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A Simulation Study of Solving Material Substitution Problem

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Abstract

The material substitution problem is a critical decision issue in the assembly industry. In practice, this problem is usually solved with managers' experiences. However, the management objectives of material substitution are various and sometimes there are conflicts between different departments. Therefore, it needs a comprehensive analysis to assess the effectiveness of adopting substitution material under different management objectives. This research uses simulation model to analyze the effectiveness of material substitution policy which includes external substitution, internal substitution and general use of material. Full factorial experimental design was applied to find the performance of proposed material substitution policy, and order quantity, purchase lead-time, due-date variance, order arrival interval, and delay cost were chosen as independent variables. The average flow time, order delay time, order fulfillment rate, and system cost were chosen as dependent variables. Experimental results showed that material substitution policies are significant on all dependent variables. Especially the external substitution policy performed better than the others in the observed four performance indices. Through external substitution policy can improve order fulfillment rate and reduce average flow time. That is, applying external substitution policy can make a great improvement in customer satisfaction which is the most impact factor in satisfying customers under the mass customization environment.

Keywords: Material substitution, External Substitution, Internal Substitution, System Cost

1. Introduction

In the highly globalized competitive era, the products of mass production have been unable to meet the consumer demand, and more and more production orders are based on customer demand to make. Enterprises must respond to the rapid production of product quickly. Therefore, the gradual trend makes the whole environment toward mass customization in order to meet customer demand (such as product variety and short order due-date, etc.). Then, consumers can obtain different products in a short period of time. The enterprises must increase the product variety to face the pressure brought by this trend (Olsen *et al.,* 1997). However, customer-oriented production model allows customers according to their demand for customized products, and is likely to increase the quantities of bill of material (BOM) significantly. Further, it will cause the complexity of BOM management. In order to simplify the BOM management, and take into account the management flexibility, we usually use two methods to solve this problem, one of which is to design a generic BOM, and simplify the BOM representation (Aydin and Gungor, 2005); another is to use a modular design to reduce the quantities of BOM. The methods will enable greater flexibility and diversity for products and parts. Then it can also reduce the product lead-time and extend the product life cycle (Kusiak and Huang, 1996). Therefore, the flexible handling of customer demand while simplifying the BOM management is top management issue which must be overcome in the mass customization environment.

However, after the implementation of modular design, enterprise can reduce the quantities of BOM through the process of simplifying the product structure. Continuous product innovation, the key modular components of customized products would increase. At this point, if the material supply is less than the demand or supply errors occur, enterprise usually needs to replenish the temporary material shortage and response to customer demand quickly. Enterprise would buy materials from different suppliers urgently or purchase the key components of customer recognition instead of the original material to be produced. The movement is likely to lead to key components prone to material substitution; the purchase of new materials will increase the management complexity. Therefore, in the mass customization environment, material substitution is a very common phenomenon. The management problem for the material substitution, whether now or in the future will be an important issue which should be discussed and solved.

In order to respond to the market demand quickly, enterprises have transferred production method from mass production into mass customization. Enterprises use modular design to reduce the quantities of BOM for production and services and achieve the diversification of products (Boynton *et al*., 1993). On the other hand, the modular design increases product variety, but customer demand for many unique design products has continuously increased. The materials for these unique products are relative increased in the probability of supply errors (supply wrong materials, delay, etc.). In order to avoid the additional cost of downtime and order delay, enterprises usually choose the material substitution method to solve the material shortage problem. Therefore, the management of material substitution becomes the most important issue in the mass customization. In order to understand the problem faced in the material shortage, we should observe in the actual production line, and further analyze the impact factors of material substitution. Material shortage situation is hard to predict in practical production environment. Different types of material shortage situation caused the different production problem. It is difficult to observe the contingency methods and their effectiveness. In this study, we use simulation to explore the impact of using material substitution in the enterprise. Firstly, this study explores alternative considerations of material substitution by expert interviews; secondly, this study uses simulation tool to analyze the impact of material substitution decision-making factors on enterprise performance.

In this study, we study material management issue in an assembly industry and analyze the material substitution management problem by simulation based on four performance indices: average flow time, order delay time, order fulfillment rate, and system cost. We explore the degree of influence of various experimental variables (purchase lead-time, order arrival interval, order quantity, delay cost and emergency order) on the performance of the assembly process of assembly industry.

2. Literature Reviews

2.1 Mass Customization

Due to the change of social environment and market economy, the consumer demand for product and service are gradually changing. The make-to-stock (MTS) and the make-to-order (MTO) methods have been unable to meet the change of consumer demand, and the production method has gradually changed to the assembly-to-order (ATO) model. Enterprises not only have to face consumer demand, but also have to focus on the competition between enterprises. Many enterprises take advantage of the reverse engineering to produce similar products for reducing cost, and cause the price competition between enterprises. There are too many similar products into the market at the same time, resulting in an oversupply phenomenon. Gradually, the enterprises have transferred the production model from traditional mass production into a multi-variety and small batch production in this overwhelming trend of mass customization.

Table 1: Literature reviews of mass customization

Scholar	Characteristics of mass customization
Eastwood (1996)	The enterprise uses high agility and flexibility of the manufacturing equipments integration and the computer system to control the production cost effectively.
Joneja & Lee (1998)	The same product families are produced through the flexible manufacturing process and are able to meet the various customer demands with mass production cost.
Duray *et al*. (2000)	The enterprise produces low cost customized products for customers who can buy the products with low price.
Tu *et al*. (2001)	Fast and reliable enterprise should have the ability to carry out new product design, production and product delivery and be able to meet the customer's specific demand with mass production cost.
Silveira *et al.* (2001)	The enterprise uses flexible manufacturing process to achieve high yield rate and reasonable product price and supply products and services to meet customer demand with low price.
Selladurai (2004)	Product cost will be reduced by the economic production scale and common parts design. Using common parts will reduce inventory and improve the demand forecast.
Partanen & Haapasalo (2004)	The enterprise is able to reach and maintain a competitive advantage with the most effective way to create performance.
Frutos & Borenstein (2004)	The main aim of customized production system is able to meet the customer requirements and is able to quickly and efficiently provide the consistent quality level, low cost, and high-quality service at the same time.

From literature reviews of mass customization in Table 1, the common factor is to supply low cost product same as mass production cost to meet the customers' specific demand. Therefore, in order to meet the characteristics of mass customization, through a modular design to reduce the material cost or in order to increase the flexible use of material for reducing inventory to achieve mass customization characteristic. These methods have relative risks, and the biggest risk is whether the key components can be supplied in time. The unstable suppliers' delivery system is the main risk factor for the material shortage. Even there are the best manufacturing processes or methods can't deliver the product on schedule, the unstable system influences the continuous development of enterprise. Therefore, the mass customization implementation should focus on how to solve the material shortage problem.

The product cost will be reduced by the economic production scale and common parts design. Using common parts will reduce inventory level and improve the demand forecast (Selladurai, 2004). In addition, some phenomenon can often be found in the mass customization industry. The same material specification and function will be chosen for specific key component, known as substitution material. The main goal is to provide the flexible use of the selected materials. It can be found that the substitution material in the product development stage is necessary. The material substitution not only supplies material for production urgently, but also provides key component to the R&D staffs for innovation. The use of material substitution in mass customization production strategy is very common and important decisions. Therefore, material substitution elements added in the mass customization environment highlight the materials flexibility and cost advantage. Then it can make a giant profit for enterprise. Blending material substitution management into mass customization can achieve the following advantages and characteristics:

High production flexibility: face the rapid change in consumer demand and use the material substitution method to improve productivity and production flexibility when material shortage occurs.

High order fulfillment rate: use high production flexibility for the production flow and the appropriate use of material substitution to maintain the material supply of the production line and reduce downtime when material shortage occurs, so that customer can get the products on time.

Low production cost: add the material substitution factors in the production process for production flexibility, not only can reduce inventory, but also can reduce the penalty cost caused by delay in delivery.

High product quality: maintain high material substitution flexibility in the production process for the yield of the process, not only can make the product quality as excellent as mass production, but also can provide high quality product to customer.

The customized product: R&D department uses the properties of material substitution to assemble the materials with innovative thinking, and thus provide a customized product variety to conform to the market trend.

According to the above characteristics, this study uses expert interviews to select four performance indices: system cost, order fulfillment rate, average delay time and average flow time as simulation measurement indices. Then the material substitution simulation results will be provided to the enterprise for reference and usage.

2.2 Related research about material substitution

Balakrishnan and Geunes (2000) mentioned in their study that because advance in product manufacturing technology and product design significantly increase the BOM flexibility. The BOM flexibility means substitutability between the different materials. The scholars have proposed two substitution scenarios: one is an independent substitution, refers to a material of a product substituted by another material does not affect the original product design/function (same as general substitution). Another is interacting substitution means that a material of product has the dependent relationship with the other component (common part) of the same level. After interacting substitution, the materials with the same level must also be substituted at the same time. Orlicky (1974) has similar view (horizontal dependent). Because Balakrishnan and Geunes (2000) focused mainly on the two-layer BOM structure that the materials with the same level must be substituted at the same time when enterprise used interacting substitution method.

Lyon *et al*. (2001) in the study mentioned the concept of two substitutions, a first called general substitution means the substitution condition does not change the materials of higher level; the corresponding materials of lower level can be substituted by other materials. Another substitution called alternative BOM, substitute the lower level materials by different materials, the corresponding materials of higher level will be changed to different materials. This substitution method changed all materials of higher and lower level to different materials, called the alternative BOM. Ram *et al.* (2006) proposed the dependent demand substitution. Such material substitution allows to using some other materials when material shortage occurred. The proportion between the two materials can be adjusted to meet the need of the final product process in time. The scholars explore the food industry which allows to adjusting the proportion of the materials when the materials shortage occurred. Our study object is an assembly industry which has not a proportion adjustment problem. Some literature reviews about material substitution are summarized in Table 2.

Table 2: Material substitution related literature

Author	Method	Description
Balakrishnan and Geunes (2000)	Interacting Substitution	A particular material of the product substituted by other material, the material with other related materials must also be substituted by other materials.
Lyon *et al.* (2001)	General Substitution	The substitution condition does not change the materials of higher level; the corresponding materials of lower level can be substituted by other materials.
Lyon *et al.* (2001)	Alternative BOM	The all materials of higher and lower level must be substituted.
Ram *et al.* (2006)	Dependent Demand Substitution	Using other materials with appropriate quantities in case of lower level material shortage occurred.

In practice, if factory encountered material shortage that lead to stop producing, it needs the similar specification of substitution material to keep on manufacturing. The material substitution may change all manufacturing processes and supply chain management. The enterprise must let customer accept the change of the material supply source and inspect the pilot run result. So the general substitution needs the client's approval. If enterprise does not take into account this issue, it will get some complaints from the customer. The material substitution methods in Table 2 do not take into consideration for this issue. This study considers external substitution and internal substitution to solve the practical substitution issue. The external substitution considers suppliers agreed by the customer for substitution material. The internal substitution uses the same modular design material to avoid product similarity. The detail descriptions are as follows:

(1) External substitution: The method is same as the general substitution; the biggest difference is material suppliers and specification limit. If material shortage and engineering change caused delay in delivery, the enterprise needs to purchase material in time to substitute the original part. The material quantities must meet the demand of process and design. The substitution could cause cost-up, but avoid the low order fulfillment rate.

(2) Internal substitution: The method is same as the general substitution; the biggest difference is the use of same modular design materials. The two products have the same modular design materials which have same function and specification after material substitution. Internal substitution does not affect the performance of the original product. The material manufacturing can consider flexible inventory mix to reduce purchase cost and share the availability of materials. This substitution approach is more flexible in product BOM, but material management becomes more complicated.

3. Research methods and architecture

3.1 Set the material substitution impact factors

Due to many material substitution impact factors in the enterprise, this study set from an enterprise functional perspective to divide the organization into the five departments: production and material management, research and development, purchase, quality control and business. Then this study discusses the material substitution impact factors of each department and then draws a cause-effect diagram of material substitution impact factors as shown as Figure 1.

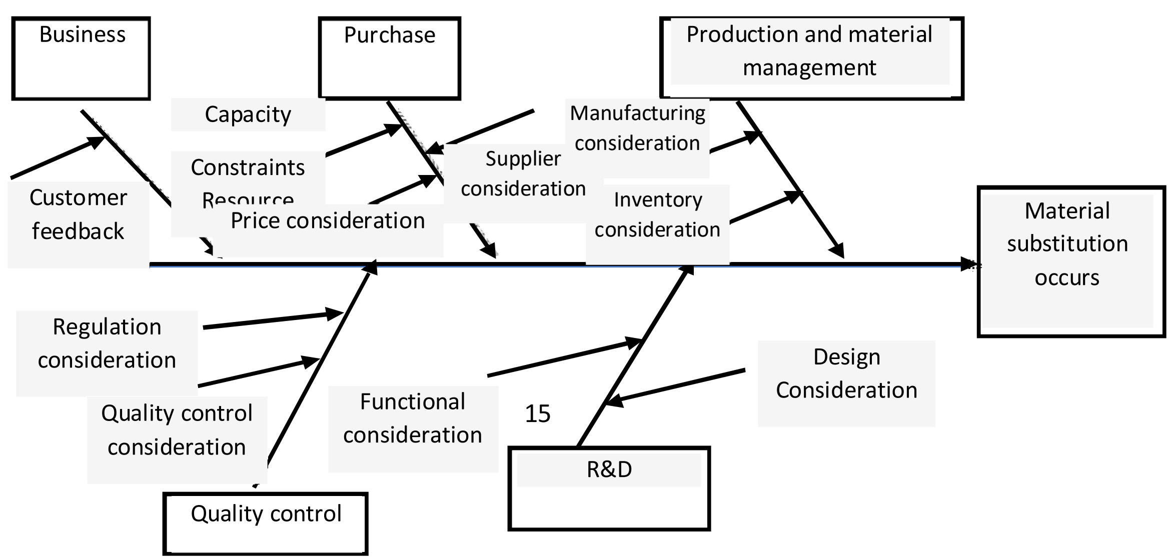

Figure 1: Cause-effect diagram of material substitution impact factors

The timing and reason of substitution are determined by the factors of sales area (location of customers), purpose, company's development process and emergency substitution. But the discussion of the resolution must be decided by engineering change and material substitution reviewing board. Through the material testing, pilot run and inspection of engineering change; the factory gets the customer's consent and makes a material substitution announcement which can provide the legality and correctness of the production information. Therefore, the timing and reason of substitution are different; it can be divided into as follows:

(1) Mandatory substitution: If the substitution reasons are product safety issue or quality problem, the material must be substituted immediately. The product must be recycled from the market immediately and the material must be substituted actively.

(2) Phased-in or optional substitution: The timing and reason of substitution are determined by the factor of sales area (such as sold in the EU and the China) or by the factor of delivery on schedule (when materials are short). At this time point, there may be a variety of coexistent materials which are mutual substitution materials. It is necessary to clarify the factor and timing of each suitable material substitution from order release to the production process. Although the processes of each company are different, but the material substitution decision must integrate the substitution method, substitution timing, sales area and order due-date to construct a complete material substitution management and evaluation model.

According to the above characteristics, this study uses expert interviews to select five experimental variables: purchase lead-time, order arrival interval, order quantity, delay cost and due-date variance as simulation variables. But due to the time point that occurred in these variables is not fixed; this study will consider the time point of substitution occurring after the time point of inventory. The order material substitution is determined by the amount of inventory. This study will observe production process changes and analyze the performance impact of the variables by material substitution simulation.

3.2 Set the material substitution flow

(1) General use of materials: This method does not consider the material substitution and the BOM are fixed. When customer orders arrive, the factory obtains the product information (order quantity, due-date, routines, and product variety). If the material inventory is over the order point, then factory releases order information to shop floor for manufacturing. If the material inventory is below the order point, then warehouse releases purchase order and factory releases order information to shop floor. The simulation is ended after materials release.

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(2) Internal substitution: In simulation system, this method depends on inventory status to release materials. When customer orders arrive, the factory obtains the product information (order quantity, due-date, routines, and product variety). If the materials inventory is over the order point, then factory releases order information to shop floor for manufacturing. If the material inventory is below the order point, then warehouse releases purchase order and checks the materials for substitution. If there are no materials for substitution, then factory waits the material scheduled receipts. If there are materials for substitution, then factory releases order information to shop floor for manufacturing. The simulation is ended after materials release.

(3) External substitution: In simulation system, this method depends on inventory status to release materials and can purchase materials urgently. When customer orders arrive, the factory obtains the product information (order quantity, due-date, routines, and product variety). If the materials inventory is over the order point, then factory releases order information to shop floor for manufacturing. If the materials inventory is below the order point, then warehouse releases purchase order and checks the materials for substitution. If there are no materials for substitution, then factory waits the material scheduled receipts. If there are enough materials for substitution, then factory releases order information to shop floor for manufacturing. If there are not enough materials for substitution, then warehouse releases purchase order urgently and factory releases order information to shop floor in accordance with production priority. The simulation is ended after materials release.

3.3 Framework of simulation

The framework of simulation in this study is shown in Figure 2. The material substitution model is consisted of the assembly process, related control parameters, six experimental variables and four performance indices. Experimental variables are material substitution, orders, purchase lead-time, delivery variance, order arrival interval, and delay cost. The four performance indices are system cost (SC), order fulfillment rate (FR), delay time (DT), and average flow time (AFT).

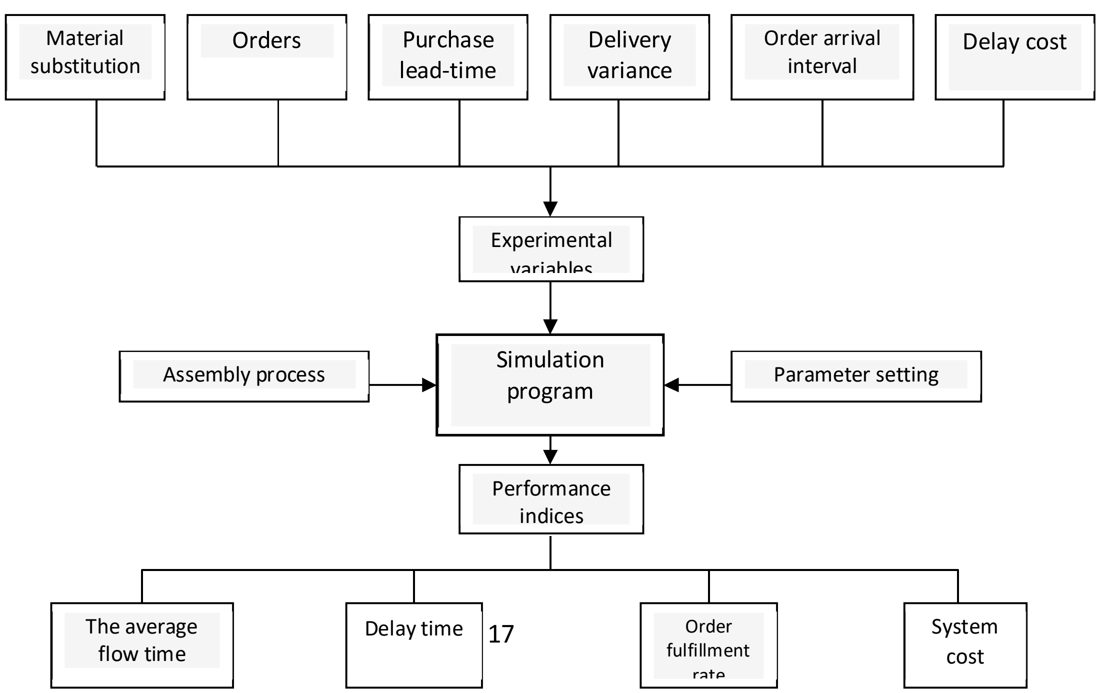

Figure 2: Framework of Simulation

This study considers all variables thoroughly to understand the impact of different experimental variables on the simulation system. This study sets the following six experimental variables and analyzes the impact of variables on material substitution:

(1) Material substitution: in simulation model, we consider three kinds of material substitution.
General use of material: When the material shortage occurred, factory does not take special replenishment and material substitution mechanism.

Internal substitution: When the material shortage occurred, factory will use the permitted materials in the BOM table for material substitution. The substitution material is another product's material in the warehouse.

External substitution: When the material shortage occurred, factory will use the permitted materials in the BOM table for material substitution. If there are enough materials for substitution, then factory releases order information to shop floor for manufacturing. If there are not enough materials for substitution, then warehouse releases purchase order urgently and factory releases order information to shop floor. The material substitution of emergency purchase is specified by the customer with different material suppliers.

Emergency purchase formula: the emergency replenishment quantity = demand - inventory - the stocks of substitution material.
(2) Order quantity: refers to a lot size of the order.

(3) Purchase lead-time: the system uncertainty will lead to interrupt supply in the supply process of upstream suppliers and cause the delay of the order. The purchase lead-time in the model is uncertainty.

(4) Delivery variance: the variance of the order due-date.

(5) Order arrival interval variance: the time variance of the order arrival interval.

(6) Delay cost: the penalty cost for the delay order.

Performance Indices

In this study, four performance indices are defined as follows:

(1) System cost: The system cost is the total system cost divided by the total orders in the effective data collection period. The system cost is consisted of the unit cost of material, the

unit cost of manufacturing, and the penalty cost of the delay order (Teunter and Laan, 2002). The system cost formula is as equation (1):

$$SC = C_h + C_p + C_l \quad (1)$$

SC: denote system cost.
C_h: denote unit cost of material.
C_p: denote unit cost of manufacturing.
C_l: denote the penalty cost of the delay order.
The penalty cost of the delay order formula is as equation (2):

$$C_l = (\text{Total delay orders} \div \text{Total orders}) \times \text{Delay cost} \quad (2)$$

(2) Order fulfillment rate (service level): The order fulfillment rate is the orders finished on time divided by the total orders (Mohebbi and Choobineh, 2005). The order fulfillment rate formula is as equation (3):

$$FR = (\text{Total orders} - \text{Total delay orders}) \div (\text{Total orders}) \quad (3)$$

(3) The delay time: The order completion date exceeds the order due-date is called delay. The delay time is sum of all delay orders time.
(4) The average flow time: The average flow time is the total process time of finished orders divided by the total finished orders. The average flow time formula is as equation (4):

$$\text{AFT} = \frac{\sum \text{Process time}}{\text{n}} \quad (4)$$

4. Simulation Analysis

4.1 Parameter Setting

The customer orders, material and production information are shown as Tables 3 to 5. The distribution of order arrival interval and order quantity is normal distribution. The processing time of each operation is a fixed time (as shown in Table 6). The levels of experimental variables in the model are two to three levels as shown in Table 7. The level design of the experimental variables is according to the industry suggestion. In Table 7, CV = 0.3 represented a low degree of variance; CV = 1.0 or CV = 0.7 represents the high degree of variance.

Table 3: Set the value of the system parameters

No.	System parameter	Value
1	Material substitution	Three mechanisms, depending on the level of the experimental variables.
2	Order arrival interval	Normal(50, σ) hour; Value > 0, σ = 15 or 35, depending on the level of the experimental variable.

3	The size of the order	Normal (250, σ) unit; Value > 0, σ = 75 or 250, depending on the level of the experimental variable.
4	Due-date variance	0.3 or 1.0, depending on the level of the experimental variable~ DDV.
5	Material lead-time	Normal (1, σ) day, σ = 0.3 or 1; Normal (3, σ) day, σ = 0.9 or 3; Normal (5, σ) day, σ = 1.5 or 5; Depending on the level of the experimental variable~ MLT.
6	Delay penalty cost (rate)	\$50 or \$150 (day×Unit); Depending on the level of the experimental variable~ DPC.
7	Order slack level	40, 30
8	Lot size of each operation of the manufacturing routine	10 units
9	Processing cost of each operation of the manufacturing routine	\$60/unit (assuming that the set-up costs is 0)

Table 4: Set the value of material parameters

No.	Material	Purchase lead-time	Purchase cost (unit)	Order point	Order quantity
1	a	Normal (3, σ) day; σ = 0.9 or 3	20	5,000	5,000
2	b	Normal (3, σ) day; σ = 0.9 or 3	25	5,000	5,000
3	c	Normal (3, σ) day; σ = 0.9 or 3	55	10,000	10,000
4	d	Normal (3, σ) day; σ = 0.9 or 3	15	10,000	10,000
5	z	Normal (3, σ) day; σ = 0.9 or 3	40	10,000	10,000
6	a’	Normal (5, σ) day; σ = 1.5 or 5	30	10,000	10,000
7	b’	Normal (5, σ) day; σ = 1.5 or 5	35	10,000	10,000
8	c’	Normal (5, σ) day; σ = 1.5 or 5	65	10,000	10,000

Table 5: Set the value of external material substitution

No.	Material	Purchase lead-time	Purchase cost (unit)
1	a	Normal (1, σ) day; σ = 0.3 or 1	20×2
2	b	Normal (1, σ) day; σ = 0.3 or 1	25×2.25
3	c	Normal (1, σ) day; σ = 0.3 or 1	55×2.5

Table 6: The processing time of each operation in production line

Operation number	Operation name	Average operation time
1	PCB plug	3 minutes
2	Test before assembly	1 minute
3	Shell assembly	3 minutes
4	Test after assembly	1 minute
5	Package	3 minutes

Table 7: Set the level of the experimental variables

No.	Experimental variables (symbols)	Level
1	Material substitution (C1)	Level 1: The use of specified material. Level 2: If the inventory of specified material = 0, then use material substitution. Level 3: If the inventory of specified material and substitution material < demand, then purchase specified material urgently.
2	The variance of order arrival interval (C2)	Level 1: CV=0.3; Level 2: CV=0.7
3	The variance of the material lead-time (C3)	Level 1: CV=0.3; Level 2: CV=1.0
4	The variance of purchase lead-time (C4)	Level 1: CV=0.3; Level 2: CV=1.0
5	The variance of due-date (C5)	Level 1: CV=0.3; Level 2: CV=1.0
6	Order delay penalty cost rate (C6)	Level 1: \$50 (Day×Unit); Level 2: \$150 (Day×Unit)

4.2 The simulation results and analysis

The results are shown as Tables 8 and 9. The analysis is described as follows:

(1) The average flow time

The average flow time of internal substitution and external substitution are less than the general use of material. The two substitutions can provide materials within a short period of time and shorten the average flow time significantly when the material shortage occurred. The external substitution reduces the average flow time by additional material supply time and is better than internal substitution which uses other product's materials. The variances of order arrival interval, purchase lead-time and order quantity is as small as possible. The large variance means that time and quantity are unstable, so factory can't make the product on schedule and increase the average flow time.

(2) Order fulfillment rate

The order fulfillment rate of internal substitution and external substitution are better than the general use of material. Because factory takes a first-in, first-out production method, the general use of material has no additional method to use, so the two substitution methods will be superior to the general use of material. The variances of order arrival interval, purchase lead-time, order quantity and due-date are as small as possible. The small variance lets system more stable, so that factory can reduce the delay orders and increase the high order fulfillment rate.

(3) The average delay time

The average delay time of internal substitution and external substitution are less than the general use of material. The two substitutions can provide materials within a short period of time and shorten the average flow time significantly when the material shortage occurred. The variances of order arrival interval, purchase lead-time, order quantity and due-date are as small as possible. The small variance lets system more stable, so that factory can reduce the delay orders and average delay time.

(4) System cost

The system cost of internal substitution and external substitution are less than the general use of material. Because the average delay time of general use of material is greater than the internal substitution and external substitution. The variances of purchase lead-time, order quantity, due-date and delay cost is as small as possible. The small variance lets system more stable, so that factory can reduce the delay orders and system cost.

According to the simulation results and analysis, this study gets the following conclusions as shown in Table 8. In addition, the comparison of performance indices and material substitution standard as the main goal of the study are shown as Table 9. Based on the average flow time, order fulfillment rate, or the average delay time for the main performance indices can be found that the internal substitution and external substitution performance are better than the general use of material, and the external substitution is better than the internal substitution. Based on the system cost for key performance index can be found that the internal substitution and external substitution are better than the general use of material and external substitution is better than the internal substitution. If the purchase cost of external substitution is too high, this study recommends internal substitution. According to the simulation results, the use of material substitution can reduce cost effectively without affecting the production capacity. But enterprise must care that whether the external substitution cost is too high, such as additional shipping cost and the material cost, to avoid violating material substitution purpose. On the other hand, customer satisfaction has become the corporate merits of the indices. Using external material substitution policy can increase the order fulfillment rate and reduce the average flow time simultaneously. However, managers should understand the situations faced by the enterprise and the pros and cons of material substitution policy.

Table 8: The degree of impact about experimental variables to performance indices

Performance indices	Experimental variables					
	Material substitution	Order arrival Interval	Purchase lead-time	Order quantity	Delivery variance	Delay cost
Average flow time	*	*	*	*		
Order fulfillment rate	*	*	*	*	*	
Average delay time	*	*	*	*	*	
System cost	*		*	*	*	*

Table 9: Comparison of performance indices and material substitution standard

Performance indices	Comparison of material substitution
Average flow time	External substitution is better than the internal substitution, and internal substitution is better than the general use of material.
Order fulfillment rate	External substitution is better than the internal substitution, and internal substitution is better than the general use of material.
Average delay time	External substitution is better than the internal substitution, and internal substitution is better than the general use of material.
System cost	External substitution is better than the internal substitution, and internal substitution is better than the general use of material.

5. Conclusion

Through the results analysis of this study, some improvement recommendations are suggested as follows: (1) an enterprise can establish a complete material substitution management model to set standard operation procedure; (2) when the material substitution occurs, the enterprise should make an substitution purpose (performance indices), and then choose alternative ways to achieve the expected effectiveness of enterprise; (3) the purchase department must maintain good relationship with suppliers, so that unexpected situations can be handled immediately.

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