Order Allocation Under Uncertainty Considering Suppliers′ Performance: A Case Study of Laminate Manufacturer

การจัดสรรคำสั่งซื้อภายใต้ความไม่แน่นอนโดยพิจารณาประสิทธิภาพของผู้ป้อนวัสดุ: กรณีศึกษาบริษัทผลิตลามิเนท

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Abstract

One of the most important decision-makings in a supply chain is how to allocate the order to suppliers under uncertainty. This type of problem requires much information in order to find the best decision for the problem at hand; therefore, it is very complicate by nature. This research focuses on how to allocate the order to a set of selected suppliers. The uncertainties considered in this research consist of fluctuation of raw material price, inaccuracy in forecasting, product quality, and ratio of on-time delivery of suppliers. We have studied a case study of a laminate manufacturer in Thailand, in which, the decision maker has to decide how to order the raw material from suppliers while each supplier has different characteristics or different uncertainty. The objective of this study is to assign the order allocation pattern, which minimize the total corresponding costs. We have developed the mathematical model and have applied the Genetic Algorithm to develop the program for optimizing the total cost. Then, algorithm has been tested using the data retrieved from the company and the data from the forecasting. Moreover, we have solved the tested case by the LINGO software in order to verify the efficiency of the proposed algorithm. The results show that our algorithm works very well under uncertainty and can suggest the best decision under each category of uncertainty.

Keywords: Supply Chain Management, Order allocation, Uncertainty

บทคัดย่อ

ในการบริหารจัดการห่วงโซ่อุปทานนั้นมีปัญหาในการตัดสินใจที่สำคัญประการหนึ่ง คือการจัดสรรคำสั่งซื้อให้กับผู้ป้อนวัสดุภายใต้ความไม่แน่นอนต่างๆ ปัญหานี้ต้องการข้อมูลจำนวนมากในการหาคำตอบที่ดีที่สุดสำหรับการตัดสินใจต่อปัญหาที่มีอยู่ ณ ขณะใดขณะหนึ่ง ดังนั้น จึงถือเป็นปัญหาที่ซับซ้อนโดยตัวของปัญหาเองงานวิจัยนี้จะมุ่งเน้นไปที่การหาวิธีการในการจัดสรรคำสั่งซื้อไปยังกลุ่มผู้ป้อนวัสดุที่มีอยู่จำนวนหนึ่ง ความไม่แน่นอนที่เกิดขึ้นในงานวิจัยนี้ประกอบด้วยความไม่แน่นอนของราคาวัสดุ ความผิดพลาดของการพยากรณ์ ความไม่สม่ำเสมอของคุณภาพวัสดุ และความไม่แน่นอนของการจัดส่ง ทีมผู้วิจัยได้ทำการศึกษากรณีศึกษาของบริษัทที่ทำการผลิตแผ่นลามิเนทซึ่งผู้ที่ทำการตัดสินใจจะต้องทำการจัดสรรปริมาณคำสั่งซื้อไปยังผู้ป้อนวัสดุแต่ละเจ้า ซึ่งมีลักษณะและมีความไม่แน่นอนที่แตกต่างวัตถุประสงค์ของการศึกษานี้คือการหารูปแบบการกระจายคำสั่งซื้อ โดยมีต้นทุนรวมต่ำที่สุด ทางทีมผู้วิจัยได้ทำการพัฒนาตัวต้นแบบทางคณิตศาสตร์ของปัญหาขึ้น และใช้วิธีการทางพันธุวิศวกรรม (Genetic Algorithm) ในการแก้ปัญหาดังกล่าว ซึ่งวิธีการที่ได้พัฒนาขึ้นนี้ถูกทดสอบโดยการใช้ข้อมูลจริงที่ได้จากบริษัทรวมกับข้อมูลบางส่วนที่ได้จากการพยากรณ์และนำไปเปรียบเทียบกับค่าที่ดีที่สุดที่ได้จากการใช้โปรแกรม LINGO ซึ่งจากผลการเปรียบเทียบพบว่าวิธีการที่ได้พัฒนาขึ้นนั้น ให้ค่าผลลัพธ์ที่ดีและยอมรับได้ภายใต้ความไม่แน่นอนต่างๆ ที่เกิดขึ้น

คำสำคัญ: การบริหารห่วงโซ่อุปทาน การจัดสรรคำสั่งซื้อ ความไม่แน่นอน

Introduction

In recent year, Supply chain management has generated much interest because of the realization that actions taken by one member of the chain can influence the profitability of all others in the chain. A supply chain is a network of facilities and distribution that are the functions of procurement of materials, transformation to finished products, and distribute these products to the customers. Nowadays, there have many researches related with the supply chain management but not many researches in field of supply chain under uncertainty such as late delivery, defect materials from supplier, or unreliable suppliers. Therefore, any research about uncertainty especially the uncertainty from supply sources should be considered. In this paper, we have investigated a manufacturer to study its purchasing system and then define the order allocation model. From the case study, we have developed the allocation method so that the company can minimize the total cost under the company's policy.

Literature Review

There are some researchers who have researched about the supplier assignment and order allocation. Followings are the concerned literature.

Papers on supplier selection:

Thomas Y. C., Janet L. H. (1996) compared supplier-selection practices based on a survey of companies at different levels in the auto industry. They used the survey method and then research method in order to make the decision. The results show that selection supplier based on the potential for a cooperative, long-term relationship is just as important to direct and indirect suppliers as it is to the auto assemblers.

Ghodsypour S.H., O'Brien C. (1998) make a trade off between these tangible and intangible factors some of which may conflict in order to select the best suppliers. They applied mixed integer, goal and multi-objective programming to solve this problem. They also use an analytical hierarchy process and linear programming is proposed to consider both tangible and intangible factors in choosing the best suppliers and placing the optimum order quantities. This model can be applied to supplier selection with and without capacity constraints. A numerical example is presented and the model advantages are discussed.

Madeleine E.P. (1998) studied the difference between managers rating of the perceived importance of different supplier attributes and their actual choice of suppliers in an experimental setting. He uses two methods: a Likert scale set of questions, to determine the importance of supplier attributes; and a discrete choice analysis (DCA) experiment, to examine the choice of suppliers. The results indicate that although managers say that quality is the most important attribute for a supplier, they actually choose suppliers based largely on cost and delivery performance.

Luitzen B., Leo van der W., Jan T. (1998) studied about the nature of initial purchasing decisions such as make-or-buy decision and supplier selection usually is complex and unstructured. They also try to solve this problem. They used the "Outranking methods" and the management science techniques as the tools to solve the problems in any cases. The results showed by means of a supplier selection example, that an outranking approach may be very well suited as a decision-making tool for initial purchasing decisions.

Christopher D., David F.L, Benkatesh N., Madhav C.R. (1999) examined whether supplier selection and monitoring practices affect the association between supplier strategies and organizational performance. They used the empirical test to test the data from the automotive and computer industries indicated that the performance gains from supplier partnerships practices are contingent on extensive use of non-price selection criteria. These selection and monitoring practices appeared to have little effect on the performance of organizations following arms-length supplier relations.

Choy K.L., Lee W.B., Victor L. (2002) presented an intelligent supplier management tool (ISMT). They used the case-based reasoning (CBR) and neural network (NN) techniques to select and benchmark suppliers. The result of which is to support the decision-making process in benchmarking suppliers in outsource manufacturing.

Stefan M. (2003) reviewed inventory models with multiple supply options which is "single-stage inventory models" and discusses their contribution to supply chain management. He used the stochastic lead times to make the analysis of the inventory models. Finally, issues for future research and a synthesis of available supply chain management and multiple supplier inventory models are proved that it's practical.

Toshiya K. (2003) solved the product allocation problem by distributing the scheduled resources based on the agent interactions in the market. He formulated supply chain model as a discrete resource allocation problem under dynamic environment, and demonstrate the applicability of the virtual market concept to this framework. It has been confirmed that careful constructions of the decision process according to economic principles can lead to efficient distributed resource allocation in SCM.

Wen-Chyuan C., Robert A.R. (2004) addresses the interaction of purchasing and routing for a propane gas supply chain. Rigorous solution methods using both set partitioning and taboo search are developed for obtaining optimal and near-optimal solutions for the purchasing/routing problem. The proposed methods are applied to a real-world propane distribution problem. The results of the study indicate that the potential annual cost savings through the integration of purchasing and routing decisions can range up to millions of dollars for large distributors.

Papers on uncertainty:

Ram G., John E.T., Yuanming G. (1999) examined the dynamics of a supply chain that has the option of using two suppliers one reliable, and the other unreliable. He calculated the expected shortages based on the normal and discrete distributions. The results show that, in the presence of a second supplier who's willing to provide a price discount, logistics managers can potentially save on annual inventory-logistics by placing a fraction of the order to this cheaper supplier.

Jukka K., Kalevi K., Antti L., Markku T. (2002) proposed a framework by which the risks related to a customer-supplier relationship, the service requirements by the customers and the strategies of the supplier company can be included in production capacity allocation and supply chain design. They used a numerical example and it is based on integrating the analytic hierarchy process (AHP) and mixed integer programming (MIP). According to the results, the supply chain is designed on the basis of the customers' strategic importance and service requirements.

Kirstin Z. (2002) investigated the supply chain coordination with uncertain just-in-time delivery by means of a single–period order and delivery-planning model within a just-in-time setting. She compared the worst cast with the best case, and then develops a coordination mechanism. The results displayed that the example demonstrates that the coordination mechanism is flexible enough to enable different allocations of these overall cost thus allowing both parties in an existing supply chain partnership to make a profit.

Anshuman G., Costas D.M. (2003) provided an overview of their previously published works on incorporating demand uncertainty in midterm planning of multisided supply chains. They modeled the manufacturing decisions as "here-and-now" and used the "CPLEX" solver to solve the model with many equations and variables. The trade-off between customer satisfaction level and production cost is also captured in the model. The proposed model provides an effective tool for evaluating and actively managing the exposure of an enterprises asset to market uncertainties.

Brian F., Sean B., Donna M. (2004) developed a model of environmental uncertainty, supply chain (SC) relationship quality and SC performance. They used the "survey instrument" and the statistical method to test the models. The results provide mixed support for the model, with the moderating role of both demand and supply uncertainty being supported, but technological uncertainty not supported.

Cheng-Liang C., Wen-Cheng L. (2004) created the multi-product, multi-stage, and multi-period scheduling model to deal with multiple incommensurable goals for a multi-echelon supply chain network with uncertain market demands and product prices. They used the fuzzy sets as the tools to solve the models. The results proved effective in providing a compromised solution in an uncertain multi-echelon supply chain network.

June Y.J., Gary B., Joseph F.P., Gintaras V.R., David E. (2004) proposed the use of deterministic planning and scheduling models which incorporate safety stock levels as a means of accommodating demand uncertainties in routine operation. To solve the model they use a simulation based optimization approach. The results display that the safety stock level, which is calculated to meet a desired level of customer satisfaction, can be provided.

Ruengsak K., and Nguyen V.H. (2005) have studied the effects of an order allocation procedure in a supply chain. This supply chain consists of a company that can order products from multiple suppliers. They used the computer simulation, order allocation, Excel, and numerical test to archive their models. The results showed that it can vary the percentage of on-time delivery and could understand the behavior of purchase cost.

From the above mentioned literatures, we have observed that some researchers have studied the order allocation under uncertainty. However, few of them have considered the real case that has more complexity and sometimes the purchasing department has to follow a policy of the company. Accordingly, in this paper we have studied a company that purchased raw materials from selected (or contracted suppliers). The company has to follow agreement signed with the suppliers (such as the minimum ordered quantity) while the cost of ordering must be minimized. With more complexity, we developed the ordering approach that tends to optimize the cost which related to the allocation pattern. The purposed approach could be applied by the company with the less effort but with high efficiency.

Problem Statements

In this paper, we have studied a case study of Thai Laminate Manufacturer (TLM) Company which produces a number of laminate products to supply to electronic industries. As shown in Figure 1, the company has ordered raw materials from a set of selected suppliers which all of suppliers locate abroad. The required amount of an item (or multiple items) will be determined by the purchasing department. An order consists of the selected supplier, quantity purchased, due date, price and other related information. Our consideration is only the part of the supplier network (inside the dot-line block in Figure 1). Since, the company can select any supplier from the list, therefore, there are many allocation patterns while ordering and come up with the question that which pattern is the best pattern when the company also has to maintain its own policy on all contract suppliers.

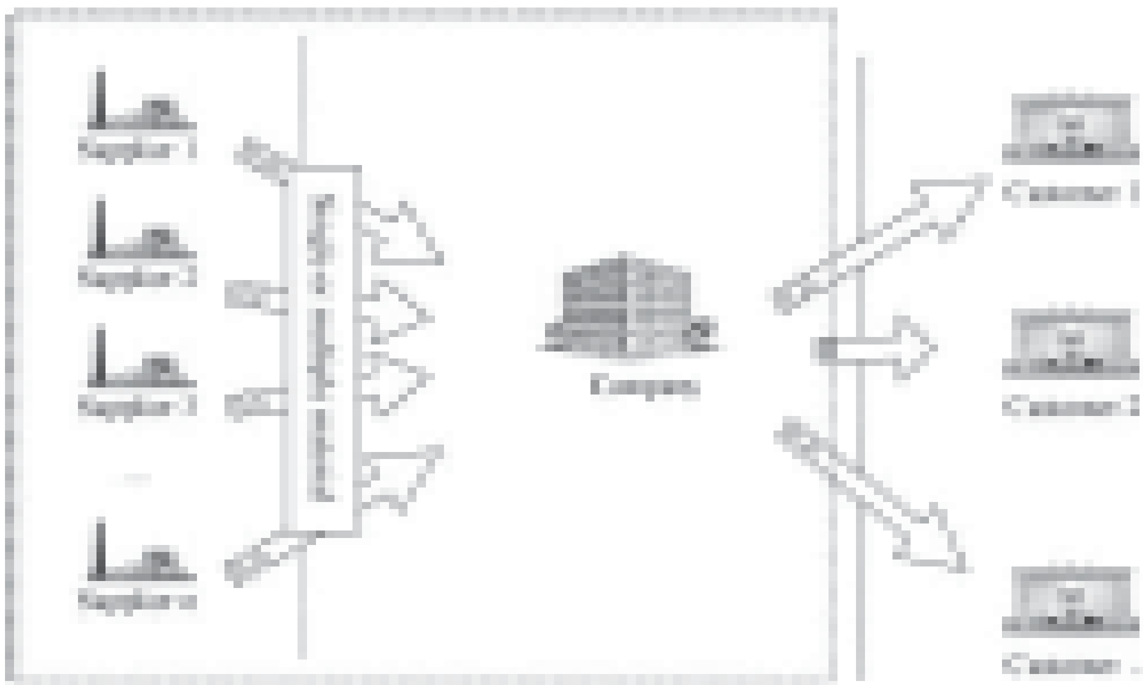

Figure 1 Supplier network of the company

In the ordering process the planner has to select supplier (or suppliers) from list, then assign the quantity and due date. However, there are many things to consider since there are many uncertainties concerned in the process. Some of uncertainties are depicted in Figure 2.

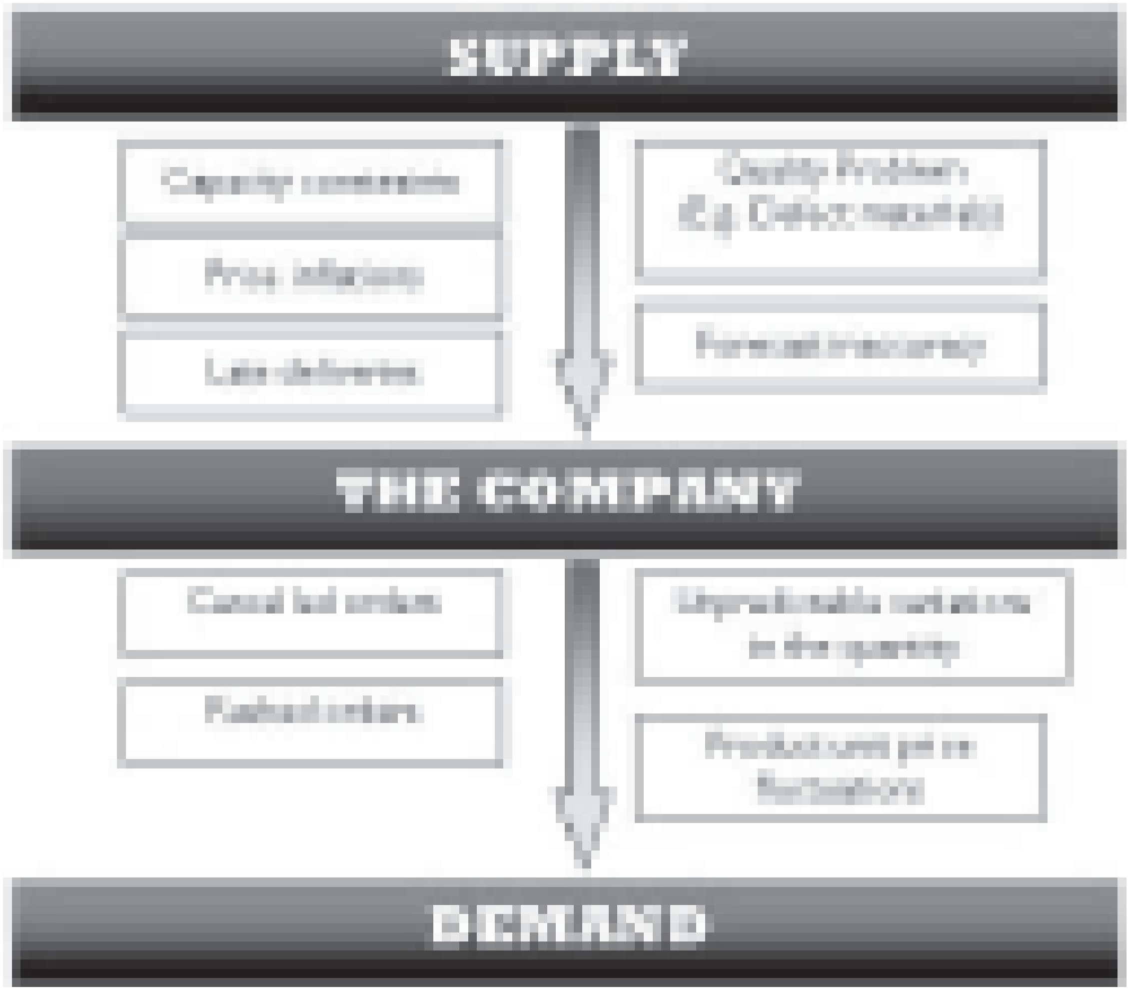

Figure 2 Factors of supplier-uncertainty and demand-uncertainty

From our study, uncertainties appeared in the order allocation process consist of:

- Capacity of suppliers; in the category each supplier has its own customers; therefore, the capacity supply for a customer may be vary. At the ordering time, the company has to check the stock of suppliers, thus sometimes the company cannot order from that supplier if the stock level is not enough.
- Price Inflation; since the price of raw material (metal such as Copper, Zinc, etc.) has been affected by the market therefore the material price is unstable (both increasing and decreasing due to the marketing condition).
- Late delivery; this category always occur since all suppliers locate abroad.

- Quality problem; the received raw material sometimes have quality problem and can not be detected until it has been used since almost materials are in the coil or strip form.
- Forecast inaccuracy; the approach used by the company has less accuracy since the order decision based on experience of the purchasing staff.

In the demand side of the company, there are many uncertainties appear, such as order cancelled, rushed order, defects, and unit price fluctuation (finished goods). But, these uncertainties are not our concerns since they are uncertainties in the demand side.

1. Material ordering process

TLM has to order raw materials from its suppliers. Ordered material consists of copper sheet, resin, etc. The concerned problem in this research is the order allocation to the selected suppliers. Since a kind of material can be ordered from more than one supplier. TLM has applied this strategy since the company wants to reduce the risk of shortage that used to occur in the past. As depicted in Figure 3, the order process starts from the production plan (received from production planning department). Then, production plan will be breakdown to the material order plan using BOM. From the material order plan, the purchasing staff will select some suppliers from list and finally assign the quantity to each selected supplier. The order allocation must be done in the manner that the total corresponding cost is minimized.

2. Order Allocation Sub-process

The quantity ordered must satisfy in order to fulfill the requirements from production plan. Since the company the a policy about the purchasing that the stock must be enough for at least one-month production when the material price is high and at most three months when the material price is low. This policy is based on the production plan that will be rolled up every month and apply the three month plan. Thus, the possible ordering patterns are; one-month stock ordering, two-month stock ordering, and three-month stock ordering. One-month stock means the ordered quantity will be used up within one month. Therefore, the best plan will be selected from the three plans generated (1-month, 2-moth and 3-month). The process is described in Figure 4.

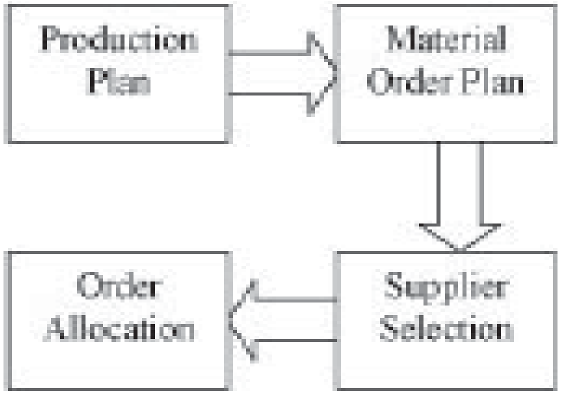

Figure 3 Ordering Process

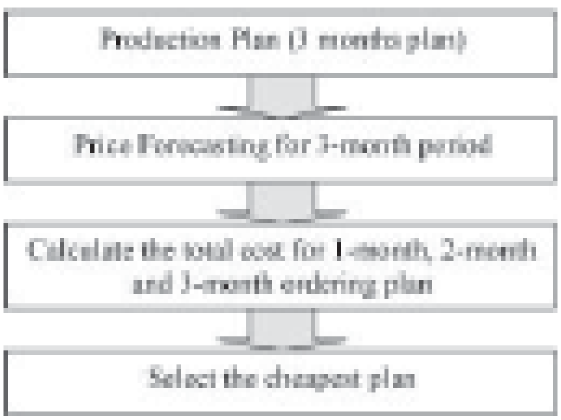

Figure 4 Ordering Allocation Sub-process

The technique used for the forecasting is exponential smoothing or double exponential smoothing depend on the best fit for each material.

3. Ordering policy

The order of a material must be done in order to minimize the total cost of material cost (purchasing price) and correspondence purchasing costs which are interest paid for the advance payment and fixed engagement fee. However, the cost should be optimized in such manner that the following constraints must be satisfied :

- Reliability of the delivery must not be less than a fixed percentage (e.g., 95%), and
- Quality of the delivered material must not be less than a fixed percentage (e.g., 95%),

Where, reliability of the delivery is the probability that an amount ordered will be late. For example 95% of reliability means among 100 units ordered, it is expected that 5 units will be late and 95 units will be delivered on-time. For the quality of delivered material, 95% means that among 100 units delivered 5 units will be defects and the remaining 95 units will be good parts.

4. Mathematical Model

The objective is to minimize the following :

$$TC_j = MC_j + PC_j \tag{1}$$

Where,

TC_j = Total cost of ordering material *j*,

MC_j = Material cost of ordering material *j*,

PC_j = Purchasing cost of ordering material *j*, including costs are interest paid for the advance payment, fixed engagement fee

Equation (1) must be optimized when the following conditions are satisfied.

Condition 1: Average on-time delivery score

$$Average\ on\text{-}time\ delivery\ score = \frac{\sum_{i=1}^{s}(R_{ijk} * OD_{ij})}{s} \qquad (2)$$

Condition 2: Average quality score

$$Average\ quality\ score = \frac{\sum_{i=1}^{s}(R_{ijk} * QL_{ij})}{s} \qquad (3)$$

Where,

R_{ijk} = Ratio for material *j* related to supplier *i* at month *k.*

OD_{ij} = Score of on-time delivery of material *j* related to supplier *i* $(0 \le OD_{ij} \le 1)$, 1 means 100% on-time delivery, this data calculated from past record. This score is computed from the quantity that delivered on-time over the total quantity ordered.

QL_{ij} = Quality of material *j* related to supplier *i* $(0 \le QL_{ij} \le 1)$, 1 means no defect from supplier, calculated from past record. This score is computed from the quantity that are non-defect over the total quantity ordered.

s = Number of suppliers.

However, since the material can be purchased for each of every 1 month, 2 moths and 3 months, therefore we have to formulate the total cost of each case as shown below.

Proportion of total reliability for material j

$$TR_{ij} = OD_{ij} * QL_{ij}\ ; \quad \text{for } i = 1,2,3,\dots,s\ ; \quad \text{for } j = 1,2,3,\dots,n \qquad (4)$$

Where,

TR_{ij} = Score of reliability of material *j* related to supplier $i\ (0 \le TR_{ij} \le 1)$.

n = Number of types of materials.

Expected quantity order for material j

$$D_{ijk} = D_{jk} * R_{ijk} \qquad (5)$$

Subject to;

$$\sum_{i=1}^{s} R_{ij} = 1 \qquad (6)$$

$$Q_{ijk} = \frac{D_{ijk}}{TR_{ij}} \qquad (7)$$

$$Q_{jk} = \sum_{i=1}^{s} Q_{ijk}\ ; \quad \text{for } i = 1,2,3,\dots,s\ ; \quad \text{for } j = 1,2,3,\dots,n\ ; \quad \text{for } k = 1,2,3 \qquad (8)$$

Where,

Q_{ijk} = Quantity of material *j* ordered to the supplier *i* at month *k*.

Q_{jk} = Quantity of material j ordered at month k.

D_{ijk} = Demand for material j related to supplier i at month k.

D_{jk} = Demand for material j at month k.

R_{ijk} = Ratio for material j related to supplier i at month k.

Total cost for material j

Case 1: One-month plan

$$TC_{j1} = \sum_{k=1}^{3}\left[\sum_{i=1}^{s}(Q_{ijk} * P_{ijk})(F/P, i_1, 4-k) + EF_k(F/P, i_2, 4-k)\right] \quad (9)$$

$$U_{j1} = \frac{TC_{j1}}{\sum_{k=1}^{3} Q_{jk}}$$; for i = 1,2, 3, …, s ;

for j = 1, 2, 3, …, n (10)

Case 2: Two-month plan

$$TC_{j2} = \sum_{k=1}^{2}\left[\sum_{i=1}^{s}(Q_{ijk} * P_{ij1})(F/P, i_1, 3)\right] + EF_1(F/P, i_2, 3) + \sum_{i=1}^{s}(Q_{ij3} * P_{ij3})(F/P, i_1, 1) + EF_3(F/P, i_2, 1) \quad (11)$$

$$U_{j2} = \frac{TC_{j2}}{\sum_{k=1}^{3} Q_{jk}}$$; for i = 1,2, 3, …, s ;

for j = 1, 2, 3, …, n (12)

Case 3: Three-month plan

$$TC_{j3} = \sum_{k=1}^{3}\left[\sum_{i=1}^{s}(Q_{ijk} * P_{ij1})(F/P, i_1, 3)\right] + EF_1(F/P, i_2, 3) \quad (13)$$

$$U_{j3} = \frac{TC_{j3}}{\sum_{k=1}^{3} Q_{jk}}$$; for i = 1,2, 3, …, s ;

for j = 1, 2, 3, …, n (14)

Where,

TC_{jm} = Monthly total cost for material j for case m, m = 1, 2, 3.

Q_{ijk} = Quantity of material j that is assigned to supplier i at month k.

P_{ijk} = Price of material j related to supplier i at month k.

EF_k = Engagement fee (fixed cost) at month k.

i_1 = Interest rate for LC.

i_2 = Interest rate for engagement fee.

U_{jm} = Unit cost of material j for case m.

Explanations of each case are as follows.

Case 1 (one-month plan, m = 1): first we calculate the raw material cost of each month by using the material price of each month multiply with the quantity of that month then change it into the future worth at month 3 with the LC interest. The raw material cost was summed for every supplier to get the total variable cost before the engagement fee which changed to future worth was added. After that we sum them for every month to get the total cost of case 1. Finally, we divide the total cost by the all expected quantity to get the unit cost at month 3.

Case 2 (two-month plan, *m* = 2): we compute raw material cost by using the total expected quantity of first month and second month multiply with the price at month 1 (we have to order for covering next 2 months so the price of ordering in next 2 months must be the same). Then we change it into the future worth at month 3 and sum this cost for all suppliers to get the total variable cost. The cost was added with the future worth of first month engagement fee. Then the variable cost and fixed cost of third month was calculated and changed into the cost at month 3. After that we divide the total cost by the expected quantity for 3 months to get the unit cost of case 2 at month 3.

Case 3 (three-month plan, *m* = 3): we sum the demand for next 3 months and multiply with the price at the first month. Then convert this variable cost to the future worth at month 3. The engagement fee was added to the total cost only once in the first month, so we converted the engagement fee like the variable cost. Similar with the previous two cases, we can divide the total cost by the expected quantity for 3 months to get the unit cost at month 3.

Finally, we compare Total cost (TC_{jm}) or Unit cost (U_{jm}) for every case *m* (*m* = 1, 2, or 3) and select the cheapest one.

Allocation Algorithm

In this paper, we have applied Genetic Algorithm as a tool to identify the optimum order allocation plan. The purposed algorithm is shown in Figure 5. Parameters and procedures for the algorithm are set as follows:

- **Initial Population**: Randomly generated
- **Crossover**: Partial-mapped Crossover (PMX) with a crossover rate of 0.2
- **Mutation**: Pairwise adjacent scheme with a rate of 10% mutation rate
- **Selection**: Roulette wheel approach

The chromosome will be represented by the integer representation. Figure 6 depicts a chromosome that we will order material 1 equal to 20 tons from supplier 1, 0 tons from supplier 2, and 15 tons from supplier 3.

Figure 5 The purposed GA algorithm for order allocation

Figure 6 Chromosome Representation

Numerical Example

In order to test the efficiency of the purposed approach, we have done an experiment using a set of materials ordered from 3 suppliers. The tested data are shown in Table 1. Here, we have tested 2 kinds of material (Copper foil and Resin) which their costs dominate the cost of other type of materials. The data have been solved by the purposed algorithm and for verifying the efficiency these data also have been solved by Lingo. The results from both approaches will be compared. Total cost of the purposed algorithm and Lingo will be compared using %RPD as shown below.

Table 1 Testing data set

Input Variables	Testing Value
1.) Number of supplier	Vary based on type of material
2.) Price	Vary
3.) Minimum on-time delivery (OD) score	0.97
4.) Minimum quality (QL) score	0.97
5.) On time delivery ratio of each supplier	0.98, 0.98, 0.96
6.) Quality ratio of each supplier	0.97, 0.97, 0.98
7.) Interest rate for LC Interest rate for engagement fee	5.15%/ month 1.25%/ month
8.) Engagement fee	$ 36 per time
9.) Demand of material	Vary

$$\%\ \text{RPD} = \frac{\text{Total cost from GA - Total cost from LINGO}}{\text{Total cost from LINGO}} \times 100\% \quad (15)$$

Ratio that exceeds 100 means the purposed algorithm is poorer than the optimum solution obtained from Lingo.

In each category, we have considered the values of RPD that compare values of GA to the values of LINGO. Results show that GA provides the values that are very close to LINGO. The RPD is higher than the optimum value obtained from LINGO at only around 1%, or we can say, the efficiency is about 99% of the optimum value.

The increasing in SD results in higher RPD values that may come up from the search spaces that are larger. This will make GA to have a lower performance. By the way,

Table 2 % RPD of the total cost for material type 1 (Copper Foil)

Demand SD	Type	Price Fluctuation	GA	Lingo
±1SD.	0.5 Oz	±1SD.	100.649	100.000
		±2SD.	100.964	100.000
		±3SD.	101.140	100.000
	1.0 Oz	±1SD.	100.590	100.000
		±2SD.	101.190	100.000
		±3SD.	101.910	100.000
±2SD.	0.5 Oz	±1SD.	100.370	100.000
		±2SD.	100.986	100.000
		±3SD.	101.118	100.000
	1.0 Oz	±1SD.	100.673	100.000
		±2SD.	101.462	100.000
		±3SD.	101.953	100.000
±3SD.	0.5 Oz	±1SD.	100.620	100.000
		±2SD.	100.247	100.000
		±3SD.	101.075	100.000
	1.0 Oz	±1SD.	100.650	100.000
		±2SD.	101.458	100.000
		±3SD.	101.994	100.000

Table 3 % RPD of the total cost for material type 2 (Resin)

Demand SD	Type	Price Fluctuation	GA	Lingo
±1SD.	Same	±1SD.	100.280	100.000
		±2SD.	100.000	100.000
		±3SD.	100.915	100.000
±2SD.		±1SD.	100.308	100.000
		±2SD.	100.000	100.000
		±3SD.	100.922	100.000
±3SD.		±1SD.	100.249	100.000
		±2SD.	100.000	100.000
		±3SD.	100.860	100.000

the benefit of the algorithm over the LINGO is that the processing is extremely short (less than 1 second) while LINGO must be coded and needs several minutes to complete. Moreover, there has no need to code the program since the purposed algorithm is coded in C++ language and had been compiled to be an executable program. Data are input directly from the screen and then the program will provide the solution.

Conclusion

As we mentioned in the first part that order allocation is the critical task for a company to minimize the inventory ordering cost. Especially when there are uncertainties occur in the ordering process. In this research, we have done the research that concerns with the order allocation under uncertainty using a real case study. From the study, we can determine the uncertainty factors in the raw material purchasing process. The model has been developed and the algorithm has been constructed using Genetic Algorithm. The purposed approach has been tested by using the real data. The main benefits obtained from this research are; an algorithm with sufficient efficiency that can suggest the near-optimum solution, appropriate forecasting techniques, and allocation approach that works simply with high efficiency. We do hope that this research will be the useful reference for a company who has to make the decision about the ordering under an uncertainty environment.

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