Chapter 13
Application in Hi-Tech Electronics Industry

13.1 Introduction

The hi-tech electronics industry produces a wide range of products. The best known examples are in consumer electronics, but around half of the produce goes to other types of end-products and B2B customers in diverse industries. While the consumer electronics sector is dominated by large OEMs, electronic parts are produced by a large number of smaller manufacturers. The specialist manufacturers form non-hierarchical collaborative supply chain networks (Scholz-Reiter et al. 2010) to produce integrated electronics end-products. These chains are characterized by short-product life cycles, high degree of customization and low margins. To respond to these pressures, a high degree of specialization can be observed in many hi-tech supply chains, where contract manufacturers offer their specialized knowledge and resources to product on-demand products.

There are manufacturers focusing on low value mass production parts and manufacturers doing their own R&D and providing high value specialized parts as well as those focusing on assembly (e.g., FoxConn[1]). In consumer electronics products, the final assembly cost often is just 5–10 % of the cost of the part used in the assembly.

The manufacturers are located around the world with the largest concentration in South East Asia, Europe, and the USA. The selection of parts manufacturers among other factors is driven by labor costs, scalability, proximity to other suppliers and customers, and quality of infrastructure. The clustering effect is particularly strong (Porter 1998). Recent experiences with part shortages due to natural disasters and other disruptive events have made many supply chains to rethink their reliance on the lean strategy and to make the supply chains shorter and more flexible. The main challenges affecting the electronics supply chains are improvement of supply chain collaboration (Siddiqui and Raza 2015) especially at the strategic and tactical

[1] http://www.foxconn.com/

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levels, risk management, sustainability, demand planning, and digital supply chains. Demand planning implies that the contract manufacturers and B2B suppliers get more involved with the end-customers through various means of real-time monitoring. The aim is to provide services in a proactive manner and to sense the demand, rather than just observe it. The supply chain digitalization implies that products are augmented with different digital services as well as many production activities are becoming virtualized.

This chapter investigates characteristics of hi-tech electronics supply chains by considering the case of a company referred to as ET, which is a medium size contract manufacturer as well as a supply chain service provider. One of the main challenges faced by the company is associated with delivery of components used in manufacturing. In recent years, the estimated industry on-time delivery performance has deteriorated from around 95 % to 93 %. The delivery timeliness is affected by various disruptive events such as earthquakes, tornados and others (Chopra and Sodhi 2004). In order to evaluate these uncertainties, a simulation model for ET is constructed in this chapter. Simulation and analytical models have been successfully applied to study supply chain disruption in several investigations, e.g., Keramydas et al. (2015), MacKenzie et al. (2014), and Carvalho et al. (2012). MacKenzie et al. (2014) specifically focus on supply chain disruptions caused be the 2011 Japanese earthquake and tsunami and their model is used to evaluate risk management and post-disruption management strategies.

13.2 Case Description

ET is a contract manufacturer located in Latvia. It is a fast-growing group providing manufacturing services to business customers. The company runs two state-of-the-art technologically compatible plants—providing production capacity backup, supply reliability, and scalability of manufacturing processes. The service range covers the entire value chain from the design and industrialization phase to after-market services. The company's core markets are Baltic states, Finland, Sweden, Norway, the UK, and Denmark (Fig. 13.1).

While many supply chains are product centric, the mainstay of ET's supply chain is knowledge and technology and products are unique for every order. Therefore, the company also works with a large number of customers and suppliers. It continuously updates its customer portfolio to ensure that there are expected orders up to six month in advance. Similarly, it also selects suppliers dynamically according to the current requirements. The main supplier selection criteria are references and observations as well as test runs.

The products produced consist of three main types of components (Fig. 13.2):

1. Commodity components—readily available standard parts used in manufacturing of many end-products.

Fig. 13.1 ET geographical location

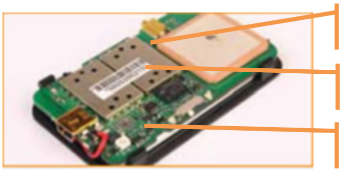

Fig. 13.2 A sample end product and main type of parts used in manufacturing

2. Custom ordered—must be ordered for every specific product, though alternative suppliers are readily available.
3. Specific components—components supplied just by limited number of suppliers (often a single supplier). These can be procured on order, or purchased from the catalog companies, though that usually costs more.

A majority of components are sourced on-demand. To ensure fulfillment of purchasing requisitions, the company has an advance agreement on prices and capacity reservation. Upon receiving a firm order, the company procures necessary materials. The materials have different delivery timeline which correlates with the type of materials, as illustrated in Fig. 13.3. In order to minimize inventory management costs, parts are sourced just-in time. The supply lead time for specialized parts is the longest one. The supply of commodity and custom parts is initiated taking into account the delivery slack available to receive the part on-time for end-manufacturing. The manufacturing is started once all parts are received. The process is completed by delivering the product to the customer. The company allows for a buffer when quoting the end-product delivery due date in order to account for supply and manufacturing uncertainties.

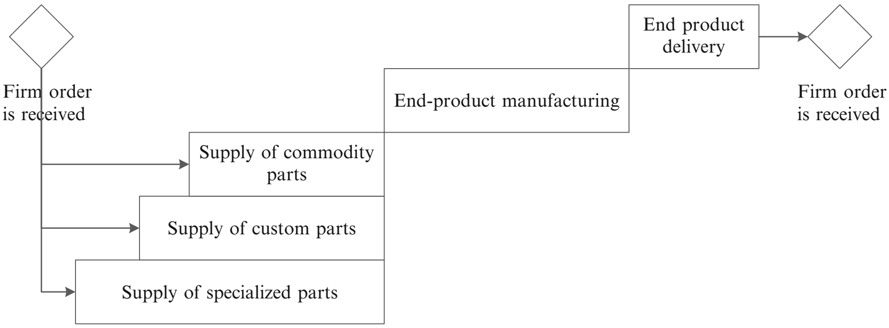

Fig. 13.3 The delivery timeline

The manufacturing order fulfillment time for approved design products is about 8 weeks (could increases to 28 weeks in the case of new products). Materials procurement time varies according to the type of material. The order quality and delivery time are agreed upon following the communication protocol given in Fig. 13.4. During the preliminary phase, the company forecasts its material requirements and informs suppliers about the expected orders. The suppliers send back their quotes specifying availability of products and their prices. At this point, both the company and the suppliers are yet to commit to firm orders. The sourcing phase starts once the manufacturing company receives firm orders from its customers. The manufacturing company commits itself to a certain end-product due date and quantity. Taking into account the material requirements, it places orders to suppliers. These orders specify the requested parts quantity and supply due data. The supplier sends back an order confirmation. It is possible that the due date promised by the supplier differs from the requested supplier's due date. The manufacturer decides upon accepting or rejecting the offer. In the case of accepting the offer, the supplier sends parts to the manufacturing company whenever these are ready for shipment. It is possible that the actual delivery date for parts is later than the promised date in the order confirmation because of unexpected disturbances. There is an important distinction between not offering the requested due date and not meeting the promised due date. In the former case, the manufacturer can take proactive measures to source the required parts within the allocated time. In the latter case, opportunities for proactive response are limited.

Differences between the required delivery date, confirmed delivery date and actual delivery date cause difficulties to meet the promised final product delivery date. Therefore, the company wants to evaluate its ability to meet the delivery date as well as to come up with strategies for dealing with the delays.

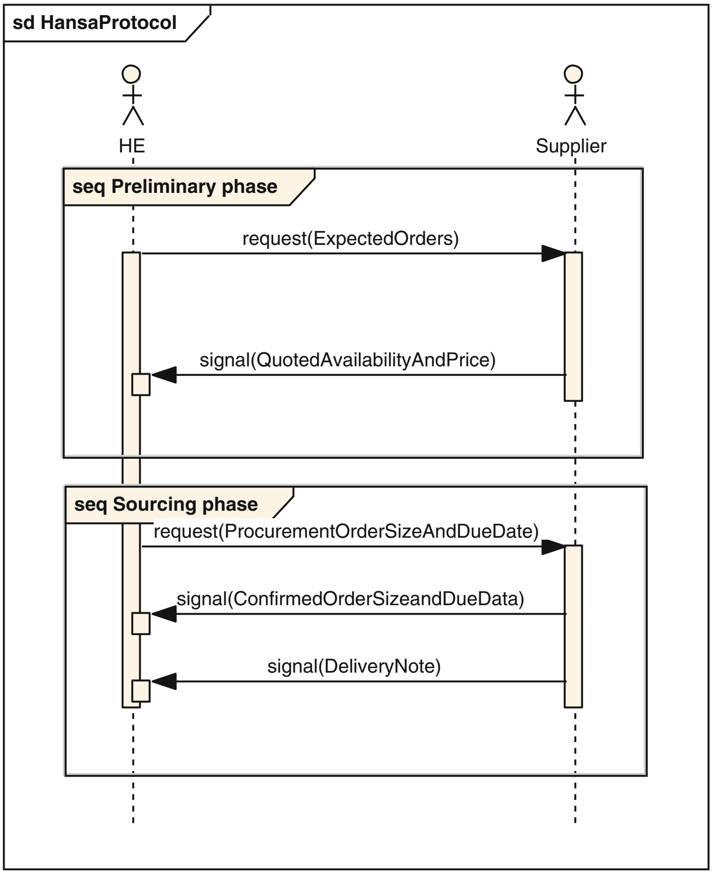

Fig. 13.4 Materials' ordering communication protocol

13.3 Scope Definition

The company pursues the efficiency strategy. It has mean manufacturing operations while relationships with customers and suppliers are agile. As part of the efficiency strategy, the company aims to ensure having as high utilization of its manufacturing facilities as possible. Paying attention to customer relationships and keeping the promised delivery performance are among the key competitive advantages of the company. Therefore, ability to evaluate feasibility of the promised delivery times are of high importance.

ET is a dominant unit of its supply chain and makes supply chain configuration decisions independently. The supply chain has a small number of fixed units since customers and suppliers are selected dynamically. Nevertheless, there is a portfolio of established customers and a pool of certified suppliers. There is a limited information sharing (the company gives suppliers in advance its own demand

Table 13.1 The supply chain configuration scope definition for the ET case

Scope parameter	Values
Objectives and criteria	Increase profit, increase capacity utilization, ensure reliable deliveries
Horizontal extent	Supply, manufacturing
Vertical extent	Strategic
Decisions	Sourcing policy
Parameters	Sourcing uncertainty, purchasing price
Processes and functions	Sourcing

predictions rather than information about the end-customer demand). The number of alternatives for selection of suppliers for commodity and customer parts is large. The summary supply chain scope definition is given in Table 13.1.

13.4 Conceptual Modeling

The conceptual modeling is performed to formally define the supply chain configuration problem in the case study. It is performed using the information modeling methods elaborated in Chap. 7. Figures 13.5 and 13.6 show the supply chain configuration objectives and the supply chain configuration concepts, respectively.

The goal view shows that the profit increase is the most important goal. In the supply chain configuration case considered, the goal is achieved by minimizing sourcing costs and increasing capacity utilization. Both goals are typical representatives of generic supply chain management objectives of cost optimization and improvement of asset management as identified in Chap. 7. The supplier selection objective facilitates the delivery reliability improvement because suppliers can be selected according to their on-time performance. The capacity utilization increase hinders delivery reliability at the manufacturing tier if too many manufacturing orders are booked at the same time.

The concept model defines main concepts relevant to the ET case. It explicitly shows that distinguishing among types of suppliers and types of materials is important. The concept model includes concepts for specifying contract suppliers and spot market suppliers as well as concepts for representing commodity, specialized and custom parts. The parts are traditionally shipped from suppliers to the manufacturer by air, which is represented by the Air Link object.

13.5 Simulation Model

Supply chain configuration evaluation experiments are designed on the basis of conceptual modeling. In order to evaluate impact of uncertainties on on-time delivery performance, simulation modeling is selected as the most appropriate

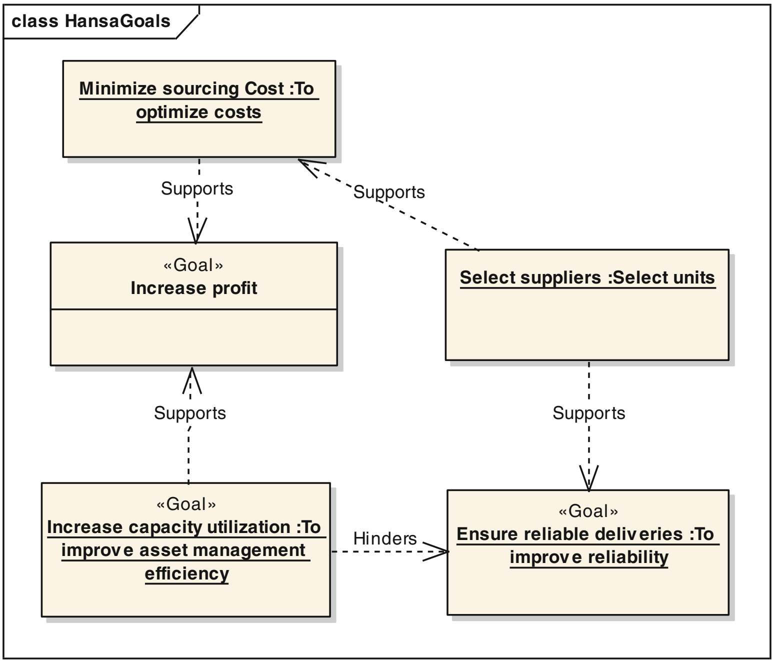

Fig. 13.5 The supply chain configuration objectives

method. The primary objective of the analytical evaluation is finding the probability to meet the promised delivery time as well as to evaluate an approach for dealing with uncertainty. This approach assumes that in the case of expected delays in parts' deliveries, they are procured at the spot market.

The main performance measures are the probability of meeting the promised delivery time, the expected delivery time and the sourcing costs. The probability p of meeting the promised delivery time T_{promised} is expressed as:

$$p = P\left(\hat{T} \le T_{\text{promised}}\right), \tag{13.1}$$

where $\hat{T}$ is the expected end-product delivery time. The expected end-product delivery time is expressed as:

$$\hat{T} = \max(T_{s1}, \ldots, T_{sn}) + T_{m} + T_{d}, \tag{13.2}$$

where $T_{si},\ i = 1, \ldots, n$ is the actual supply time for the ith supplier, T_{m} is the end-product manufacturing time, and T_{d} is the end-product delivery time to the customer. The sourcing cost C is expressed as:

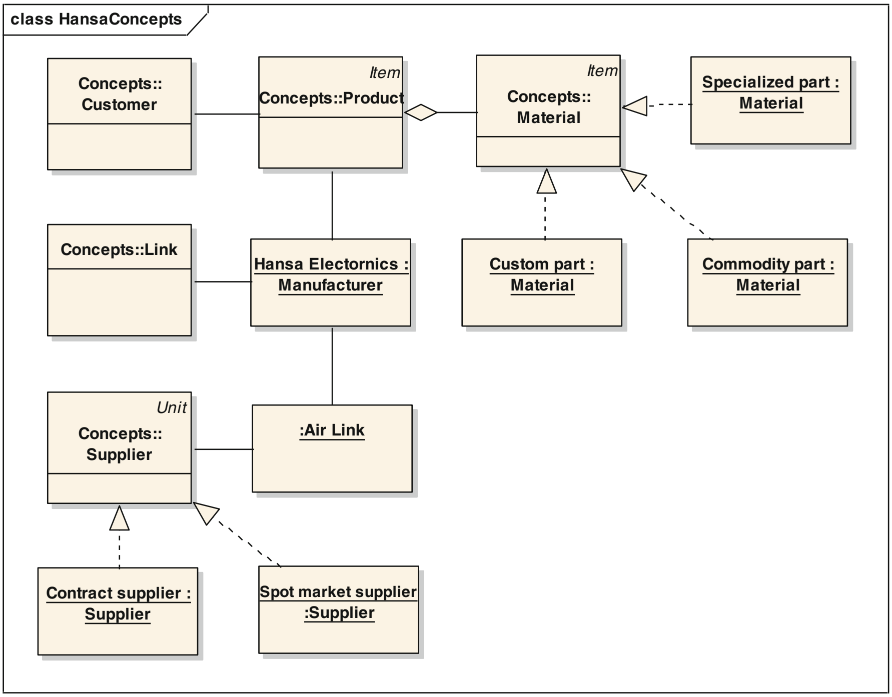

Fig. 13.6 The supply chain configuration concepts

$$C = c_1 \sum_{i=1}^{n} Q_i + c_2 \sum_{i=1}^{n} X_i + c_3 D \max\left(T - T_{\text{promised}}, 0\right), \qquad (13.3)$$

where c_1, c_2, and c_3 are the cost coefficients representing the regular purchasing price, spot market purchasing price, and late delivery penalty, respectively. Q_i is the quantity of materials sourced from the ith supplier at the regular price, X_i is the quantity of materials sourced from the ith supplier at the spot market, and D is the end-product demand.

The simulation model is built according to the simulation modeling principles presented in Chap. 9. Figure 13.7 shows the top level simulation model, where the first section represents the planning activities, the second section represents sourcing of commodity, custom and specialized components, respectively; and the third section represents the end-product processing. The sourcing activities are further elaborated in sub-model. Figure 13.8 shows a sub-model for sourcing of the specialized components. The sub-model is also developed using the principle of self-similarity, where sourcing operations are represented similarly for all suppliers. The top-level models shows that the quoted supply time T_{quoted} is provided by suppliers and the orders are sent out to suppliers. The manufacturing process can continue manufacturing operations of all components received. The specialized component sub-model shows that for every supplier T_{quoted} is compared with required supply time T_{required}. Meeting the required supply time should ensure

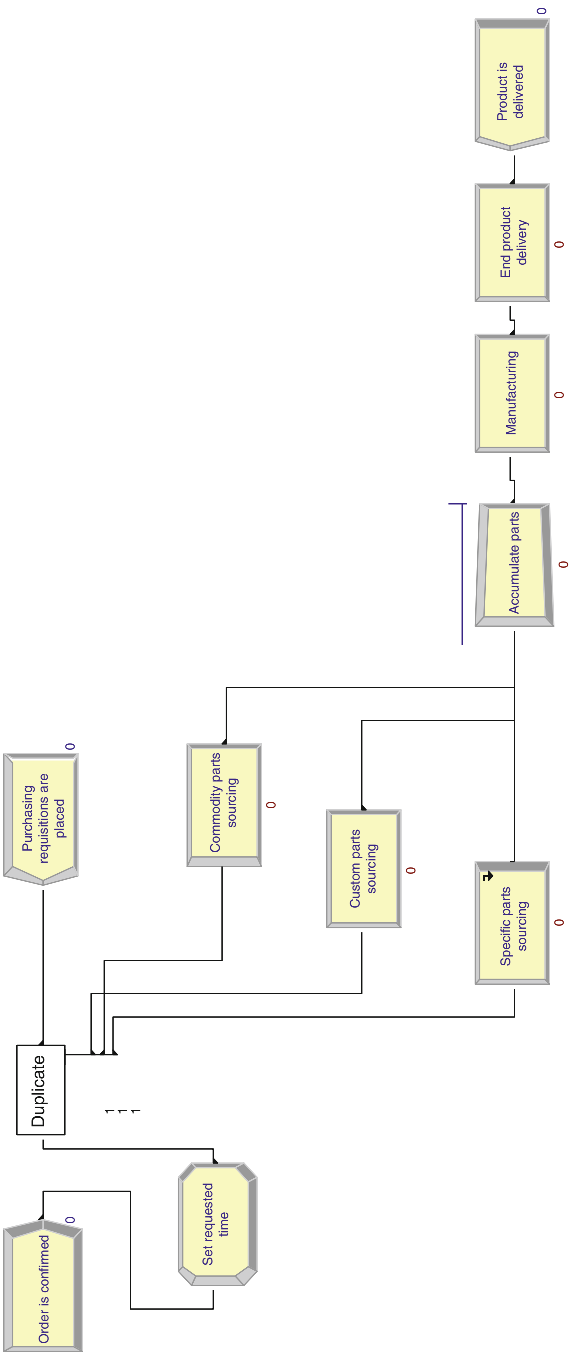

Fig. 13.7 The top-level simulation model

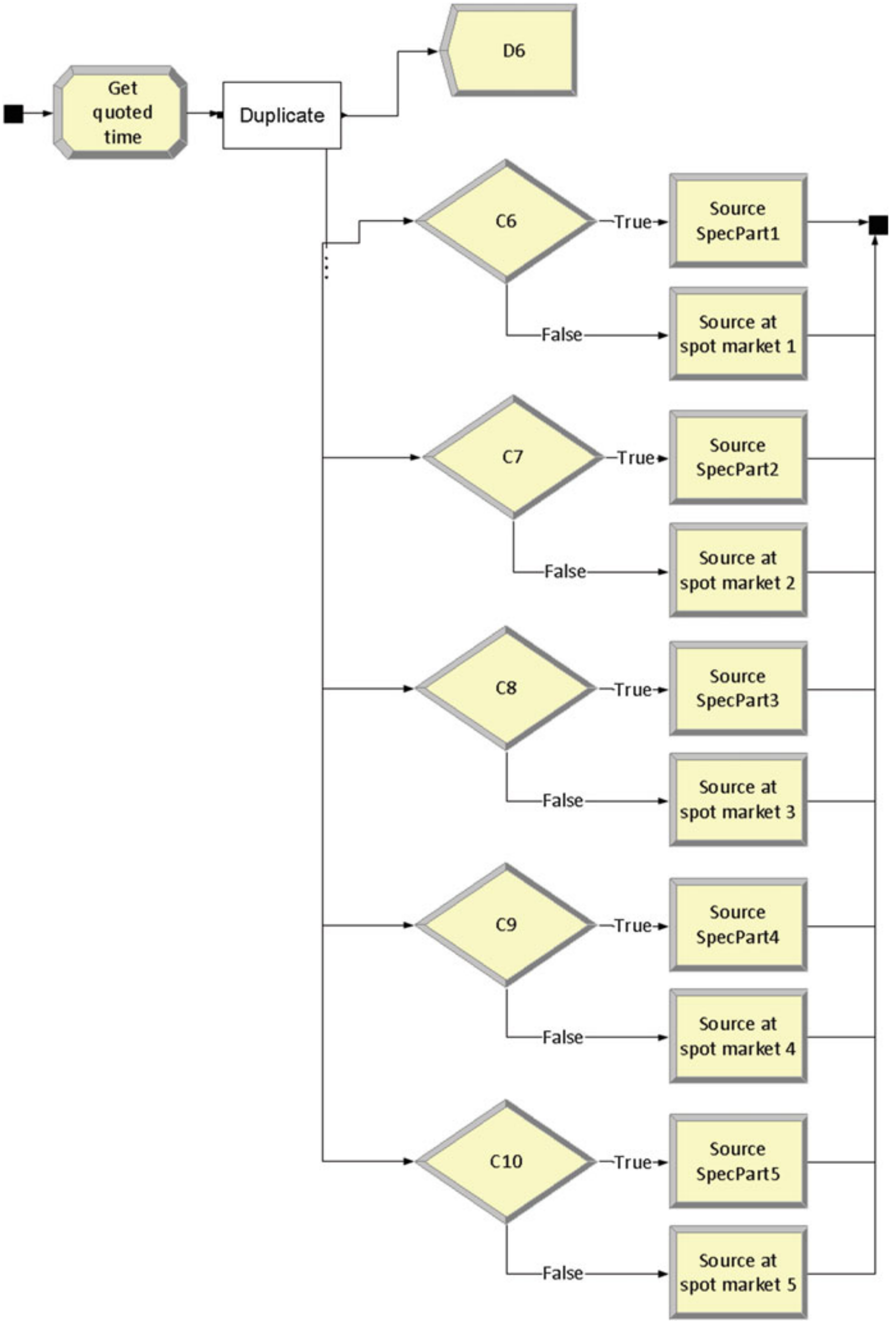

Fig. 13.8 The specialized parts sourcing sub-model

Table 13.2 Values of the experimental factors

Level	δ	β	α	$r = \alpha/c_3$
Low	1.1	0.1	1.2	1
High	1.3	0.5	1.5	5

on-time delivery of the end-product. If $\delta T_{\text{quoted}} \geq T_{\text{required}}$ then the order for the given component is placed at spot market instead of sourcing from the regular supplier. δ is called a switching threshold; given that the manufacturer allows a buffer to deal with delays and there is a tolerance level for late deliveries. The cost of parts in the spot market are higher $c_2 = \alpha c_1,\ \alpha > 1$, where α is the spot market purchasing threshold. The end-product demand is given by the customer. The execution time for all activities in the simulation model is log-normally distributed with the average value μ and standard deviation $\sigma = \beta\mu$, where β characterizes the level of activity execution uncertainty. In the case of sourcing activities, it characterizes the level of delivery uncertainty.

The simulation is performed at the strategic level and other factors influencing sourcing costs and delivery time are disregarded.

In order to evaluate the supply chain performance and to identify strategies for dealing with late deliveries, a set of experiments are conducted. A full factorial design of experiments is constructed for three experimental factors and one policy variable (Table 13.2). The experimental factors are: (1) a level of delivery uncertainty; (2) spot market premium; and (3) a ratio between the spot market premium and the late delivery penalty. The policy variable is the expected delivery lateness threshold δ at which the purchasing at the spot market is triggered.

The simulation model is developed in the ARENA modeling environment. The simulation is performed for 100 replications.

13.6 Experimental Results

The expected delivery performance is initially evaluated. The delivery time in the model depends only upon the level of delivery and the switching threshold while the spot market premium and late delivery penalty affect only the sourcing cost. Figure 13.9 shows the distribution of the expected delivery time as estimated over 100 simulations. The promised delivery time $T_{\text{promised}} = 49$ days. It can be observed that increasing β significantly affects the delivery time, while lower switching threshold helps improve on-time delivery performance. In the case of low delivery uncertainty, for the given end-product delivery buffer, the on-time delivery probability is 1. In the case of high delivery uncertainty, the on-time delivery probability is 0.97 and 0.89 for low and high values of the switching threshold, respectively. Therefore, the high supply lateness tolerance does not allow to achieve the average industry wide on-time delivery performance.

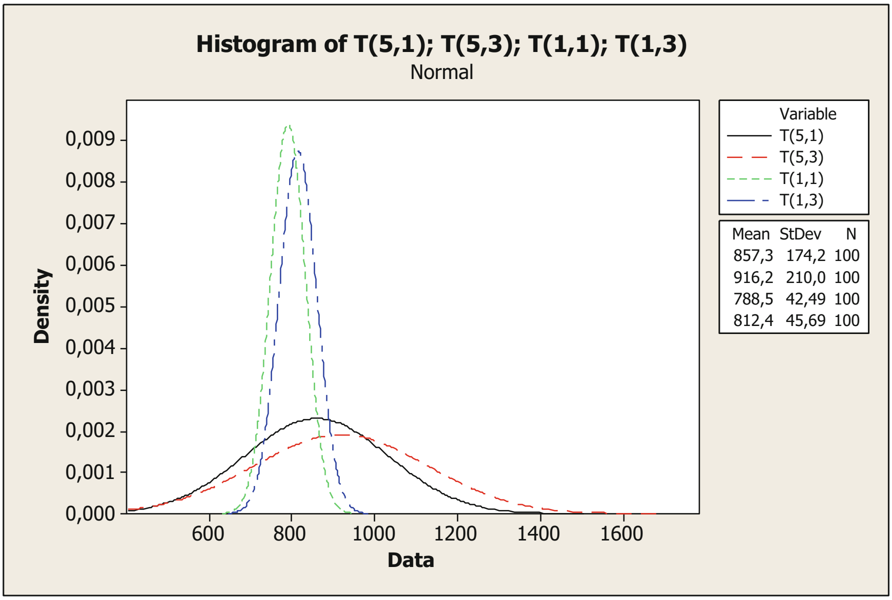

Fig. 13.9 The distribution of the expected delivery time

The impact of the switching threshold on the sourcing cost and interactions between the experimental factors are shown in Fig. 13.10. The sourcing cost is most significantly affected by the level of delivery uncertainty and spot market premium. The high level of delivery uncertainty increases the number of cases when parts are ordered in the spot market and at the same time increases the late delivery penalty. In the case of low level of delivery uncertainty, having the higher lateness tolerance is advantageous compared with too early switching to the spot market (Fig. 13.10a). There are no significant interactions among the spot market premium and the switching policy (Fig. 13.10b). The switching threshold has an opposite effect on the cost depending upon the r (Fig. 13.10c). The low lateness tolerance causes heavy purchasing on the spot market to avoid late delivery but for low r, spot market purchasing premium outweighs reduction in late delivery penalty. The opposite effect is observed in the case of high lateness tolerance.

13.7 Summary

This chapter describes the case study of supply chain configuration at an electronics manufacturing company. The main attention was devoted to suppliers' relationships management, in order to adopt appropriate policies for supplier selection. The main supplier selection driver was the impact of supply reliability on promised

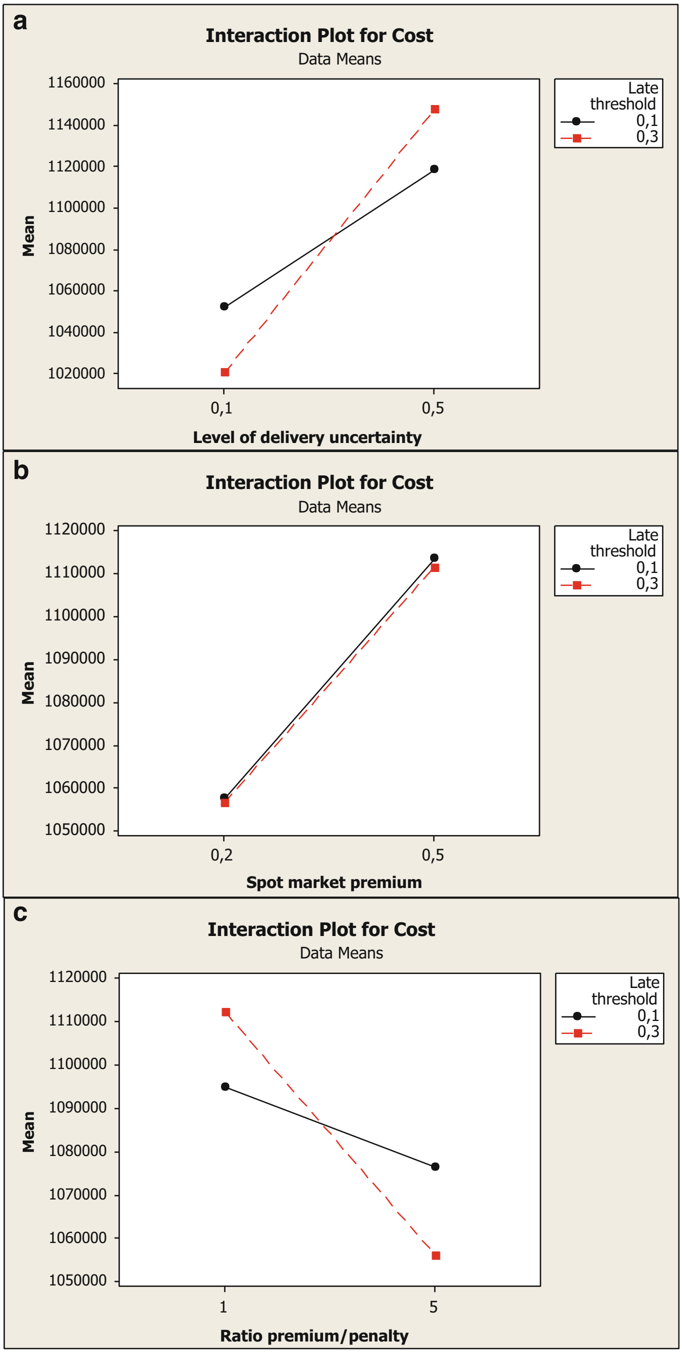

Fig. 13.10 The sourcing cost depending on interactions between the sourcing policy and experimental factors: (**a**) level of delivery uncertainty; (**b**) spot market premium; and (**c**) ratio between premium and penalty

end-product delivery time. The simulation modeling approach was used for evaluation purposes. The conceptual model developed can be used for exploring the supplier selection problem as well as for investigation of other supply chain configuration issues at the company.

The case study revealed that electronics supply chains are highly flexible, and supply chains are frequently established on project-to-project basis for manufacturing, particularly custom-built end-products. In every project, the main configuration variables are associated with supplier selection while logistics operations are streamlined without having to use multitiered storage facilities. Despite the high level geographical distribution in the electronics supply chains the transportation is relatively efficient because the parts and end-products are high value, low mass products. However, a major issue is that the supply chains are vulnerable to disruptive events and occasional shortages of specific parts. The decision-making complexity is affected by the type of parts required in manufacturing and each type requires a different sourcing strategy. The most challenging task is sourcing of the specialized parts. The manufacturing margins are low in the electronics supply chains, and companies compete by quality and delivery reliability. The dynamic modeling methods, such as simulation are the most useful methods for investigating the electronics supply chains.

The characteristic feature of contract manufacturing companies is that by handling their own manufacturing operations they acquire significant supply chain management expertise and are able to offer this expertise as a service to other companies.

References

Carvalho H, Barroso AP, MacHado VH, Azevedo S, Cruz-Machado V (2012) Supply chain redesign for resilience using simulation. Computers and Industrial Engineering 62(1):329–341

Chopra S, Sodhi MS (2004) Managing risk to avoid: supply-chain breakdown. MIT Sloan Manage Rev 46(1):53–61

Keramydas C, Tsiolias D, Vlachos D, Iakovou E (2015) A simulation methodology for evaluating emergency sourcing strategies of a discrete part manufacturer. Int J Data Anal Tech Strat 7 (2):141–155

MacKenzie CA, Barker K, Santos JR (2014) Modeling a severe supply chain disruption and post-disaster decision making with application to the Japanese earthquake and Tsunami IIE transactions. Inst Ind Eng 46(12):1243–1260

Porter ME (1998) Clusters and the new economics of competition. Harvard Bus Rev 76(6):77–90

Scholz-Reiter B, Heger J, Meinecke C, Rippel D, Zolghadri M, Rasoulifar R (2010) Supporting non-hierarchical supply chain networks in the electronics industry. In: Pawar K, Canetta L, Thoben K, Boer C (eds) Proceeding of the 16th international conference on concurrent enterprising. Centre for Concurrent Enterprise, Nottingham University Business School, Nottingham, pp 1–6

Siddiqui AW, Raza SA (2015) Electronic supply chains: status & perspective. Comput Ind Eng 88:536–556