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Apply 3C Theory in Spare Parts Management in Mobile Phone Industry

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Abstract: The product lifecycle of mobile phones are usually less than six months. Once mobile phone products have no commercial value any more in the market, their associated spare parts will soon becoming idle stocks, or even dead stocks. Even if some manufacturers may promise to have after-sale warranty to customers, however, due to the nature of the uncertainty in demand and supply information from the service company, manufacturer will usually have to take all the risk of the dead stock. Therefore, the study applies the 3C theory to monitor the demand of specific spare parts in the market demand based on the commonality, capacity and consumption (3C) of the spare parts. Meanwhile, an adaptive replenishment system for each spare part based on 3C theories and the dependency between one spare part with the other has been proposed.

Key words: 3C theory, spare part replenishment system, adaptive replenishment system

INTRODUCTION

Grant and Schlesinger (1995) pointed out that there were three ways to increase their profit. The first way was to attract more customers and expand customer base; the second way was to raise the utility rate of customers; the third way was to keep good and long-term relationship with customers. Although repair is a customer service activity in terminal management, damage is possible for any product. In order to keep good interactions with customers and enhance brand loyalty, more and more mobile phone manufacturers leave after-sale repair to professional repair operators. Chen (2001) argued that the motivation for collaborative use in repair management is to allow all members in entire repair process participate jointly in the management through Internet as media and effectively improve the time-efficiency of entire maintenance. Under customer-oriented and service-oriented trend, repair service has played a role in creating competitive edges by enterprises. Therefore, professional repair operators for mobile phones will become an important ring in the supply chain of mobile phone products. Integrating subcontractors on business value chains including purchasers, suppliers, logistic operation and cash flow to enhance integral operation efficiency is the direction of future development of supply chains.

Analyzing from the angle of entire supply chain, after manufactured by Original Equipment Manufacturer (OEM) or Original Design Manufacturer (ODM), a mobile phone will be launched in a sales channel like channel distributors and retailers for purchase and use by customer. If there is any damage during one-year factory warranty period in use, it is the time for a professional repair operator to provide their services. A professional operator of mobile phones is certified and given authorization by contract as a qualified repair operator that is responsible for repairs in the period of factory warranty (normally one year). From the angle of the process of repair, the repair process of mobile phones is shown as Fig. 1.

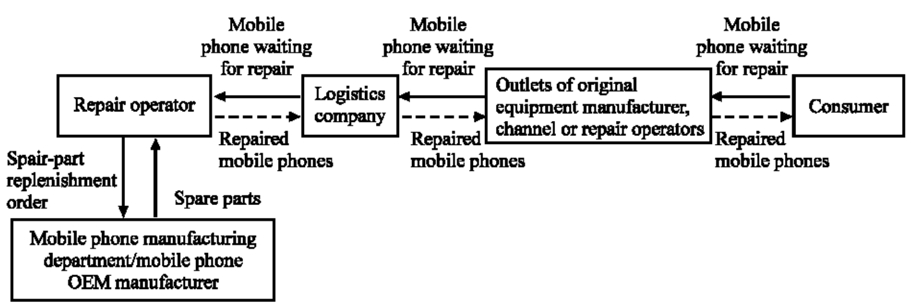

Fig. 1: Mobile phone repair flowchart (Kao, 2004)

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As the Fig. 1 shown, the original equipment manufacturers, retailers and repair operators should agree on principles of the receiving, delivery, transportation and repair. When customers send their breakdown mobile phones to the outlets of original equipment manufacturer, channel or repair operators, the outlets or channel operators will transfer the articles to logistics and repair operators will repair the mobile phones transferred by the logistics according to the agreed principle. The repair operation has to complete the repair in time and return the repaired article to original manufacturer, channel operator or an outlet of repair operator before the mobile phone is returned in the hands of customer (Christopher, 1992).

Now, let's discuss the method of the order and replenishment of spar parts. There are many manufacturers and retailers of mobile phones and new products are launched continuously, but usually the product life cycle in the mobile phone markets is half of year. Although a product may not sell in the markets, the maintenance and repair should continue for a period of time. According to the practical experiences of the companies in the case studies and research, the repair rates of product is 1 to 2% that this experienced ratio was considered as the basis of spare parts replenishment in the past. Besides, in order to deal with the variations of quality and the uncertainty of demand and supply, traditionally an enterprise has to use stock to deal with the problem. But it is a high cost and inflexible method. One of purposes of supply chain management is to solve the problem. The enterprises hope to link upstream and downstream partners to increase their own competitive edges, strengthen relationship of reliability between the partners and establish a supply chain system that will penetrate and link upstream, midstream and downstream partners.

The repair service of mobile phone has played a very important role in the supply chain of communication products. With the coming of Internet, the repair operators of mobile phones in Taiwan have to collaborate and cooperate with other members in the supply chain to provide consumers with better and quicker services. Therefore, through literature reviews, the research recommends using 3C theory to solve the problem of spare parts of mobile phones stock and introduce the solution of 3C Theory-Based Spare Parts Stock Management System.

COMPARISONS BETWEEN TRADITIONAL MRP AND JIT SYSTEMS

The 3C approach developed by Lucent in its Spanish Tres Cantos plant (Fernandez-Ranada *et al*., 1999) links sales planning seamlessly to component suppliers using a collaboration process based on ranking maximum usage rates of individual components (Holmstrom *et al*., 2002). 3C Theory is the basic theory for realizing global supply chain management and designed to plan and realize global resource project. In the past, we even do not know the disruption between activity processes of order model, purchase, production and manufacturing because we were lack of demand prediction model that could be applied to short product life cycle. For example, the traditional relationship between order model and material requirement planning (MRP) is planning is planning, order is order, no direct relationship between, that is, there exists some problems in the stock management of Re-Order Point (ROP) (Sameer and Meade, 2002).

Naturally, it is difficult to guarantee the accuracy of the policy-decision on material supply on such basis. Besides, when we use traditional MRP to work out a Master Production Schedule (MPS), what we think will be how much is the production of a product in a certain period not total production of a certain group of products. There is big difference between the production and actual demands of individual product. On the contrary, the difference between predicted total production and actual production of a group of products will be certainly much smaller. That is, traditional MRP could only plan for the requirement of material of individual finished products and lack of capability of material demand planning for a group of products under duplicated production. In the deployment process of Bill of Material (BOM), although MRP combines common raw materials in calculation that is only for the consideration of batch purchase, the actual purchase strategy is still based on the production demand of MPS that often neglects the purchase benefit brought by the combination of common raw materials (Mohebbi *et al*., 2007).

On the contrary, JIT system can detect the consumption only after the materials are consumed, so it can be used only when the accumulated lead time from the materials to finished product is very short and the future demand is stable. It cannot be used in long-term prediction of material purchase besides, JIT system only consider the flow between of two manufacturing processes of each material not the relationship between materials, that is, not use BOM. Furthermore, JIT System applies only to the premise of hypothesis that the production line is balanced (Huq and Huq, 1994). But in reality, a production line is difficult to reach balance. Therefore, there is insufficiency in practices for planning material demand according to JIT system. The calculation of number of billboard in JIT system is based on experiences and not considers future demands, the changes of commonality of materials. Also under the situation that lacks of function of integral planning, it cannot timely adjust replenishment supply of materials to respond to the changes of demand.

Comparing to the relationship between order model and resource requirement plans of 3C, the 3C model is an operation model that will integrate the relationship between order model and resource requirement plans. The biggest difference between 3C model and traditional model is 3C accepts order only when it could do it whereas the traditional idea is that accepts order before confirming whether it has capability to carry out. This difference is the key to win in competition for an enterprise (Huang, 2004). The value of 3C theory in application is to help enterprises to solve the problem of resource management and reestablish global supply chain management system.

SOLVE THE PROBLEM OF MOBILE PHONE SPARE PARTS STOCK WITH 3C THEORY

3C theory is to classify and expand the prediction of demands from markets by the model of commonality, capacity and the replenishment of consumption with the changes of markets. Followings are their descriptions:

Introduction of 3C theory

- The basic idea and value of commonality is to achieve the goal of reducing the cost of development, simplifying resource management, reducing the quantity of stock and providing customers with diversified products through extensive use of the strategy of common material or resources. The characteristics of commonality are enhancing the commonality of materials and reducing the number of product varieties and considering the expression of product on Internet at the stage of research and development.
- The basic idea of capacity is to plan the allocation of resources through the application of Theory of Constrain (TOC) at the same time of accepting the order to enhance the client satisfaction and avoid delivery delay due to running out of stock or insufficient capacity.

The characteristics of capacity is that the demand of material and capacity have their ceiling, so when a manufacturer receives order, they have to consider whether material and capacity have capability to fulfill their promise to customers. It is an act according to their ability and a model that compares the material situation in the plan with the product varieties or materials selected by customer before answering to the customer.

- The basic idea of consumption is a mechanism that combines the replenishment model of market demand through instant market information to buy materials when need. Such mechanism aims to achieve the goals including reduction of stock standard, fund reserve and loss due to discount of stock. The characteristics of consumption are that the materials are purchased with the changes of practical demands in the markets and emphasize on the simultaneity with the demands from the markets. In order to solve the problem that there is market information about new products and materials for reference, the man-made prediction values are included only under following conditions and in the rest of time, for preventing man-made over-intervention, the system will produce purchase lists automatically.

- Use of new products and materials (product phase-in)
- Last sale and purchase of existing products and materials (product phase-out)
- Special promotion activities (Promotion)
- Avert the rise of specific materials

The exploration of stock model and recommendations: The basic idea of consumption in 3C Theory is emphasizing on planning the resource requirement with the changes of markets by daily material resource plans to quickly adjust the purchase and application of resource. It also emphasizes on the design of the information communication and collaborated calculation with upstream and downstream suppliers and customers. Enterprises have to plan and install the transaction rules through information system to respond quickly the demands from customers. On such basis, the purposes that 3C spare parts replenishment management system wants to achieve are as follows:

- Independence of maintenance operation
- Meet the changes of product demands
- Make production schedule more flexible
- Provide business with the protection from the changes of delivery time of raw materials
- Able to obtain the benefit of economy of scale

The deployment of 3C spare parts replenishment management system: In the structure of 3C theory, the deployment of material requirement is to classify and deploy with the models of commonality, capacity and consumption replenished with the variations of demands from markets. Therefore, in the exploration on the material replenishment policy, we have to know whether there is dependency between the requirements of spare parts and take it as the basis of demand prediction to decide which one is the appropriate stock model. 3C spare parts replenishment management system introduced in this research are as follows:

The definition of terms in 3C theory:

- **Maximum Output Rate (MOR):** The maximum output rate of product p at production unit f is MOR_{pf}.
- **Maximum Sales Rate (MSR):** The maximum sales rate of Product p, MSR_p, is the output rate of the product in the supply chains $MSR_p = \min\{MOR_{pf}\}$.
- **Estimated sales rate or Table of Pull (TOP):** The peak sales rate of product p that everyone agree is TOP_p and $TOP_p \leq MSR_p$.
- **Actual sales rate:** The average daily quantity of order of product p is CO_p.
- **Utilization:** The utilization of functional unit is U_f, $U_f = \sum_p CO_p / MOR_{pf} \leq 1$.
- **Summarized bill of material:** A summary of all materials and their quantities used by a product structure. It does not consider the class of materials. Any material will be listed only once. The unit use amount is total use amount. In summarized bill of material, the total amount of material m used by one unit product p is BOM_{pm}.
- **Rate Bill of Material (RBOM):** It is the basis of 3C planning which considers all products not individual product in product lines. That is, RBOM is the list of all materials produced in the same production line or factory, not the list of materials for any product.
- $RBOM_m = \max\{TOP_p \times BOM_{pm}\}$°.

The construction of spare parts management system of 3C theory: Based on the definitions, the construction of 3C Theory in stock management system is conducted according to following procedures:

- **Calculate maximum consumption rate of each material based on capacity limit:** Estimated sales rate of a product multiplying by the use amount of material m by the product, we could obtain the consumption rate of material m by the product. Then pick up the maximum value of consumption rates of material m by individual products to obtain $RBOM_m$. In fact, the has considered $RBOM_m$, consumption (multiplies), commonality (maximum value of consumption of m by individual products). It is the core of 3C theory. Its algorithm is as follows:

$RBOM_m \leftarrow 0$;
U←0; //capacity usage
$ORCON_{pm} \leftarrow MSR_p \times BOM_{pm}$; //output rate of consumption
Rank p in descending order of $ORCON_{pm}$;
Select first p;
DO WHILE (U<1 AND p exists)
$RBOM_m \leftarrow RBOM_m + TOP_p \times BOM_{pm} \times \min\{(1-U)/(TOP_p/MSR_p),1\}$;
$U \leftarrow U + \min\{(1-U)/(TOP_p/MSR_p),1\}$; //capacity usage
Select next p;
LOOP

The material commonality index is used as the performance indicator of stock management. Commonality is not only a conception but also the concrete indicator that could be measured and called commonality index. In the best situation, the commonality is 1 whereas at the worst situation, the commonality is 0. At the best situation, the stock amount is the lowest, set as Inv_{best}, the stock amount is highest at the worst situation, set as Inv_{worst}. The description is shown as Fig. 2.

In Fig. 2, COMI is commonality index under normal situation, Inv_{pract} is the stock amount under the situation. Assume the cost of material m is C_m and there are P varieties of products, then:

- At the best situation, all products completely use common materials, that is, total only one product, so P = 1, the stock amount is: $Inv_{best} = \sum_m TOP_1 \times BOM_{1m} \times C_m$°
- At the worst situation, all products completely not use common materials. So, $Inv_{worst} = \sum_p \sum_m TOP_p \times BOM_{pm} \times C_m$°
- Under normal situation, the stock amount is: $Inv_{pract} = \sum_m RBOM_m \times C_m$.
- $COMI = (Inv_{worst} - Inv_{pract})/(Inv_{worst} - Inv_{best}) = [p/(p-1)][1 - Inv_{pract}/Inv_{worst}]$

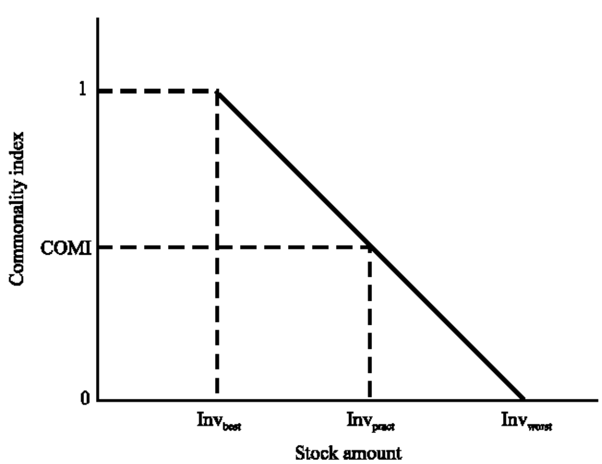

Fig. 2: Commonality index and stock amount

The decision on order policy: The process of Order Policy Choice Model recommended by the research is as follows:

Step 1: The analysis of requirements of independency and dependency in the use of spare parts.

- Decide on the prediction method for the material requirements in stock system
- Requirement of independence the requirements between different items are not interrelated
- Requirement of dependency the requirement of item comes from the requirements of other items

Step 2: Conduct ABC analysis of the ratio of value and requirement of use of individual spare parts.

- When the resource is limited, we have to efficiently use the limited resources to control stock. According to Pareto Theorem (Sen, 1993), we should focus our attention on the most important articles in stock and it is impossible to give one model to each product or completely control it. We can firstly conduct classification of ABC.

Step 3: Choose corresponding stock model according to spare part classifications.°

By the data of actual material consumption, the Economic Order Quantity (EOQ) and Safety Stock (SS) can be easily calculated (Silver *et al*., 1998). Because 3C is in an environment of repeated production and considering commonality, so its EOQ and SS are very low. The higher commonality of material is, the lower of the SS will be. Assumed the lead time of material m from a supplier to factory is LT_m.

- A type of product and its COMI > 0.5, should use regular order model as Fig. 3 demonstrates:

The purchase cycle could be obtained from following formula:

- $TBP_m = EOQ_m/RBOM_m$
- Order-Up-to-Level $OUT_m = RBOM_m \times TBP_m + SS_m$°
- The reorder point of material m: $OP_m = RBOM_m \times LT_m + SS_m$°
- When the inventory level reaches the reorder point, an order with its quantity equal to the economic order quantity minus the current stock quantity will be generated.

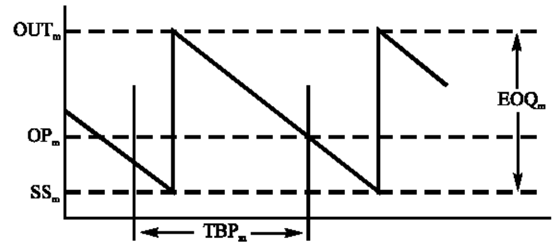

Fig. 3: Regular order model

- When a product is A type and its COMI < 0.5 or the product is B type and COMI > 0.5, we should use fixed quantity order model--when the stock is reduced to reorder point, we should place an EOQ order.
- $EOQ_m = \sqrt{\frac{2MRP_m K}{H}}$
- Reorder Point: $ROP_m = RBOM_m \times LT_m + SS_m$
- When a product is B type and its COMI<0 or the product is C type and COMI>0.5, we should use double-box system. When a product is C type and COMI < 0.5, we should use single-box system.
- The optimal stock of single-box system = $RBOM_m + TBP_m$.
- The reorder point of double-box system: when a box of stock used up, place a single-box order.
- The reorder point of single-box system: $ROP_m = RBOM_m \times LT_m + SS_m$°.

CASE STUDY

Suppose there are three mobile phone IC modules and two coil modules and both are independent materials that could be used to assembly three varieties of NOKIA mobile phones. The data which is obtained from the analysis according to 3C Spare Parts Replenishment Management System introduced by the research is as:

First, according the given data on Table 1, MRP_m and $RBOM_p$ are defined as $MRP_m = \sum_p TOP_p \times BOM_m$ and $RBOM_m = \max\{TOP_p \times BOM_{pm}\}$ Then, take IC_1 as example, the requirement for IC_1 based on MRP_m and $RBOM_p$ can be calculated as $MRP_m = 100*0+300*1+200*1 = 500$ and $RBOM_p = \max\{100*0, 300*1, 200*1\} = 300$. As a result, the requirement for each material can be calculated accordingly and resulted on Table 2.

Second, according to the material commonality index, the, $Inv_{best} = \sum_m TOP_{1m} \times BOM_{1m} \times C_m$, $Inv_{worst} = P \times Inv_{best}$ and $Inv_{pract} = \sum_m RBOM_m \times C_m$ then, Inv_{worst} = (500*200+400*210+200*220+1000*100+1400*80) = 440,000 and Inv_{pract} = (300*200+300*210+200*220+400*100+900*80)=279,000. After accumulating all materials, the Inv_{worse} and Inv_{pract} are

Table 1: The table of pull (TOP) and bill of material (BOM) of products

		BOM_{pm}				
Product	TOP_p	IC_1	IC_2	IC_3	Coil_1	Coil_2
NOKIA_7360	100	0	1	0	3	1
NOKIA-6280	300	1	1	0	1	3
NOKIA_6111	200	1	0	1	2	2
C_m		200	210	220	100	80

Table 2: The computing result of each spare part applied in 3C theory

Material	IC_1	IC_2	IC_3	Coil_1	Coil_2	Total
MRP_m	500	400	200	1000	1400	
$RBOM_m$	300	300	200	400	900	
Inv_{worst}	100,000	84,000	44,000	100,000	112,000	440,000
Inv_{pract}	60,000	63,000	44,000	40,000	72,000	279,000
OMI						0.5488

Table 3: ABC analysis and the choice of order model

Material m	IC_1	IC_2	IC_3	Coil_1	Coil_2
ABC classification	A	A	B	C	A
Order policy	Regular order	Regular order	Fixed quantity order	Double-box system	Regular order

Table 4: Order policy analysis

Material m	IC_1	IC_2	IC_3	Coil_1	Coil_2
Hold cost			$C_m\times10\%$		
Order cost			100		
LT_m (Year)	2/300	3/300	2/300	4/300	4/300
TBP_m (Year)	0.2357	0.2057	-	0.3535	0.2078
EOQ_m	71	62	43	142*2	187
OUT_m	74	65	45	284	196
OP_m	5	6	4	142	21
SS_m	3	3	2	142	9

※$SS_m = RBOM_m\times1\%$

shown in Table 2 and the commonality index (COMI) can be calculated as COMI = $(Inv_{worst}-Inv_{pract})/(Inv_{worst}-Inv_{best}) = [p/(p-1)][1-Inv_{pract}/Inv_{worst}] = (3/2)*(1-279/440) = 0.5488$.

Third, according the COMI obtained from Table 2, the order policy of each material can be generated based on material classification and step 3 of Decision Order Policy shown in Table 3. Meanwhile, the relative order information for each material are calculated and shown in Table 4. For example, for IC_1, $EOQ_m = \sqrt{2*100*500/200*0.1} = 71$, $TBP_m = 71/300 = 0.2357$, $SS_m = 300*0.01 = 3$, $OUT_m = 71+3 = 74$ and $OP_m = 300*(2/300)+3 = 5$.

CONCLUSION

The idea of consumption of 3C Theory emphasizes that resource requirement plans will follow the changes of markets and quickly adjust the purchase and application of resource with once-a-day material resource plans. Particularly it emphasizes on the design of information communication and collaborated calculation between upstream and downstream suppliers and customers. Enterprises have to do their best to plan and install their transaction rules through information system to have basic planning of quick response to customer's demand. Thus, in the structure of 3C Theories, 3C Spare Part Replenishment Management System proposed in this paper classified and deployed the predictions of market requirements of mobile phone spare parts with the models of commonality, capacity and consumption with the changes of demands from markets. Then based on the ABC analysis of each spare part and the Commonality Index (COMI), a suitable order policy can be generated for each spare part. As results, 3C Spare Part Replenishment Management System we proposed in this paper could not only effectively reduce stock cost but also enhance the customer satisfaction.

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