	41	400	45	600
173	16698	1436	42	400	12232	11930	302	30	400	49	600
174	19500	17413	48	400	24648	14314	10334	36	400	43	600
175	17252	872	50	342	12034	11647	387	68	171	43	600
176	24582	13038	71	342	25270	9363	15907	54	171	57	600
177	17774	505	45	400	12094	10650	1444	27	400	51	600
178	22573	14729	57	400	24941	11500	13441	28	400	55	600
180	17942	628	45	400	12505	9900	2605	25	400	26	1140
181	23272	12713	58	400	24057	8300	15757	20	400	32	1140
182	14782	2238	37	400	16791	13500	3291	34	400	39	600
183	19100	11784	48	400	30751	15900	14851	40	400	48	600
190	17500	863	43	400	12201	11500	701	28	400	84	400
191	16583	1231	42	400	12024	11900	124	29	400	80	400
192	16300	2020	40	400	12331	12441	-110	31	400	81	400
193	16157	1940	40	400	11868	12700	-832	32	400	75	400
194	16300	2372	40	400	12320	11991	329	30	400	88	400
195	19125	-1160	48	400	11918	11100	818	27	400	93	400
196	17100	2638	42	400	13010	12327	683	31	400	77	400
197	18097	540	45	400	12376	11900	476	29	400	85	400
198	17100	2599	42	400	13223	12895	328	32	400	74	400
199	16300	2440	41	400	12348	12908	-560	32	400	78	400
201	17637	1307	44	400	12599	12326	273	31	400	57	400
202	16300	1905	40	400	12119	12300	-181	31	400	52	400
203	15598	2945	39	400	12334	12525	-191	31	400	55	400

Scenario	PM Sale	PM Shortage	PM Contract	PM Amount	PN Demand	PN Sale	PN Shortage	PN Contract	PN Amount	MM Contract	MM Amount
204	15900	2004	40	400	11842	12700	-858	32	400	51	400
205	17090	1725	42	400	12500	13900	-1400	35	400	58	400
206	18315	52	46	400	12125	12300	-175	31	400	60	400
207	17900	633	44	400	12405	11100	1305	28	400	53	400
208	16300	1975	41	400	12172	13500	-1328	34	400	51	400
209	17100	1356	42	400	12306	12046	260	30	400	51	400
210	16336	2726	41	400	12717	12300	417	31	400	59	400
212	23206	2035	49	475	25253	24525	728	51	475	50	475
213	23455	1522	49	475	25243	24050	1193	51	475	53	475
214	23590	1788	50	475	25643	24050	1593	50	475	45	475
215	23100	1371	49	475	24789	24050	739	50	475	59	475
216	24525	264	51	475	24548	24050	498	50	475	57	475
217	23688	1959	50	475	25727	24050	1677	50	475	51	475
218	24117	1950	51	475	25833	23342	2491	49	475	53	475
219	23575	2984	50	475	26664	23616	3048	50	475	47	475
220	23802	1363	50	475	25042	23218	1824	49	475	46	475
221	23575	3143	49	475	26476	24672	1804	52	475	46	475
222	29100	2155	72	400	20867	17768	3099	45	400	50	600
223	35900	24865	91	400	40632	12700	27932	31	400	54	600
224	29100	1515	74	400	20619	17522	3097	44	400	45	600
225	31741	27767	79	400	40286	14700	25586	36	400	53	600
226	17100	13343	44	400	20144	6700	13444	16	400	27	600
227	20580	37618	51	400	38942	4300	34642	10	400	35	600

Note:

ML Contract – the total contracts from Mokia to London
ML Amount – the order amount in an ML contract
NM Contract – the total contracts from Notorola to Markham
NM Amount – the order amount in an NM contract
NL Contract – the total contracts from Notorola to London
NL Amount – the order amount in an NL contract
MHM Contract – the total contracts from Markham to Housing for Morkia Housing
MHM Amount – the order amount in an MHM contract
MHN Contract – the total contracts from Markham to Housing for Notorola Housing
MHN Amount – the order amount in an MHN contract

Scenario	ML Contract	ML Amount	NM Contract	NM Amount	NL Contract	NL Amount	MHM Contract	MHM Amount	MHN Contract	MHN Amount
1	27	1140	25	760	22	760	33	760	26	760
2	35	1140	8	760	9	760	53	760	7	760
3	12	1140	14	760	13	760	24	760	15	760
4	28	1140	18	760	24	760	38	760	18	760
5	27	1140	24	760	16	760	41	760	23	760
6	14	1140	12	760	16	760	22	760	12	760
7	25	1140	20	760	24	760	41	760	20	760
8	32	1140	17	760	15	760	43	760	17	760
9	13	1140	15	760	13	760	24	760	16	760
10	25	1140	23	760	21	760	41	760	23	760
11	33	1140	12	760	13	760	48	760	11	760
12	12	1140	15	760	13	760	25	760	16	760
13	24	1140	22	760	22	760	38	760	23	760
14	29	1140	18	760	14	760	47	760	17	760
15	16	1140	15	760	12	760	19	760	16	760
16	46	600	33	600	31	600	46	600	33	600
17	43	600	40	600	40	600	36	600	39	600
18	26	600	19	600	16	600	28	600	19	600
19	41	600	35	600	31	600	58	600	35	600
20	80	600	41	600	50	600	82	600	41	600
21	27	600	20	600	17	600	28	600	20	600
22	48	600	31	600	29	600	49	600	31	600
23	57	600	22	600	23	600	55	600	22	600
24	25	600	22	600	13	600	28	600	22	600
25	50	600	31	600	32	600	33	760	25	760
26	61	600	18	600	18	600	46	760	14	760
27	28	600	12	600	23	600	20	760	10	760

Scenario	ML Contract	ML Amount	NM Contract	NM Amount	NL Contract	NL Amount	MHM Contract	MHM Amount	MHN Contract	MHN Amount
29	51	600	31	600	32	600	45	600	30	600
30	55	600	23	600	21	600	58	600	21	600
31	51	600	29	600	30	600	47	600	29	600
32	50	600	27	600	32	600	48	600	25	600
33	53	600	31	600	30	600	44	600	30	600
34	54	600	27	600	24	600	53	600	25	600
35	51	600	30	600	29	600	46	600	29	600
36	61	600	19	600	21	600	57	600	18	600
37	49	600	31	600	27	600	50	600	30	600
38	48	600	30	600	29	600	50	600	29	600
39	49	600	33	600	28	600	46	600	32	600
40	60	600	19	600	16	600	61	600	18	600
41	48	600	30	600	27	600	51	600	30	600
42	58	600	23	600	19	600	58	600	21	600
43	25	1140	26	760	21	760	47	600	33	600
44	24	1140	25	760	23	760	51	600	31	600
45	52	600	24	760	22	760	46	600	30	600
46	52	600	22	760	23	760	48	600	27	600
47	77	400	50	400	40	400	45	600	33	600
48	76	400	42	400	41	400	51	600	28	600
49	53	600	45	400	36	400	49	600	28	600
50	43	600	49	400	50	400	46	600	33	600
51	67	400	28	600	36	600	46	600	28	600
52	69	400	33	600	30	600	50	600	32	600
53	47	600	33	600	26	600	50	600	33	600
54	58	600	21	600	22	600	56	600	19	600
55	50	600	46	600	37	600	48	600	36	600
56	61	600	38	600	36	600	46	600	32	600
57	48	600	34	600	39	600	50	600	27	600
58	64	600	19	600	15	600	68	600	13	600
59	48	600	0	0	0	0	53	600	0	0
60	67	600	0	0	0	0	72	600	0	0
61	58	600	0	0	59	600	38	600	0	0
62	60	600	0	0	54	600	43	600	0	0
63	41	600	58	600	0	0	55	600	57	600
64	45	600	56	600	0	0	56	600	55	600
65	51	600	32	600	30	600	44	600	31	600
66	59	600	22	600	21	600	56	600	22	600
67	46	600	30	600	35	600	44	600	29	600
68	52	600	24	600	24	600	57	600	24	600
69	45	600	33	600	30	600	50	600	32	600

Scenario	ML Contract	ML Amount	NM Contract	NM Amount	NL Contract	NL Amount	MHM Contract	MHM Amount	MHN Contract	MHN Amount
70	43	600	38	600	34	600	43	600	37	600
71	53	600	29	600	34	600	40	600	29	600
72	46	600	32	600	40	600	38	600	31	600
73	43	600	38	600	27	600	48	600	38	600
74	48	600	32	600	26	600	52	600	31	600
75	47	600	31	600	28	600	36	760	25	760
76	51	600	23	600	25	600	45	760	18	760
77	45	600	30	600	35	600	37	760	23	760
78	52	600	22	600	30	600	42	760	16	760
79	43	600	29	600	36	600	49	600	29	600
80	51	600	30	600	27	600	48	600	30	600
81	52	600	24	600	33	600	25	1140	19	760
82	53	600	25	600	31	600	26	1140	20	760
83	48	600	28	600	31	600	51	600	28	600
84	56	600	22	600	24	600	55	600	21	600
85	47	600	29	600	30	600	50	600	28	600
86	50	600	33	600	28	600	46	600	31	600
87	51	600	29	600	35	600	44	600	28	600
88	49	600	29	600	28	600	51	600	28	600
89	48	600	36	600	29	600	48	600	35	600
90	55	600	32	600	27	600	48	600	30	600
91	50	600	37	600	26	600	45	600	35	600
92	58	600	20	600	21	600	58	600	19	600
93	54	600	33	600	35	600	49	600	33	600
94	55	600	45	600	46	600	58	600	44	600
95	48	600	31	600	30	600	50	600	30	600
96	47	600	29	600	31	600	51	600	28	600
97	2	600	3	600	3	600	1	600	1	600
98	3	600	3	600	2	600	0	0	1	600
100	25	1140	22	760	27	760	36	760	22	760
101	26	1140	21	760	22	760	41	760	21	760
102	15	1140	12	760	17	760	22	760	13	760
103	29	1140	23	760	18	760	37	760	23	760
104	27	1140	21	760	19	760	41	760	22	760
105	14	1140	14	760	15	760	21	760	15	760
106	27	1140	20	760	25	760	34	760	20	760
107	29	1140	17	760	18	760	44	760	16	760
108	17	1140	17	760	12	760	19	760	18	760
109	23	1140	24	760	23	760	40	760	25	760
110	27	1140	19	760	20	760	42	760	19	760
111	11	1140	14	760	15	760	27	760	15	760

Scenario	ML Contract	ML Amount	NM Contract	NM Amount	NL Contract	NL Amount	MHM Contract	MHM Amount	MHN Contract	MHN Amount
112	50	600	39	600	29	600	51	600	38	600
113	85	600	65	600	49	600	84	600	65	600
114	51	600	29	600	39	600	50	600	29	600
115	82	600	62	600	56	600	81	600	62	600
116	53	600	35	600	36	600	52	600	35	600
117	84	600	68	600	63	600	84	600	68	600
118	42	600	35	600	33	600	56	600	34	600
119	85	600	67	600	60	600	85	600	67	600
120	53	600	35	600	36	600	52	600	34	600
121	82	600	59	600	69	600	85	600	59	600
122	47	600	35	600	31	600	44	600	35	600
123	49	600	25	600	30	600	54	600	24	600
124	44	600	32	600	35	600	45	600	31	600
125	51	600	26	600	26	600	54	600	24	600
126	51	600	29	600	32	600	45	600	28	600
127	43	600	38	600	36	600	42	600	37	600
128	44	600	37	600	35	600	40	600	37	600
129	46	600	29	600	31	600	50	600	28	600
130	41	600	37	600	42	600	37	600	36	600
131	51	600	28	600	29	600	49	600	26	600
132	28	950	24	950	23	950	37	600	38	600
133	27	950	20	950	22	950	45	600	32	600
134	28	950	38	600	33	600	40	600	37	600
135	31	950	26	600	31	600	51	600	24	600
136	55	400	54	400	57	400	43	600	36	600
137	72	400	46	400	46	400	48	600	30	600
138	59	400	38	600	35	600	44	600	37	600
139	78	400	26	600	28	600	52	600	24	600
140	38	600	59	400	55	400	41	600	39	600
141	45	600	55	400	46	400	44	600	36	600
142	63	400	56	400	54	400	41	600	37	600
143	86	400	31	400	32	400	60	600	19	600
144	44	600	38	600	34	600	40	600	38	600
145	48	600	29	600	33	600	47	600	28	600
146	45	600	35	600	30	600	49	600	34	600
147	48	600	27	600	31	600	52	600	26	600
148	47	600	32	600	33	600	43	600	31	600
149	50	600	30	600	26	600	52	600	29	600
150	53	600	32	600	35	600	47	600	32	600
151	86	600	67	600	59	600	86	600	66	600
152	50	600	28	600	32	600	45	600	28	600

Scenario	ML Contract	ML Amount	NM Contract	NM Amount	NL Contract	NL Amount	MHM Contract	MHM Amount	MHN Contract	MHN Amount
153	58	600	17	600	20	600	62	600	15	600
155	46	600	30	600	38	600	45	600	30	600
156	39	600	40	600	42	600	41	600	39	600
157	51	600	29	600	31	600	47	600	28	600
158	54	600	26	600	26	600	54	600	25	600
159	44	600	33	600	34	600	47	600	32	600
160	40	600	37	600	39	600	44	600	37	600
161	48	600	29	600	36	600	44	600	28	600
162	42	600	36	600	36	600	44	600	34	600
163	42	600	13	600	11	600	43	600	11	600
164	52	600	3	600	3	600	49	600	1	600
165	49	600	30	600	26	600	50	600	30	600
166	46	600	35	600	34	600	45	600	33	600
167	50	600	28	600	32	600	48	600	27	600
168	47	600	29	600	33	600	47	600	28	600
169	43	600	32	600	33	600	48	600	31	600
170	50	600	28	600	28	600	50	600	28	600
171	49	600	26	600	27	600	53	600	25	600
172	35	600	38	600	40	600	44	600	37	600
173	41	600	29	600	35	600	48	600	29	600
174	48	600	35	600	30	600	43	600	34	600
175	48	600	31	600	32	600	43	600	31	600
176	57	600	23	600	22	600	57	600	22	600
177	48	600	34	600	24	600	50	600	33	600
178	54	600	24	600	25	600	54	600	22	600
180	28	1140	29	600	25	600	50	600	29	600
181	29	1140	19	600	21	600	61	600	18	600
182	44	600	21	950	26	950	38	600	34	600
183	41	600	22	950	21	950	47	600	35	600
190	58	400	70	400	20	400	55	600	45	600
191	60	400	57	400	38	400	52	600	37	600
192	57	400	61	400	35	400	53	600	41	600
193	58	400	69	400	33	400	50	600	45	600
194	52	400	65	400	29	400	57	600	44	600
195	57	400	56	400	27	400	61	600	37	600
196	54	400	72	400	31	400	50	600	48	600
197	58	400	67	400	25	400	55	600	44	600
198	60	400	61	400	40	400	49	600	41	600
199	55	400	70	400	32	400	51	600	46	600
201	82	400	36	400	60	400	57	400	36	400
202	88	400	25	400	69	400	52	400	25	400

Scenario	ML Contract	ML Amount	NM Contract	NM Amount	NL Contract	NL Amount	MHM Contract	MHM Amount	MHN Contract	MHN Amount
203	77	400	25	400	75	400	55	400	25	400
204	77	400	28	400	75	400	51	400	28	400
205	80	400	31	400	64	400	58	400	31	400
206	83	400	35	400	57	400	60	400	35	400
207	86	400	32	400	62	400	53	400	32	400
208	80	400	30	400	71	400	51	400	30	400
209	86	400	34	400	61	400	51	400	34	400
210	74	400	22	400	77	400	59	400	22	400
212	49	475	51	475	48	475	50	475	51	475
213	46	475	49	475	53	475	53	475	49	475
214	54	475	45	475	55	475	45	475	45	475
215	41	475	52	475	48	475	59	475	52	475
216	44	475	44	475	54	475	57	475	44	475
217	48	475	51	475	49	475	51	475	51	475
218	47	475	53	475	44	475	53	475	53	475
219	52	475	50	475	50	475	47	475	50	475
220	53	475	53	475	46	475	46	475	53	475
221	53	475	49	475	52	475	46	475	49	475
222	46	600	29	600	32	600	49	600	29	600
223	64	600	20	600	20	600	54	600	19	600
224	54	600	28	600	31	600	44	600	27	600
225	57	600	25	600	23	600	52	600	23	600
226	32	600	10	600	12	600	26	600	9	600
227	34	600	8	600	7	600	34	600	7	600

Note:

LHM Contract – the total contracts from London to Housing for Morkia Housing

LHM Amount – the order amount in a LHM contract

LHN Contract – the total contracts from London to Housing for Notorola Housing

LHN Amount – the order amount in a LHN contract

MPM Contract – the total contracts from Markham to PCBA for Morkia House

MPM Amount – the order amount in an MPM contract

MPN Contract – the total contracts from Markham to PCBA for Notorola House

MPN Amount – the order amount in an MPN contract

LPM Contract – the total contracts from London to PCBA for Morkia House

LPM Amount – the order amount in a LPM contract

Scenario	LHM Contract	LHM Amount	LHN Contract	LHN Amount	MPM Contract	MPM Amount	MPN Contract	MPN Amount	LPM Contract	LPM Amount
1	41	760	23	760	32	760	26	760	40	760
2	54	760	8	760	53	760	8	760	53	760
3	19	760	14	760	24	760	15	760	19	760
4	42	760	24	760	38	760	19	760	42	760
5	41	760	15	760	41	760	24	760	41	760
6	22	760	17	760	22	760	12	760	22	760
7	37	760	24	760	42	760	19	760	38	760
8	48	760	15	760	43	760	16	760	48	760
9	20	760	13	760	24	760	16	760	20	760
10	37	760	22	760	40	760	23	760	37	760
11	50	760	12	760	48	760	12	760	50	760
12	19	760	14	760	25	760	16	760	19	760
13	36	760	23	760	38	760	23	760	36	760
14	43	760	13	760	47	760	18	760	43	760
15	25	760	13	760	19	760	16	760	25	760
16	45	600	30	600	46	600	33	600	45	600
17	42	600	39	600	35	600	39	600	41	600
18	26	600	16	600	28	600	19	600	26	600
19	42	600	32	600	58	600	35	600	42	600
20	80	600	51	600	82	600	41	600	80	600
21	28	600	18	600	28	600	20	600	28	600
22	48	600	29	600	49	600	30	600	47	600
23	56	600	23	600	54	600	22	600	56	600
24	25	600	13	600	28	600	22	600	25	600

Scenario	LHM Contract	LHM Amount	LHN Contract	LHN Amount	MPM Contract	MPM Amount	MPN Contract	MPN Amount	LPM Contract	LPM Amount
25	39	760	26	760	32	760	24	760	39	760
26	48	760	13	760	46	760	14	760	48	760
27	23	760	19	760	20	760	10	760	23	760
29	50	600	31	600	45	600	30	600	50	600
30	54	600	19	600	58	600	22	600	54	600
31	50	600	29	600	47	600	29	600	50	600
32	49	600	30	600	48	600	26	600	49	600
33	52	600	28	600	44	600	30	600	52	600
34	53	600	23	600	53	600	26	600	53	600
35	51	600	28	600	46	600	29	600	51	600
36	61	600	20	600	56	600	18	600	60	600
37	49	600	26	600	50	600	31	600	49	600
38	48	600	29	600	50	600	29	600	48	600
39	48	600	28	600	46	600	33	600	48	600
40	59	600	16	600	61	600	18	600	58	600
41	47	600	26	600	51	600	30	600	47	600
42	58	600	17	600	58	600	22	600	58	600
43	48	600	26	600	48	600	33	600	48	600
44	45	600	29	600	50	600	31	600	45	600
45	52	600	27	600	47	600	30	600	52	600
46	52	600	28	600	49	600	27	600	52	600
47	50	600	27	600	46	600	33	600	50	600
48	50	600	27	600	51	600	27	600	50	600
49	53	600	23	600	49	600	29	600	53	600
50	42	600	34	600	46	600	32	600	42	600
51	44	600	36	600	47	600	28	600	44	600
52	45	600	29	600	50	600	31	600	45	600
53	47	600	25	600	51	600	32	600	47	600
54	57	600	20	600	56	600	20	600	57	600
55	41	600	27	600	48	600	37	600	41	600
56	47	600	30	600	46	600	31	600	47	600
57	48	600	30	600	50	600	28	600	48	600
58	63	600	9	600	68	600	14	600	63	600
59	48	600	0	0	53	600	0	0	48	600
60	67	600	0	0	72	600	0	0	67	600
61	57	600	59	600	38	600	0	0	57	600
62	59	600	53	600	43	600	0	0	60	600
63	41	600	0	0	55	600	56	600	41	600
64	45	600	0	0	55	600	55	600	45	600
65	50	600	29	600	43	600	31	600	49	600
66	58	600	20	600	55	600	22	600	58	600

Scenario	LHM Contract	LHM Amount	LHN Contract	LHN Amount	MPM Contract	MPM Amount	MPN Contract	MPN Amount	LPM Contract	LPM Amount
67	47	600	35	600	45	600	29	600	47	600
68	52	600	24	600	56	600	24	600	52	600
69	45	600	29	600	50	600	32	600	44	600
70	42	600	33	600	44	600	36	600	42	600
71	53	600	34	600	40	600	29	600	52	600
72	46	600	39	600	38	600	30	600	46	600
73	42	600	27	600	47	600	38	600	41	600
74	47	600	25	600	52	600	31	600	47	600
75	37	760	23	760	36	760	25	760	37	760
76	40	760	19	760	46	760	18	760	40	760
77	44	600	35	600	36	760	23	760	43	600
78	51	600	28	600	42	760	17	760	51	600
79	42	600	35	600	50	600	29	600	42	600
80	50	600	26	600	47	600	30	600	49	600
81	51	600	32	600	25	1140	19	760	51	600
82	53	600	29	600	25	1140	19	760	53	600
83	47	600	30	600	51	600	27	600	47	600
84	55	600	23	600	55	600	22	600	56	600
85	47	600	29	600	50	600	29	600	47	600
86	49	600	26	600	46	600	32	600	49	600
87	50	600	33	600	44	600	28	600	50	600
88	48	600	27	600	52	600	28	600	48	600
89	47	600	29	600	49	600	34	600	47	600
90	55	600	26	600	48	600	31	600	54	600
91	50	600	25	600	45	600	36	600	49	600
92	57	600	20	600	59	600	19	600	57	600
93	54	600	34	600	49	600	33	600	54	600
94	55	600	45	600	58	600	44	600	55	600
95	47	600	28	600	49	600	30	600	46	600
96	46	600	30	600	52	600	28	600	46	600
97	0	0	1	600	0	0	1	600	1	600
98	1	600	1	600	1	600	1	600	1	600
100	38	760	26	760	36	760	22	760	38	760
101	39	760	21	760	42	760	21	760	39	760
102	22	760	18	760	22	760	13	760	22	760
103	44	760	17	760	37	760	23	760	44	760
104	40	760	19	760	41	760	21	760	40	760
105	22	760	16	760	21	760	15	760	22	760
106	41	760	25	760	34	760	20	760	41	760
107	43	760	17	760	44	760	17	760	44	760
108	26	760	12	760	19	760	18	760	26	760

Scenario	LHM Contract	LHM Amount	LHN Contract	LHN Amount	MPM Contract	MPM Amount	MPN Contract	MPN Amount	LPM Contract	LPM Amount
109	34	760	24	760	40	760	25	760	34	760
110	41	760	20	760	41	760	19	760	40	760
111	16	760	15	760	27	760	15	760	16	760
112	50	600	30	600	51	600	38	600	50	600
113	85	600	50	600	84	600	65	600	85	600
114	52	600	39	600	50	600	29	600	52	600
115	83	600	57	600	81	600	62	600	83	600
116	54	600	37	600	52	600	35	600	54	600
117	84	600	64	600	84	600	68	600	84	600
118	43	600	34	600	56	600	34	600	43	600
119	85	600	61	600	85	600	67	600	85	600
120	53	600	36	600	52	600	34	600	53	600
121	82	600	69	600	85	600	59	600	82	600
122	46	600	31	600	44	600	35	600	46	600
123	48	600	28	600	54	600	24	600	48	600
124	44	600	35	600	46	600	31	600	44	600
125	50	600	24	600	54	600	25	600	50	600
126	50	600	31	600	46	600	28	600	50	600
127	42	600	35	600	42	600	37	600	42	600
128	44	600	34	600	40	600	37	600	44	600
129	45	600	31	600	49	600	28	600	44	600
130	40	600	42	600	37	600	36	600	40	600
131	50	600	27	600	49	600	27	600	50	600
132	45	600	36	600	37	600	38	600	44	600
133	43	600	35	600	44	600	32	600	42	600
134	44	600	33	600	40	600	36	600	44	600
135	48	600	29	600	51	600	25	600	48	600
136	36	600	38	600	43	600	36	600	36	600
137	47	600	29	600	49	600	30	600	48	600
138	39	600	34	600	43	600	37	600	38	600
139	52	600	26	600	52	600	25	600	52	600
140	37	600	37	600	41	600	38	600	37	600
141	45	600	30	600	44	600	35	600	45	600
142	42	600	35	600	41	600	36	600	42	600
143	56	600	21	600	60	600	19	600	56	600
144	43	600	33	600	39	600	38	600	42	600
145	48	600	32	600	47	600	27	600	48	600
146	44	600	29	600	48	600	34	600	43	600
147	47	600	30	600	52	600	27	600	46	600
148	46	600	32	600	43	600	32	600	46	600
149	49	600	25	600	51	600	29	600	49	600

Scenario	LHM Contract	LHM Amount	LHN Contract	LHN Amount	MPM Contract	MPM Amount	MPN Contract	MPN Amount	LPM Contract	LPM Amount
150	54	600	36	600	47	600	32	600	54	600
151	87	600	60	600	86	600	66	600	87	600
152	49	600	31	600	45	600	28	600	48	600
153	57	600	18	600	62	600	16	600	57	600
155	46	600	37	600	44	600	29	600	46	600
156	37	600	41	600	41	600	38	600	38	600
157	50	600	31	600	48	600	28	600	50	600
158	53	600	24	600	54	600	25	600	53	600
159	42	600	34	600	48	600	33	600	43	600
160	39	600	38	600	43	600	36	600	38	600
161	47	600	35	600	44	600	27	600	47	600
162	41	600	35	600	44	600	35	600	41	600
163	41	600	9	600	44	600	12	600	41	600
164	51	600	1	600	50	600	2	600	51	600
165	48	600	26	600	49	600	30	600	47	600
166	45	600	32	600	44	600	34	600	44	600
167	49	600	31	600	49	600	27	600	49	600
168	46	600	33	600	48	600	28	600	46	600
169	42	600	31	600	48	600	32	600	42	600
170	50	600	27	600	49	600	28	600	50	600
171	49	600	26	600	54	600	25	600	49	600
172	34	600	39	600	44	600	36	600	34	600
173	41	600	35	600	48	600	29	600	41	600
174	47	600	30	600	43	600	34	600	47	600
175	48	600	32	600	42	600	31	600	48	600
176	56	600	22	600	56	600	22	600	56	600
177	48	600	24	600	50	600	33	600	47	600
178	54	600	24	600	54	600	23	600	54	600
180	53	600	24	600	49	600	29	600	52	600
181	55	600	20	600	61	600	17	600	55	600
182	42	600	41	600	38	600	34	600	43	600
183	41	600	33	600	47	600	35	600	40	600
190	58	400	20	400	55	600	46	600	58	400
191	60	400	38	400	52	600	37	600	60	400
192	57	400	35	400	53	600	41	600	57	400
193	58	400	33	400	50	600	45	600	58	400
194	52	400	29	400	56	600	44	600	52	400
195	57	400	27	400	62	600	37	600	57	400
196	54	400	31	400	51	600	48	600	54	400
197	58	400	25	400	56	600	44	600	58	400
198	60	400	40	400	49	600	41	600	60	400

Scenario	LHM Contract	LHM Amount	LHN Contract	LHN Amount	MPM Contract	MPM Amount	MPN Contract	MPN Amount	LPM Contract	LPM Amount
199	55	400	32	400	51	600	46	600	55	400
201	53	600	40	600	57	400	36	400	53	600
202	58	600	46	600	52	400	25	400	58	600
203	51	600	50	600	55	400	25	400	51	600
204	51	600	50	600	51	400	28	400	51	600
205	52	600	42	600	58	400	31	400	52	600
206	55	600	37	600	60	400	35	400	55	600
207	56	600	41	600	53	400	32	400	56	600
208	52	600	47	600	51	400	30	400	52	600
209	56	600	41	600	51	400	34	400	55	600
210	48	600	50	600	59	400	22	400	48	600
212	49	475	48	475	50	475	51	475	49	475
213	46	475	53	475	53	475	49	475	46	475
214	54	475	55	475	45	475	45	475	54	475
215	41	475	48	475	59	475	52	475	41	475
216	44	475	54	475	57	475	44	475	44	475
217	48	475	49	475	51	475	51	475	48	475
218	47	475	44	475	53	475	53	475	47	475
219	52	475	50	475	47	475	50	475	52	475
220	53	475	46	475	46	475	53	475	53	475
221	53	475	52	475	46	475	49	475	53	475
222	45	600	31	600	48	600	29	600	44	600
223	63	600	19	600	53	600	19	600	63	600
224	53	600	31	600	43	600	27	600	52	600
225	56	600	21	600	52	600	24	600	56	600
226	32	600	11	600	26	600	8	600	32	600
227	33	600	6	600	33	600	7	600	32	600

Note:

LPN Contract – the total contracts from London to PCBA for Notorola Housing
LPN Amount – the order amount in a LPN contract
HM Contract – the total contract from Housing to Metal
HM Amount – the order amount in an HM contract
HS Contract – the total contract from Housing to Silicon
HS Amount – the order amount in a HS contract
PCM Contract – the total contract from PCBA to Metal
PCM Amount – the order amount in a PCM contract
PCS Contract – the total contract from PCBA to Silicon
PCS Amount – the order amount in a PCS contract

Scenario	LPN Contract	LPN Amount	HM Contract	HM Amount	HS Contract	HS Amount	PCM Contract	PCM Amount	PCS Contract	PCS Amount
1	23	760	34	2850	34	2850	32	2850	32	2850
2	9	760	33	2850	33	2850	33	2850	33	2850
3	14	760	20	2850	20	2850	20	2850	20	2850
4	24	760	32	2850	32	2850	34	2850	34	2850
5	16	760	32	2850	32	2850	34	2850	34	2850
6	17	760	21	2850	21	2850	21	2850	21	2850
7	23	760	33	2850	33	2850	33	2850	33	2850
8	14	760	34	2850	34	2850	32	2850	32	2850
9	13	760	21	2850	21	2850	21	2850	21	2850
10	22	760	33	2850	33	2850	33	2850	33	2850
11	13	760	33	2850	33	2850	33	2850	33	2850
12	14	760	21	2850	21	2850	21	2850	21	2850
13	23	760	33	2850	33	2850	33	2850	33	2850
14	14	760	32	2850	32	2850	34	2850	34	2850
15	13	760	21	2850	21	2850	21	2850	21	2850
16	30	600	33	2850	33	2850	33	2850	33	2850
17	39	600	33	2850	33	2850	33	2850	33	2850
18	16	600	20	2850	20	2850	20	2850	20	2850
19	32	600	36	2850	36	2850	37	2850	37	2850
20	51	600	55	2850	55	2850	56	2850	56	2850
21	18	600	22	2850	22	2850	21	2850	21	2850
22	29	600	33	2850	33	2850	33	2850	33	2850
23	23	600	33	2850	33	2850	33	2850	33	2850
24	13	600	20	2850	20	2850	20	2850	20	2850
25	25	760	33	2850	33	2850	33	2850	33	2850
26	14	760	32	2850	32	2850	34	2850	34	2850
27	19	760	21	2850	21	2850	21	2850	21	2850

Scenario	LPN Contract	LPN Amount	HM Contract	HM Amount	HS Contract	HS Amount	PCM Contract	PCM Amount	PCS Contract	PCS Amount
29	30	600	33	2850	33	2850	33	2850	33	2850
30	20	600	33	2850	33	2850	33	2850	33	2850
31	29	600	34	2850	34	2850	32	2850	32	2850
32	31	600	33	2850	33	2850	33	2850	33	2850
33	29	600	32	2850	32	2850	34	2850	34	2850
34	23	600	33	2850	33	2850	33	2850	33	2850
35	27	600	33	2850	33	2850	33	2850	33	2850
36	20	600	33	2850	33	2850	33	2850	33	2850
37	27	600	33	2850	33	2850	33	2850	33	2850
38	28	600	33	2850	33	2850	33	2850	33	2850
39	28	600	33	2850	33	2850	33	2850	33	2850
40	16	600	33	2850	33	2850	33	2850	33	2850
42	18	600	33	2850	33	2850	33	2850	33	2850
41	27	600	33	2850	33	2850	33	2850	33	2850
43	26	600	32	2850	32	2850	34	2850	34	2850
44	29	600	33	2850	33	2850	33	2850	33	2850
45	27	600	33	2850	33	2850	33	2850	33	2850
46	29	600	32	2850	32	2850	34	2850	34	2850
47	27	600	33	2850	33	2850	33	2850	33	2850
48	27	600	33	2850	33	2850	33	2850	33	2850
49	23	600	33	2850	33	2850	33	2850	33	2850
50	34	600	33	2850	33	2850	33	2850	33	2850
51	36	600	33	2850	33	2850	33	2850	33	2850
52	28	600	33	2850	33	2850	33	2850	33	2850
53	24	600	33	2850	33	2850	33	2850	33	2850
54	21	600	32	2850	32	2850	34	2850	34	2850
55	28	600	33	2850	33	2850	33	2850	33	2850
56	30	600	33	2850	33	2850	33	2850	33	2850
57	31	600	32	2850	32	2850	34	2850	34	2850
58	10	600	33	2850	33	2850	33	2850	33	2850
59	0	0	22	2850	22	2850	22	2850	22	2850
60	0	0	31	2850	31	2850	31	2850	31	2850
61	59	600	33	2850	33	2850	33	2850	33	2850
62	53	600	33	2850	33	2850	33	2850	33	2850
63	0	0	33	2850	33	2850	33	2850	33	2850
64	0	0	34	2850	34	2850	32	2850	32	2850
65	29	600	33	2850	33	2850	33	2850	33	2850
66	20	600	33	2850	33	2850	33	2850	33	2850
67	35	600	33	2850	33	2850	33	2850	33	2850
68	23	600	34	2850	34	2850	32	2850	32	2850
69	29	600	33	2850	33	2850	33	2850	33	2850

Scenario	LPN Contract	LPN Amount	HM Contract	HM Amount	HS Contract	HS Amount	PCM Contract	PCM Amount	PCS Contract	PCS Amount
70	32	600	33	2850	33	2850	33	2850	33	2850
71	33	600	33	2850	33	2850	33	2850	33	2850
72	38	600	33	2850	33	2850	33	2850	33	2850
73	27	600	33	2850	33	2850	33	2850	33	2850
74	26	600	33	2850	33	2850	33	2850	33	2850
75	23	760	33	2850	33	2850	33	2850	33	2850
76	20	760	32	2850	32	2850	34	2850	34	2850
77	35	600	33	2850	33	2850	33	2850	33	2850
78	30	600	33	2850	33	2850	33	2850	33	2850
79	35	600	33	2850	33	2850	33	2850	33	2850
80	26	600	33	2850	33	2850	33	2850	33	2850
81	32	600	32	2850	32	2850	34	2850	34	2850
82	30	600	33	2850	33	2850	33	2850	33	2850
83	30	600	34	2850	34	2850	32	2850	32	2850
84	23	600	33	2850	33	2850	33	2850	33	2850
85	29	600	33	2850	33	2850	33	2850	33	2850
86	27	600	32	2850	32	2850	34	2850	34	2850
87	34	600	33	2850	33	2850	33	2850	33	2850
88	28	600	33	2850	33	2850	33	2850	33	2850
89	29	600	34	2850	34	2850	34	2850	34	2850
90	26	600	34	2850	34	2850	34	2850	34	2850
91	26	600	33	2850	33	2850	34	2850	33	2850
92	20	600	33	2850	32	2850	34	2850	34	2850
93	34	600	38	2850	39	2850	38	2850	37	2850
94	45	600	45	2850	44	2850	45	2850	45	2850
95	29	600	36	2850	33	2850	34	2850	33	2850
96	31	600	34	2850	33	2850	36	2850	33	2850
97	1	600	0	0	1	2850	0	0	1	2850
98	0	0	0	0	1	2850	0	0	1	2850
100	27	760	33	2850	33	2850	33	2850	33	2850
101	22	760	32	2850	32	2850	34	2850	34	2850
102	18	760	22	2850	22	2850	21	2850	21	2850
103	18	760	32	2850	32	2850	34	2850	34	2850
104	18	760	33	2850	33	2850	33	2850	33	2850
105	16	760	21	2850	21	2850	21	2850	21	2850
106	25	760	33	2850	33	2850	33	2850	33	2850
107	18	760	32	2850	32	2850	34	2850	34	2850
108	12	760	21	2850	21	2850	21	2850	21	2850
109	23	760	33	2850	33	2850	33	2850	33	2850
110	20	760	33	2850	33	2850	33	2850	33	2850
111	15	760	21	2850	21	2850	21	2850	21	2850

Scenario	LPN Contract	LPN Amount	HM Contract	HM Amount	HS Contract	HS Amount	PCM Contract	PCM Amount	PCS Contract	PCS Amount
112	30	600	38	2850	38	2850	38	2850	38	2850
113	50	600	62	2850	62	2850	61	2850	61	2850
114	39	600	37	2850	37	2850	39	2850	39	2850
115	57	600	61	2850	61	2850	62	2850	62	2850
116	37	600	41	2850	41	2850	39	2850	39	2850
117	64	600	65	2850	65	2850	64	2850	64	2850
118	34	600	37	2850	37	2850	36	2850	36	2850
119	61	600	64	2850	64	2850	65	2850	65	2850
120	36	600	39	2850	39	2850	39	2850	39	2850
121	69	600	63	2850	63	2850	65	2850	65	2850
122	30	600	33	2850	33	2850	33	2850	33	2850
123	29	600	33	2850	33	2850	33	2850	33	2850
124	35	600	33	2850	33	2850	33	2850	33	2850
125	25	600	33	2850	33	2850	33	2850	33	2850
126	31	600	33	2850	33	2850	33	2850	33	2850
127	34	600	34	2850	34	2850	32	2850	32	2850
128	34	600	32	2850	32	2850	34	2850	34	2850
129	31	600	34	2850	34	2850	32	2850	32	2850
130	42	600	34	2850	34	2850	32	2850	32	2850
131	28	600	33	2850	33	2850	33	2850	33	2850
132	36	600	33	2850	33	2850	33	2850	33	2850
133	35	600	34	2850	34	2850	32	2850	32	2850
134	32	600	34	2850	34	2850	32	2850	32	2850
135	30	600	32	2850	32	2850	34	2850	34	2850
136	38	600	33	2850	33	2850	33	2850	33	2850
137	29	600	33	2850	33	2850	33	2850	33	2850
138	34	600	33	2850	33	2850	33	2850	33	2850
139	27	600	33	2850	33	2850	33	2850	33	2850
140	36	600	33	2850	33	2850	33	2850	33	2850
141	30	600	33	2850	33	2850	33	2850	33	2850
142	35	600	33	2850	33	2850	33	2850	33	2850
143	20	600	33	2850	33	2850	33	2850	33	2850
144	33	600	34	2850	34	2850	32	2850	32	2850
145	31	600	34	2850	34	2850	32	2850	32	2850
146	29	600	33	2850	33	2850	33	2850	33	2850
147	31	600	33	2850	33	2850	33	2850	33	2850
148	33	600	33	2850	33	2850	33	2850	33	2850
149	25	600	33	2850	33	2850	33	2850	33	2850
150	36	600	37	2850	37	2850	39	2850	39	2850
151	60	600	64	2850	64	2850	64	2850	64	2850
152	31	600	33	2850	33	2850	33	2850	33	2850

Scenario	LPN Contract	LPN Amount	HM Contract	HM Amount	HS Contract	HS Amount	PCM Contract	PCM Amount	PCS Contract	PCS Amount
153	19	600	33	2850	33	2850	33	2850	33	2850
155	38	600	158	600	158	600	157	600	157	600
156	40	600	158	600	158	600	157	600	157	600
157	31	600	33	2850	33	2850	157	600	157	600
158	25	600	33	2850	33	2850	157	600	157	600
159	34	600	33	2850	33	2850	33	2850	33	2850
160	37	600	33	2850	33	2850	33	2850	33	2850
161	34	600	34	2850	34	2850	32	2850	32	2850
162	35	600	32	2850	32	2850	34	2850	34	2850
163	10	600	24	2850	24	2850	24	2850	24	2850
164	2	600	23	2850	23	2850	23	2850	23	2850
165	26	600	33	2850	33	2850	33	2850	33	2850
166	33	600	33	2850	33	2850	33	2850	33	2850
167	32	600	32	2850	32	2850	34	2850	34	2850
168	33	600	33	2850	33	2850	33	2850	33	2850
169	32	600	33	2850	33	2850	33	2850	33	2850
170	27	600	33	2850	33	2850	33	2850	33	2850
171	26	600	33	2850	33	2850	33	2850	33	2850
172	38	600	33	2850	33	2850	33	2850	33	2850
173	35	600	33	2850	33	2850	33	2850	33	2850
174	30	600	33	2850	33	2850	33	2850	33	2850
175	32	600	33	2850	33	2850	33	2850	33	2850
176	21	600	34	2850	34	2850	32	2850	32	2850
177	24	600	34	2850	34	2850	32	2850	32	2850
178	24	600	33	2850	33	2850	33	2850	33	2850
180	25	600	33	2850	33	2850	33	2850	33	2850
181	19	600	34	2850	34	2850	32	2850	32	2850
182	41	600	32	2850	32	2850	34	2850	34	2850
183	33	600	33	2850	33	2850	33	2850	33	2850
190	20	400	33	2850	33	2850	33	2850	33	2850
191	38	400	33	2850	33	2850	33	2850	33	2850
192	35	400	34	2850	34	2850	32	2850	32	2850
193	33	400	33	2850	33	2850	33	2850	33	2850
194	29	400	33	2850	33	2850	33	2850	33	2850
195	27	400	33	2850	33	2850	33	2850	33	2850
196	31	400	33	2850	33	2850	33	2850	33	2850
197	25	400	33	2850	33	2850	33	2850	33	2850
198	40	400	33	2850	33	2850	33	2850	33	2850
199	32	400	33	2850	33	2850	33	2850	33	2850
201	40	600	33	2850	33	2850	33	2850	33	2850
202	46	600	33	2850	33	2850	33	2850	33	2850

Scenario	LPN Contract	LPN Amount	HM Contract	HM Amount	HS Contract	HS Amount	PCM Contract	PCM Amount	PCS Contract	PCS Amount
203	51	600	33	2850	33	2850	33	2850	33	2850
204	50	600	33	2850	33	2850	33	2850	33	2850
205	41	600	33	2850	33	2850	33	2850	33	2850
206	38	600	33	2850	33	2850	33	2850	33	2850
207	40	600	33	2850	33	2850	33	2850	33	2850
208	48	600	33	2850	33	2850	33	2850	33	2850
209	41	600	33	2850	33	2850	33	2850	33	2850
210	52	600	33	2850	33	2850	33	2850	33	2850
212	48	475	198	475	198	475	198	475	198	475
213	53	475	201	475	201	475	201	475	201	475
214	55	475	199	475	199	475	199	475	199	475
215	48	475	200	475	200	475	200	475	200	475
216	54	475	199	475	199	475	199	475	199	475
217	49	475	199	475	199	475	199	475	199	475
218	44	475	197	475	197	475	197	475	197	475
219	50	475	199	475	199	475	199	475	199	475
220	46	475	198	475	198	475	198	475	198	475
221	52	475	200	475	200	475	200	475	200	475
222	31	600	34	2850	34	2850	32	2850	32	2850
223	19	600	33	2850	33	2850	33	2850	33	2850
224	31	600	34	2850	34	2850	32	2850	34	2850
225	22	600	33	2850	33	2850	33	2850	36	2850
226	10	600	17	2850	19	2850	16	2850	17	2850
227	6	600	17	2850	19	2850	16	2850	18	2850

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