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Semiconductor supply planning by considering transit options to take advantage of pre-productions and order cancellations

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ABSTRACT

One of the objectives of supply planning is to find when and how many productions have to be started to minimize total cost. We aim to find the optimum. Base data like the length of transit time are important parameters to plan for the optimum start of production. In this research, we considered two kinds of transit options: normal transit and emergency transit, and we distinguished between planned and executed transit. The decision regarding which transit option to choose for the execution is trivial because emergency is only used when it is needed since normal transit is more cost efficient. However, for planning purpose, it is more difficult to decide which transit option should be used since the uncertainty in demand and supply between plan and execution can allow to plan an emergency transit but to execute the delivery with normal transit, which is a huge benefit in the competitive capital intensive semiconductor industry. If we planned an emergency, we can save inventory and production cost as we can delay the start of production. In contrast, we need pay additional transit cost in case that emergency transit is actually executed. Many characteristics of the semiconductor industry, which might be the front runner for many other industries, are considered in this model such as demand uncertainty, supply uncertainty and economic volatility. In our numerical experiments, we could gain the optimum, depending on each economic situation. Furthermore, we conducted sensitivity analysis of the effect of demand and supply uncertainties on total cost.

1. Introduction

Supply planning has played an important role for supply chain management. Supply planning role is to best match the demand on the available capacities to enable efficient production planning and order management (in resource and time). There are many methods to solve a supply planning problem such as optimization and simulation, and one of the objectives is usually to minimize the total cost associated with a release plan such as production cost, transit cost and penalty cost [24].

It is important to focus on the semiconductor industries because there are many unique characteristics in the semiconductor industry, which might be front-runner for many other industries. Thus, there are many supply chain researches which focus on semiconductor industries. One of these characteristics is that cycle time tends to be quite long because of the

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complexity of production [9]. Consequently, it is difficult to forecast customers' demand accurately at the time when production starts [15], and there is a high possibility that orders are cancelled. It is also difficult to forecast production cycle time because of the complex production process [21]. Production cycle time from wafer facilities to customers is about 4 months long and production may be finished earlier or later than expected. Thus it is difficult to forecast uncertainty of the production cycle time accurately [19]. To deal with these uncertainties, it is quite important to shorten cycle time. Next, the economic volatility is also an original characteristic of semiconductor industries. This high economic volatility stems largely from the bullwhip effect [8]. When an economic situation is strong, production and transit are very busy because we have to produce and transport many items in contrast to downturn period [3].

Supply planning problem was studied by many researchers. Byrne et al. [5] used optimization to solve production and supply planning. While they did not consider demand and supply uncertainty, they could evaluate the solution of optimization by using simulation. There are also many researches about evaluation of uncertain elements, such as demand, supply and lead time uncertainties. Heydari et al. [12] researched lead-time variation impact on supply chain performance by using simulation. Acar et al. [1] studied the impact of demand and supply uncertainties in addition to lead-time variation on supply chain performance. Chong et al. [7] analyzed the impact of frequency of inventory information update, demand variability and due date variability on the semiconductor supply chain. Hung and Chang [13] aimed to determine safety stocks for production planning in uncertain production. They considered the uncertainty of flow times and yield rates as two major sources of uncertainty in semiconductor manufacturing. They formulated the simulation to solve this problem. Rastogi et al. [23] considered capacity planning for semiconductor manufacturing with uncertain demand. They formulated this problem as a stochastic mixed integer program with recourse that reduces the overall risk in planning. It is quite important to consider uncertain elements in semiconductor industry because of the existence of high variability of demand and supply. Furthermore, a lot of researchers aimed to consider these uncertainties on supply planning problems. Zhang et al. [26] considered demand uncertainty to make supply plan. They assumed that there are two kinds of demand uncertainties. One is the seasonal demand fluctuations and the other is market growth. They formalized this problem as a two-stage stochastic optimization problem. Liu et al. [18] considered both demand and supply uncertainty in production planning for semiconductor manufacturing. Manufacturing capabilities and order information from customers are random variables. They used genetic algorithm (GA) to solve optimization problem. And they used simulation when they evaluated each chromosome in GA. That is way they integrated simulation and optimization. Thus, solution of optimization was feasible and beneficial under any circumstances. Han et al. [11] studied supply planning in semiconductor industry where the quality of product is uncertain. They formulated dynamic multi-period yield management problem of a two-stage make-to-stock system with substitution faced by a semiconductor manufacturing firm. They tried to determine the optimum production input quantity in order to maximise the firm's profit. Ponsignon and Mönch [22] solved master planning problems that arise in semiconductor industry. They formulated this problem as a mixed-integer programming (MIP) model, and proposed heuristic procedures to solve the problem efficiently. However, they did not consider uncertainty such as demand variability, and they assumed a fixed production lead time. Leachman and Ding [17] solved the manufacturing management problem which integrated the speed economics. The prices of semiconductors decline very quickly compared with other industries. And they concluded the value of manufacturing speed is substantial in the semiconductor industry.

It is useful to set up multi transit options to save the supply planning cost. If there are multi transit options, we can choose the transit option flexibility in accordance with the production cycle. However, there are not so much researches which considered transit options in supply chain design and management. The earliest model with emergency transit may be built by Barankin [4]. In this paper, a single period model was developed in which a shipment is received at the beginning of the period and an emergency order is placed at some time during the period. Khouja [14] determined the profit maximising order quantity for a single period model with an emergency supply option, and showed that this quantity is smaller than the solution of the newsvendor model. Pishvaee and Rabbani [20] considered two kinds of transit options: via Distribution Center (DC) and directly to customers. They solved this problem as facility location problem. The objective is to minimize total cost including fixed opening costs, processing and transportation costs and penalty costs. They decided where factories and DC have to be built and how many items are transported. However, they did not consider any uncertain elements. In this study, graph theoretic approach is used to escape from the complexity of mixed integer mathematical programming models. Chan and Zhang [6] considered the impact of the length of transportation lead time on supply chain performance. They built the simulation model, and conducted sensitive analysis on supply chain cost: holding cost, penalty cost and ordering cost. Their results revealed that flexibility of transportation could reduce the retailer's total cost and improve its service level.

There is no research that integrates transit options into supply planning problem. Consequently, the uniqueness of this research is that we consider transit options in the semiconductor supply planning problem. In addition, we consider demand uncertainty, supply uncertainty and economic volatility to make this research practical.

2. Proposed model

2.1. Problem outline

In this research, we aim to make a supply plan that minimizes the total cost. Fig. 1 depicts the supply chains which were used in this research. Products are produced at the factory. Normally, products are sent to a Distribution Center (DC) and