Improvement of Inventory Control and Forecast According to Activity-Based Classifications: T Company as an Example

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Abstract: - Inventory management is a major issue for all the industries. The supply of products to customers requires the readiness of the inventory. This allows rapid delivery and reduces waiting time for customers so that companies can profit from it. Any stock out or insufficiency will lead to loss of customers because their needs cannot be met. This will hurt firm profitability and market competitiveness. Inventory control is critical to retain liquidity and avoid overstocking. This is also the key to firm's survival and sustainability. To ensure an appropriate level of inventory, it is necessary to manage the inventory levels with sales forecast on an on-going basis. This paper seeks to assist Company T to improve its inventory control. Firstly, the products offered by Company T are classified into groups. The R programming language is then used to stimulate and forecast future sales of different products. Different techniques are applied to manage the inventory levels according to the results of categorizations and forecasts.; 3.Consolidation of all the product items and grouping them into activity-based classifications; 4.Simulation and forecasting of future sales according to the categorization results; 5.Formulation of different control techniques based on the simulations and forecasts, and application of these methods to inventory management.

Key-Words: - Improvement of Inventory Control, Forecast, Activity-Based Classificat

1 Introduction

1.1 Research background

Inventory management is a major issue for all the industries. The supply of products to customers requires the readiness of the inventory. This allows rapid delivery and reduces waiting time for customers so that companies can profit from it. Any stock out or insufficiency will lead to loss of customers because their needs cannot be met. This will hurt firm profitability and market competitiveness. Inventory control is critical to retain liquidity and avoid overstocking. This is also the key to firm's survival and sustainability. To ensure an appropriate level of inventory, it is necessary to manage the inventory levels with sales forecast on an on-going basis.

1.2 Research Motives and Objectives

Company T does not differentiate the relative importance of products. Inventory is managed with the rule of the thumb. As a result, all the products have similar stock levels. Equal amount of time and efforts is dedicated for the inventory management and sale forecasting of different products. This paper seeks to assist Company T to improve its inventory control. Firstly, the products offered by Company T are classified into groups. The R programming language is then used to stimulate and forecast future sales of different products. Different techniques are applied to manage the inventory levels according to the results of categorizations and forecasts.

1. Consolidation of all the product items and grouping them into activity-based classifications;
2. Simulation and forecasting of future sales according to the categorization results;
3. Formulation of different control techniques based on the simulations and forecasts, and application of these methods to inventory

management.

2 Literature Review

2.1 Background of Company T

Company T, founded in 1984, is a hardware wholesaler in Taiwan. It mainly sells PVC soft plastic cloths, rubber products (e.g. rubber boards and hoses), spray paints, brushes, aluminum ladders, gloves, cleaning supplies, raincoats, face masks, packaging materials, ropes, plastic products (e.g. buckets and baskets). In 2010, Company T became a distributor for 3M products. Over the past three decades, Company T has established close ties with its customers by providing efficient services and offering high-quality products. Meanwhile, Company T has three sizable warehouses, packed with a large variety of products. The hoarding of these stocks leads to high inventory costs.

2.2 Inventory Control

Bassin (1990) believes that effective inventory control is critical to all companies. Yoshikawa (1998) indicates that inventory contains raw materials, work in process, semi-finished goods, components and finished products. Meanwhile, inventory varieties differ depending on the markets served in food, clothing, accommodation, transportation, education or entertainment. Therefore, different inventory management methods should be deployed accordingly. Chen et al. (2011) suggest that overstocking is a waste of capital, as it increases procurement costs and causes idle materials. Li et al. (2011) say that inventory is a double-bladed sword. An appropriate level of inventory maintains the service levels. This is a great responsibility for companies.

2.2.1 Purpose of Inventory Management

Fogarty et al. (1991) define inventory as a measure to mitigate the uncertainty associated with the timing and quantity of demand and supply. In the era of globalization, efficient inventory management maintains an appropriate level of products, semi-finished goods, work in progress, components and raw materials in stock. This maintains competitive advantages and increases economic benefits.

All the inventory management models aim to address the issues outlined in Table 2.1. It is possible to minimize the total costs and meet the market demand if all the steps described in Table 2.1 are taken.

Table 2.1 Issues in Inventory Control

Determination of a regular level of stocks	Comprehensive variety of goods
	Focus on fastest-selling products
	Highlighting of company characteristics with the right products
Assessment of an appropriate level of stocks	Forecasting of sales
	Evaluation the risk of stock-out
	Appraisal of the risks of excess inventory
Maintenance of the appropriate level of stocks	Budgeting of sales
	Confirmation of orders and inventory levels
	Planned and efficiency procurement to keep up with sales

Source: Hsieh (2011)

2.2.4 Inventory Control Methods

Johson and Montgomery (1974) think that inventory control aims to satisfy the demand and reduce inventory costs, so as to improve firm profitability. Orders can be issued when the inventory level falls below a specific point in order to avoid inventory depletion with the arrival of ordered goods in a timely manner.

Hu (2010) indicates that inventory models determine on the ordering volume and timing. It is typically managed with two different methods as follows:

1. Fixed-Order Quantity Model
   This is also known as Economic Order Quantity (EOQ). An order is issued for additional goods when the inventory falls below a specific level (i.e. the reorder point). The reorder point depends on the consumption in the lead time. The advantage of this model is that the ordering volume is fixed. However, a continuous review

is required to keep an eye on the inventory level at all times. This method is suitable for the inventory management of highly important products.

2. Fixed-Time Period Model
   This method requires ordering at a fixed time interval for the volume equivalent to the difference between the maximum capacity of the warehouse and the level of inventory at the time of ordering. There is no need to keep an eye on the stock level or calculate the existing level of inventory. It is suitable to the inventory management of materials not important.

2.2.4.1 1. Fixed-Order Quantity Model

Liang (2011) explains that the fixed-order quantity model is about the constantly updating of the inventory records, sales and other relent information and the benchmarking of the reorder timing for fixed quantity (i.e. economic order quantity). Order is made for specific volumes whenever the inventory falls below the predetermined level.

2.2.4.2 1. Fixed-Time Period Model

Ordering is made at a fixed and predetermined interval by assuming the following:

1. Demand is variable;
2. Lead time is regular;
3. Ordering is for restocking to the full;
4. The ordered volume is not fixed but the timing of the order is fixed;
5. Safety levels are much higher than the ordered volumes.

On the basis of the above presumptions, the following equations are derived:
Maximum inventory $((I_{max}))$= average demand volume during the covered period + safety margin of inventory

$$I_{max} = \bar{d}(t+L) + Z_a \times \sqrt{t+L} \times \sigma_d \qquad \text{Eq. 2.1}$$

$\bar{d}$is the average demand,
t as the fixed interval for reorders, L is the lead time, σ_d is the standard deviation of demand

Ordered volumes (Q_i)= maximum capacity for inventory—existing level of inventory (I_i)

$$Q_i = I_{max} - I_i = \bar{d}(t+L) + Z_a \times \sqrt{t+L} \times \sigma_d - I_i \qquad \text{Eq. 2.2}$$

2.2.4.3 Economic Order Quantity

Harris (1915) develops the economic order quantity model to determine the optimal volume for each order. The basic assumptions are as follows:

1. Demand is known and steady;
2. Production or procurement is in batches;
3. Ordering costs and inventory holding costs are known and fixed;
4. Goods arrive at the company.

In the EOQ model, annual demand (D), storage costs (C_o) and ordering costs (C_h) are known. On the basis of these three factors, the optimal ordering volume (Q^*) can be derived:

$$\text{Annual holding costs} = \frac{Q}{2} \times \qquad \text{Eq. 2.3}$$

$$\text{Annual storage costs} = C_o \times \frac{D}{Q} \qquad \text{Eq. 2.4}$$

$$\text{Hence, Total costs TC} = \frac{Q}{2} \times C_h + C_o \times \frac{D}{Q} \qquad \text{Eq. 2.5}$$

$$\text{Let } \frac{d(TC)}{d(Q)} = 0$$

$$\text{Then } Q^* = \sqrt{\frac{2C_o \times D}{C_h}} \qquad \text{Eq. 2.6}$$

$$\text{Ordering interval } T = \frac{Q}{D} \qquad \text{Eq. 2.7}$$

2.2.4.4 Reorder Point

Reorder points refer to specific inventory levels. Reordering is triggered to avoid any stock-out once the inventory falls below the reordering points. The decision on reorder points depend on the following four factors:

1. Demand (d);
2. Lead time (L);
3. Standard deviation of demand (σ_d) and standard deviation of lead time (σ_L);
4. Acceptable risks of stock-outs (%).

The first three factors are determined by external environments. The acceptable risks of stock-outs are the probability of running out of inventory acceptable to the company by assuming the variances of demand and lead time are in a normal distribution. Depending on the changes in lead time, the ROP model can lead to four equations for the calculation of reorder points:

(1) Fixed demand runrate and fixed lead time

$$r = ROP = d \times L + 0 \quad \text{Eq. 2.8}$$

(2) Variable demand runrate and fixed lead time

$$r = ROP = \bar{d} \times L + SS \quad \text{Eq. 2.9}$$

(3) Fixed demand runrate and variable lead time

$$r = ROP = d \times \bar{L} + SS \quad \text{Eq. 2.10}$$

(4) Variable demand runrate and variable lead time

$$r = ROP = \bar{d} \times \bar{L} + Z_a \times \sqrt{\bar{L} \times \sigma_d^2 + \bar{d}^2 \times \sigma_L^2} \quad \text{Eq. 2.11}$$

2.2.4.5 Service Level

Service levels indicate the probability of meeting with demand with existing levels of inventory. The safety margin of stocks in the ROP model depends on service levels. Stock-out risks and service levels are the two sides of the same coin. The lower the stock-out risks, the higher the probability of demand being met and the higher the levels of services. If a company decides to keep the service level at 99% and set up the safety margin of inventory levels accordingly, then the stock-out risk is 1%. In other words, the probability of meeting demands in the lead time is 99%.

2.3 Activity Based Classification Analysis

Activity-based classification analysis is an effective method on the basis of the Pareto law (Ravinde & Misra, 2014). It can enhance management efficiency by allocating the value or volume of procurements by following the law of distributions.

In 1905, Lolenz applied the Pareto to analyze the distribution of wealth, land ownership and incomes. According to Lolenz, if the distributions are even, the relationship between the number of people and the income earned should be linear, as the diagonal line depicted in Figure 2.8. If the distributions are uneven, it could be a deviation or a normal distribution curve. This economic analytical framework was developed in 1951 by H. F. Deck who worked for General Electric into materials management. It was later evolved into activity-based classification analysis, frequently used in cost accounting (Hsu, 1986).

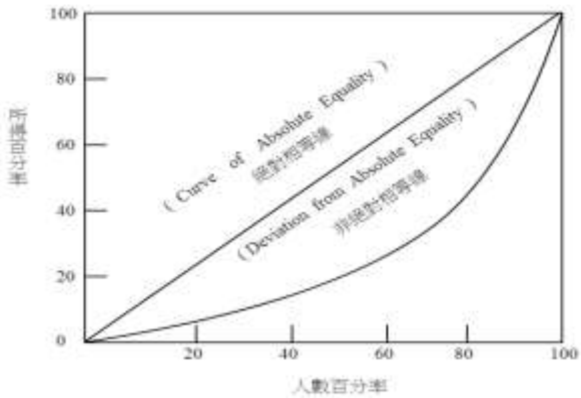


Figure 2.1 Lolen Curve
Source: Hsu (1986)

2.3.1 Purposes of Activity-Based Classification Analysis

Wan (2007) ranks all the goods in the warehouse according to the annual sales (or consumption) of goods in an illustration to effectively manage a large amount of inventory. All the products are bucketed into one of the three subgroups for different inventory management strategies, Product Group A accounts for only 10% of the total inventory items, but over 70% of the total sales. This is by far the most important product category for the company. In contrast, Product Group C account for 70% of the inventory items but only contribute to 10% of the total sales. Product Group B is the rest. These numbers may be arbitrary. It is possible to step up the level of control on specific segments.

2.3.3 Steps for Activity-Based Classification

Kumar and Anas (2013) describe the steps of activity-based classification as follows:

(1) Confirmation of material names,

specifications, unit prices and annual assumption;
(2) Calculation of annual units consumed on the basis of the unit price;
(3) Ranking of materials from the largest to the smallest value of consumption;
(4) Estimation of the unit of specific material as a percentage of the total annual consumption;
(5) Determination of the cutoff points for Product Groups A, B and C according to the value of materials.

2.4 Forecast

Diebold (2015) indicates that forecasting is done everywhere but the two key areas of forecasting is (1) economic forecasts by government agencies, corporates, policymakers, central banks and financial institutions; (2) management forecasts by companies for specific areas such as operational management and control (e.g. recruitment, production, inventory and investment), marketing (e.g. pricing and advertising) and accounting (budgetary planning for incomes and expenses).

2.4.1 Purposes of Forecasting

Shih (2002) suggests that forecasting is not to achieve 100% accuracy. Rather, it is about estimating the acceptable margin of errors as the basis for risk budgeting, decision making or strategic planning. The most important elements are decision making and planning, as well as operational management. Forecasting has inherent limitations as it is never possible to accurately foresee the future. Instead of wasting a large amount of resources to develop slightly better but way too complex forecasting models, it is suggested to use simple models and focus resources on management and operations. After all, accurate forecasting alone cannot achieve targets without the timely or proper control.

2.4.3 Considerations for Selection of Forecasting Methods

There is a plethora of forecasting methods. Which forecasting methods are the best to accommodate different environments and cost-benefit considerations? What are the best ways to select the optimal forecasting methods? Rice and Mahmoud (1990) believe that before making any forecasts, it is necessary to answer three questions, i.e. what to forecast, how to forecast or how to implement the forecasts.

Chase (1997) indicates that there is no perfect forecasting method to fit all the situations. It is necessary to select the most appropriate method according to different circumstances. To achieve this purpose, it is necessary to understand the pros and cons of different forecasting methods.

2.5 Simulations

Simulations are a tool to derive solutions, often used to solve engineering and physics questions in the early days. Li (2011) indicates that simulations are about the establishment of statistical models to derive solutions for what-if or if-then problems. Yeh (2008) posits that there are three types of statistical concepts, i.e. mathematical statistics, experimental designs and computer simulations. In fact, computer simulations are highly relevant to the model specifications. Models are required to run simulations (Figure 2.11). Parameters should be defined and data should be entered into the predetermined parameters in the simulation equations in order to produce outputs. Such simulation models usually provide certainty, i.e. similar results regardless of the number of computations done by the computer.

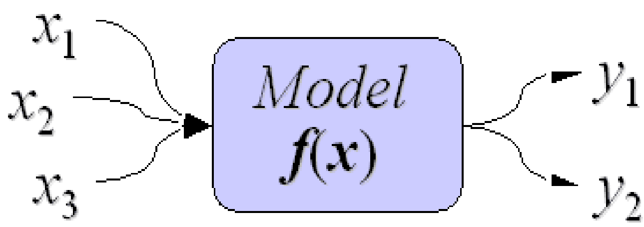


Figure 2.2 Model Specifications, Inputs and Outputs
Source: Yeh (2008)

3 Research Methodology

3.1Activity-Based Classification Analysis

Before any classification, it is necessary to summarize all the product items of Company T.

1. Stage 1: Collation of the data regarding all the

product items of Company T;
2. Stage 2: Classification of products with letters A to Z according to product attributes and the tally of the number of products in each category;
3. Stage 3:
   (1) Reference to the classification rules developed by H. F. Deckie (1951);
   (2) Conducting of activity-based classification for products A~Z;
4. Stage 4: Classification of products A~Z to three categories, A, B and C;
5. Stage 5: Graph and chart analysis.

3.2Simulations & Forecasts

Simulations and forecasts are done by selecting one product from each of Product Group A, Product Group B and Product Group C from the inventory of Company T. The flow chart is depicted in Figure 3.3.

1. Stage 1: Selection of one product from each of Product Group A, Product Group B and Product Group C;
2. Stage 2: Application of the R programming language according to the concept of focus forecasting to identify the program codes suitable for the simulations of Company T's future sales;
3. Stage 3: Implementation of simulation forecasting;
4. Stage 4: Graph and chart analysis.

3.3Problem Analysis for Company T

This paper interviewed the management of Company T to understand the problems and explored measures for improvement on the basis of activity-based classification and simulation forecasts. The results were then fed into the inventory management flows of Company T. An analysis was conducted to examine the implementation outcome. Table 3.1 summarizes the list of issues identified.

Table 3.1 Issues and Desirable Outcomes for Company T

Issue	Measure	Target
A massive and disorganized list of products	Establishment of a product catalogue for Company T according to the lists provided by suppliers	Improvement in product search efficiency
Relative importance of products	Application of activity-based classification to organize Company T's products into groups	Identification of Product Group A, Product Group B and Product Group C items for Company T
Largely the same levels of inventory	Simulation forecasts on the basis of activity-based classification results and implementation of different inventory control methods according to forecasts	Reduction of inventory levels and costs

4. Result of validation and Analysis

4.1 Activity-Based Classification

This paper discussed with Company T in the coding of all products with 26 English letters from A to Z (Table 4.1).

Product		Product	
A	Spray and oil paints	N	3M products
B	Containers	O	Supplies for medical and hygienic purposes
C	Plastic mats, films, canvases and floor mats	P	Adhesive types, packaging materials and ropes
D	Horticultural products	Q	Raincoats and umbrellas
E	Household appliances	R	Plastic bags and products
F	Hardware tools	S	Solvents, gels and silicone
G	Soft and hard materials for hoses	T	Transportation equipment
H	Security and defense devices	U	Toiletry and plumbing supplies
I	Brushes, paint brushes and building materials	V	Utensils
J	Gloves	W	Nets
K	Grinders	X	Stationery
L	Aluminum ladders	Y	Detergents and cleaning products
M	Rubber plates and products	Z	Consumables for offices

Table 4.1 Product Codes from A~Z

Table 4.2 summarizes the quantities and annual sales of all the products classified to appropriate groups.

Table 4.2 Quantity and Annual Sales of Products

A~Z

	Product	Quantity (units)	Annual Sales (NT)
A	Spray and oil paints	205	4,032,182
B	Containers	321	438,153
C	Plastic mats, films, canvases and floor mats	191	1,469,637
D	Horticultural products	700	25,120
E	Household appliances	561	32,105
F	Hardware tools	1,354	60,512
G	Soft and hard materials for hoses	398	5,309,747
H	Security and defence devices	297	2,157,763
I	Brushes, paint brushes and building materials	245	1,843,201
J	Gloves	136	2,230,879
K	Grinders	164	117,570
L	Aluminum ladders	215	812,032
M	Rubber plates and products	83	561,843
N	3M products	814	1157,108
O	Supplies for medical and hygienic purposes	145	612,385
P	Adhesive types, packaging materials and ropes	384	513,205
Q	Raincoats and umbrellas	192	212,050
R	Plastic bags and products	398	318,238
S	Solvents, gels and silicone	345	713,250
T	Transportation equipment	313	223,841
U	Toiletry and plumbing supplies	125	191,235
V	Utensils	551	73,215
W	Nets	707	103,518
X	Stationery	523	135,871
Y	Detergents and cleaning products	616	84,122
Z	Consumables for offices	438	51,284

This paper refers to annual sales as the principle for activity-based classification of Company T's products. Table 4.2 lists the products items (from A to Z) classified into Product Group A, Product Group B and Product Group C according to their respective annual sales (from the highest to the lowest). Tables 4.3, 4.4 and 4.5 show the classification results.

Table 4.3 Company T's Product Group A

Product		Quantity (units)	Annual sales (NT)	Quantity %	Cumulative quantity %	Annual sales %	Cumulative annual sales %
G	Soft and hard materials for hoses	398	5,309,747	3.82	3.82	22.61	22.61
A	Spray and oil paints	205	4,032,182	1.97	5.79	17.17	39.79
J	Gloves	136	2,230,879	1.31	7.09	9.50	49.29
H	Security and defense devices	297	2,157,763	2.85	9.94	9.19	58.48
I	Brushes, paint brushes and building materials	245	1,843,201	2.35	12.29	7.85	66.33
C	Plastic mats, films, canvases and floor mats	191	1,469,637	1.83	14.13	6.26	72.58

Below is Product Group A for Company T:

(1) Products
G (soft and hard materials for hoses); A (spray and oil paints); J (gloves); H (security and defense devices); I (brushes, paint brushes and building materials); C (plastic mats, films, canvases and floor mats)
(2) Quantities
The total number of units for Product Group A is 1,472, accounting for 14.13% of the total.
(3) Annual sales
The total annual sales of Product Group A is NT$ 17,043,409, contributing to 72.58% of Company T's total annual sales.

Table 4.4 Company T's Product Group B

Product		Quantity (units)	Annual sales (NT)	Quantity %	Cumulative quantity %	Annual sales %	Cumulative annual sales %
N	3M products	814	1,157,108	7.81	7.81	4.93	4.93
L	Aluminum ladders	215	812,032	2.06	9.87	3.46	8.39
S	Solvents, gels and silicone	345	713,250	3.31	13.18	3.04	11.43
O	Supplies for medical and hygienic purposes	145	612,385	1.39	14.57	2.60	14.03
M	Rubber plates and products	83	561,843	0.80	15.37	2.39	16.43

Below is Product Group B for Company T:

(1) Products
N (3M products); L (aluminum ladders); S (solvents, gels and silicone); Q (supplies for medical and hygienic purposes); M (rubber plates and products)

(2) Quantity
The total number of units for Product Group B is 1,602, accounting for 15.37% of the total.
(3) Annual sales
The total annual sales of Product Group B is NT$ 3,856,618, contributing to 16.43% of Company T's total annual sales.

Table 4.5 Company T's Product Group C

Product		Quantity (units)	Annual sales (NT)	Quantity %	Cumulative quantity %	Annual sales %	Cumulative annual sales %
P	Adhesive tapes, packaging materials and ropes	384	513,205	3.68	3.68	2.19	2.19
B	Containers	321	438,153	3.08	6.77	1.87	4.06
R	Plastic bags and products	398	318,238	3.82	10.58	1.36	5.42
T	Transportation equipment	313	223,841	3.00	13.59	0.95	6.37
Q	Raincoats & umbrellas	192	212,050	1.84	15.43	0.90	7.27
U	Toiletry and plumbing supplies	125	191,235	1.20	16.63	0.81	8.08
X	Stationery	523	135,871	5.02	21.65	0.58	8.66
K	Grinders	164	117,570	1.57	23.22	0.50	9.16
W	Nets	707	103,518	6.78	30.01	0.44	9.6
Y	Detergents and cleaning products	616	84,122	5.91	35.92	0.36	9.96
V	Utensils	551	73,215	5.29	41.21	0.31	10.27
F	Hardware tools	1,354	60,512	12.99	54.20	0.26	10.53
Z	Consumables for offices	438	51,284	4.20	58.40	0.22	10.75
E	Household appliances	561	32,105	5.38	63.78	0.14	10.89
D	Horticultural products	700	25,120	6.72	70.50	0.11	10.99

Below is Product Group C for Company T:

(1) Products:
P (adhesive types, packaging materials and ropes); B (containers); R (plastic bags and products); T (transportation equipment); Q (raincoats and umbrellas); U (toiletry and plumbing supplies); X (stationery); K (grinders); W (nets); Y (detergents and cleaning products); V (utensils); F (hardware tools); Z (consumables for offices); E (household appliances); D (horticultural products)

(2) Quantity
The total number of units for Product Group C is 7,347, accounting for 70.48% of the total.

(3) Annual sales
The total annual sales of Product Group C is NT$ 2,580,039, contributing to 10.99% of Company T's total annual sales.

The above tables detail the items under Product Group A, Product Group B and Product Group C, as well as the respective quantities and annual sales contribution of each group.

4.2 Simulation Forecasting Model

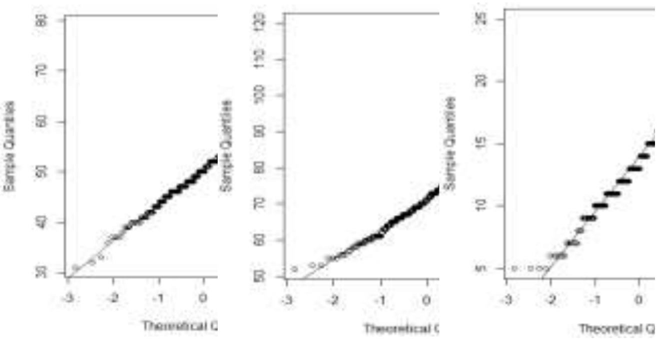
This paper used the R programming language to construct the simulation model to forecast Company T's sales. Inputs were the results of activity-based classifications described above. Simulations were done with each product from Product Group A, Product Group B and Product Group C, respectively. Appropriate inventory control
A methods were applied according to the results of simulation forecasts. The purpose of this exercise was to introduce a practical solution based on numbers and statistics.

Figure 4.2 Workflows for Simulation Forecasting

Figure 4.2 illustrates the workflow of simulation forecasts of Company T's sales with the R programming language. The process consists of three stages.

Stage 3: Simulation Results Analysis

(1) Data distribution:
The first step is to examine the distribution of simulation results (shown in graphs). The weekly sales of clear plastic wraps (Product Group A), face masks for adults (Product Group B) and traffic cones (Product Group C) are in a normal distribution (Figure 4.3).

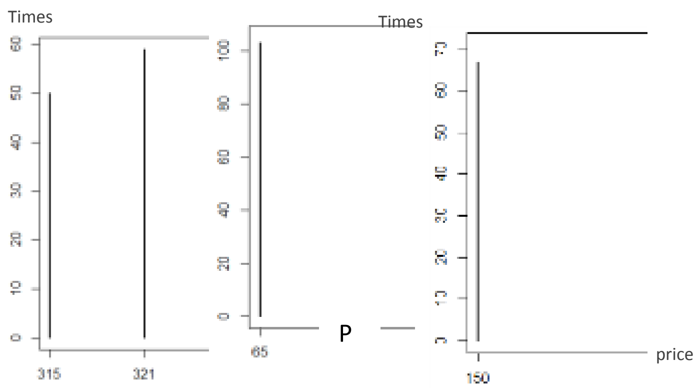


Clear plastic wraps (A) Face masks for adults (B) Traffic cones (C)

Figure 4.1 Normal Distribution of Weekly Sales of Individual Products

Figure 4.1 illustrates the distribution of simulated statistics. The linear shape in all the three graphs suggests that the simulated statistics are in a normal distribution.

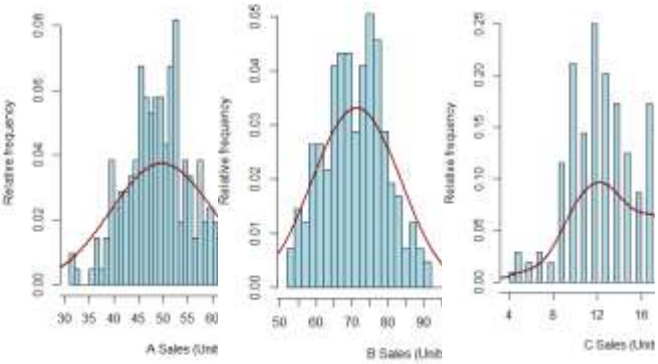
(2) Results of Simulation Forecasts
Figure 4.4 show the number of times individual products are sold at different prices. Most of the pricing points for clear plastic wraps (A) fall on NT$ 321, followed by NT$ 327, NT$ 315 and NT$ 331. The unit selling price of face masks for adults (B) is mainly NT$ 68, followed by NT$ 65. Traffic cones (C) are mostly sold at a unit price of NT$ 162, followed by NT$ 159 and NT$ 150. This graph sheds light on the selling prices and expected profits of different products for Company T.



Clear plastic wraps (A) Face masks for adults (B) Traffic cones (C)

Figure 4.2 No. of Times Individual Products Sold at Different Prices

(3) Forecasted Sales based on Simulations
This paper simulated the weekly sales of the three products, sampled from Product Group A, Product Group B and Product Group C. The results were depicted in graphs (Figure 4.5), to provide an intuitive presentation of the frequency of transactions at different pricing points.



T Clear plastic wrap (A) Face masks for adults (B) Traffic cones (C)

Figure 4.3 Simulation of Weekly Sales of Individual Products

Table 4.6 shows the data depicted.

Table 4.6 Weekly Sales of Individual Products from Product Group A, Product Group B and Product Group C

Product \ Item	Clear plastic wrap (A)	Face masks for adults (B)	Traffic cones (C)
Range of units sold per week	30~80	50~120	2~22
Units sold per week most of the time	45~55	65~75	9~13
Average units sold per week	50	70	12

Some products report a sudden surge in sales due to external factors. For instance, the expected units of face masks for adults (B) sold may reach 120 in the event of avian influenza or other diseases outbreaks. In this case, it is necessary to stock a large volume than usual to meet the demand.

4.2.1 Inventory Control Based on Simulation Results

1. Integration of Product Information

This paper determines that fixed-order quantity model should be used for Product Group A and Product Group B and fixed-time period model should be used for Product Group C. The higher the relative importance, the greater the service levels should be. Hence, the service levels for Product Group A, Product Group B and Product Group C are set at 99%, 95% and 80%, respective (Table 4.7).

Table 4.7 Summary of Order Methods and Parameters for Different Product Groups

Product \ Item	Clear plastic wrap (A)	Face masks for adults (B)	Traffic cones (C)
Order method	Fixed quantity	Fixed quantity	Fixed period
Inventory monitoring	Strict	Loose	Loose
Lead time (L, days)	3	2	2
Service level (SL,%)	99%	95%	80%
Safety coefficient (□□)	2.33	1.65	0.84
Standard deviation (□□)	7.38	9.2	3.53
Average turnover (□̄, days)	10	12	2

2. Order Methods

(1) Fixed-Order Quantity Model

Reorder points are defined as demand (d) + safety margin of inventory (ss). In the ROP model, the demand for clear plastic wraps (A) and face masks for adults (B) is in a normal distribution (as assumed) as shown in Figure 4.3. Except for the specific scenarios where the demand fluctuates due to external factors, the reorder points and the safety margin of inventory are both fixed throughout the year. Safety margin of inventory is the product of safety coefficients (Z_a) and standard deviation of demand (σ_d) (ss $= Z_a \times \sigma_d$). The safety coefficients Z_a under 99% and 95% service levels are 2.33 and 1.65, respectively (Table 4.8).

Table 4.8 Reorder Points and Safety Margin of

Inventory for Clear Plastic Wraps (A) and Face Masks for Adults (B)

Product	Reorder points (units)	Safety margin of inventory (units)
Clear plastic wraps (A)	60	30
Face masks for adults (B)	46	22

(2) Fixed-Time Period Model

In the fixed-time period model, the maximum inventory (I_{max}) is defined as the average demand during the covered period ($\bar{d}$)) + safety margin of inventory (ss). The demand for traffic cones (C) is in a normal distribution as assumed (Figure 4.3). The average daily demand is 3 weeks and the ordering cycle is determined at every two weeks for a service level of 80% and a safety coefficient Z_a of 0.84 (Table 4.9).

Table 4.9 Reorder Points and Safety Margin of Inventory for Traffic Cones (C)

Product	Reorder points (units)	Safety margin of inventory (units)
Traffic cones (C)	34	10

As stated above, this paper exercises inventory control with the fixed-order quantity model for Product Group A and Product Group B and the fixed-time period model for Product Group C. The maximum inventory levels, reorder points and the safety margin of inventory are defined and the workflows of the inventory control are graphed in Figure 4.6.

4.3 Effectiveness Evaluation of Inventory Control Measures

The support from Company T's personnel was one of the reasons for the success of the new inventory management system. All the employees acknowledged the benefits of the new methodology even before the implementation and fully collaborated for the new inventory scheme. Below is an analysis of the improvement in three aspects.

1. Overly large and disorganized list of product items by suppliers

This paper took the steps depicted to resolve this problem. All the products were coded from A to Z according to product characteristics. The supplier codes were also renamed.

The original product codes are kept in large for the ease of use by Company T's personnel. The A to Z codes are on top of the previous product codes. This enabled employees to quickly and easily adapt to the new system. Tables 4.10 and 4.11 show the situations before and after the catalogue change.

Table 4.10 Catalogue – Before Change

Product	Specifications
Star Spray Coating	101 red 102 white 103 sky blue 104 gray 105 green 106 light gray 107 light green
Puff Dino Spray Paint	101 red 102 white 103 bright blue 104 dark gray 105 green 106 light gray
3M 1017 Steri-Drape™	blue/green/red/white/yellow

Table 4.11 Catalogue – After Change

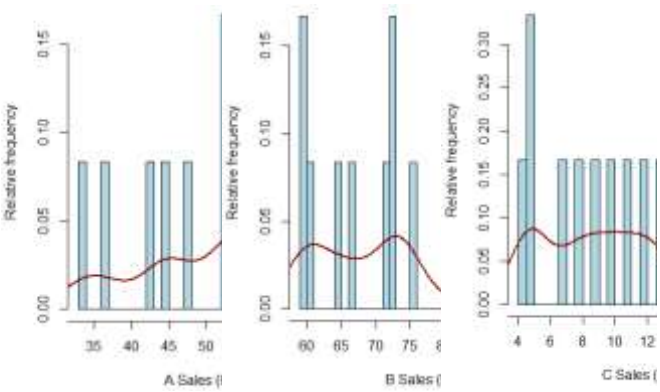
Product code	Product group	Unit	Product name
AB101	A	Jar	100% spray coating: red
AB102	A	Jar	100% spray coating: white
AG101	A	Jar	Puff Dino Spray Paint: red
AG102	A	Jar	Puff Dino Spray Paint: white
N13B	N	Piece	3M 1017 Steri-Drape™: blue
N13G	N	Piece	3M 1017 Steri-Drape™: green
N13R	N	Piece	3M 1017 Steri-Drape™: red

Before the change there was no consistency in product naming. All the codes of the products of the same nature were sorted by different suppliers. Staff spent a lot of time searching for the product codes if they forgot what the codes were. The revised catalogue allows fast searches if even the staff forgets about the product names.

1. Relative importance of products
   Since its inception over a decade ago, Company T has added many suppliers to meet with various needs of customers. The variety of its offerings will only increase over time. The activity-based classification results described in Section 4.1 can help to differentiate the relative importance of products and initiate the implementation of different inventory control methods on different products according to their relative importance. The purpose is to avoid any loss of revenue or customer base due to a stock-out of highly important Product Group A, or the incurrence of unnecessary inventory costs due to overstocking of Product Group C. The classification results are summarized in Tables 4.3, 4.4 and 4.5.
2. Similar inventory levels for different products
   The new inventory control measures were implemented on the basis of simulation results. An analysis was conducted to examine the impacts of the new inventory scheme. Appendix 3 shows the daily sales of different products within the first three month under the new system. The results are summarized in Table 4.12. Product sales are presented in Figure 4.8.

Table 4.12 Product Sales

Month	Week	Clear plastic wrap (A)	Face masks for adults (B)	Traffic cones (C)	Unit
October	1	45	97	5	pcs
	2	33	93	13	
	3	68	76	4	
	4	53	85	8	
November	1	64	65	18	
	2	53	59	7	
	3	37	61	11	
	4	43	73	5	
December	1	54	60	20	
	2	60	73	10	
	3	71	72	9	
	4	66	67	12	



Clear plastic wrap (A) Face masks for adults (B) Traffic cones (C)

Figure 4.4 Weekly Sales of Different Products

Figure 4.4 highlights the comparison between actual weekly sales and the simulation results shown the difference was limited. Table 4.13 and Table 4.14 present the difference between the weekly sales and inventory levels, respectively, before and after the new inventory control measures. Figure 4.9 summarizes the comparison results.

Table 4.13 Actual Weekly Sales and Simulated Weekly Sales of Product Group A, Product Group B and Product Group C

Product / Item	Clear plastic wrap (A)	Face masks for adults (B)	Traffic cones (C)
Range of weekly sales (units)	30~70 / 30~80	55~100 / 50~120	2~20 / 2~22
Weekly sales most of the time (units)	45~60 / 45~55	60~75 / 65~75	7~13 / 9~13
Average weekly sales (units)	53 / 50	73 / 70	10 / 12

Table 4.14 Inventory Control by Company T and by This Study

Product / Item	Clear plastic wrap (A)	Face masks for adults (B)	Traffic cones (C)
Order method	Rule of the thumb/ fixed quantity	Rule of the thumb/ fixed quantity	Rule of the thumb/ fixed quantity

Maximum inventory (units)	130	144	25 / 34
Reorder points (units)	45 / 60	58 / 46	13 / ordering every two weeks
Safety margin of inventory (units)	20 / 30	25 / 22	8 / 10
Inventory monitoring	Strict / strict	Strict / strict	Strict / strict

(1) Clear plastic wraps (A)

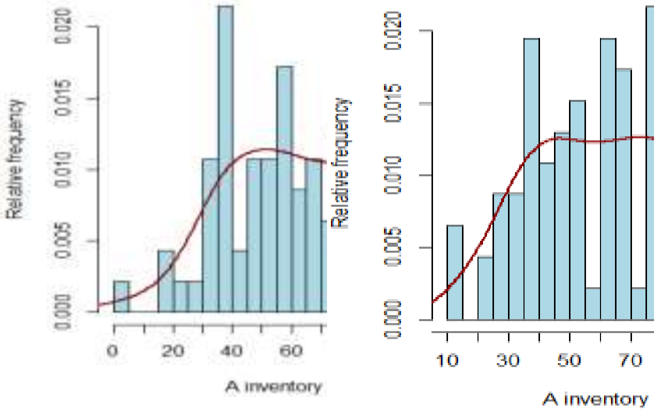
- Order method:
  Company T sets the maximum level of inventory at 130 units based on the rule of the thumb. Reorders are made at the reorder points, for the volume equivalent to the delta between the maximum level of inventory and the existing level of inventory. This paper adopts the fixed-order quantity model, also based on the maximum level of inventory at 130 units, but the reordering volume is fixed at 60 units.

- Appendix 3-Table 1 (based on Table 4.15) shows the difference in the ordering pattern between the thumb of the rule management by Company T and the fixed-order quantity model introduced by this paper for clear plastic wraps (A) during the first three months.

Table 4.15 Order Method Comparison for Clear Plastic Wraps (A)

Product	No. of orders	No. of stock-outs
Clear plastic wraps (A)	8 / 11	1 / 0

- According to the inventory records for clear plastic wraps (A) shown in Figure 4.10, the inventory level implemented by this paper is more stable than under the old system in Company T. Under the new scheme, the inventory ranges between 40 and 80 units, and the frequency of overstocking at more than 90 units and understocking at below 40 units is lower. The new system of inventory management implemented by this paper can better accommodate various demand levels and avoid overstocking or under-stocking.



Old System in Company T New System by This Paper

Figure 4.5: Comparison of Inventory Records for Clear Plastic Wraps (A)

- Order volumes: The fixed volume ordered under the new system designed by this paper is less than the old system run by Company T whereby the reorder is based on the difference between the maximum level of inventory and the current level of inventory. Generally speaking, the inventory value of Product Group A is high and the reduction in inventory levels can reduce inventory costs and avoid a strain on liquidity.

- If the reorder points and the safety margin of inventory in Company T can be improved, it will lower the probability of stock-outs. Without changing the reorder volumes, it will not be possible to lower the inventory levels and costs.

- Inventory monitoring:

  The new system designed by this paper and the old system managed by Company T both keep a close eye on inventory levels. As Product Group A is the key product lines, it is necessary to maintain comprehensive and accurate inventory information, so as to avoid the loss of profits due to stock-outs.

(2) Face masks for adults (B)

- Order method:
  Company T sets the maximum level of inventory at 144 units (6 boxes) based on experience. Reorders are made at the reorder points, for 120 units (5 boxes). This paper adopts the fixed-order quantity model, also based on the maximum level of inventory at 144 units (6 boxes), but the reordering volume is fixed at 96 units (4 boxes).

  - Appendix 3-Table 2 (based on Table 4.16) shows the difference in the ordering pattern between the heuristic system managed by Company T and the fixed-order quantity model introduced by this paper for face masks for adults (B) during the first three months.

Table 4.16 Order Method Comparison for Face Masks for Adults (B)

Product	No. of orders	No. of stock-outs
Face masks for adults (B)	8 / 10	0

- This paper sets a lower service level for Product Group B than that of Product Group A, as Product Group B is not as important as Product Group A. The reorder points and the safety margin of inventory for Product Group B are also relatively low. According to Table 4.16, the numbers of orders made are similar and there is no stock-out during the time period. Hence, the service level specified by this paper can meet with variable demand levels.

- According to Figure 4.6, the frequency for the inventory level to exceed 120 under the old system run by Company T is higher than under the new system implemented by this study. However, the frequency for the inventory level to fall below 40 is higher under the new system designed by this paper than under the previous system managed by Company T. This paper intends to readjust the safety coefficient to calculate reorder points and the safety margin of inventory, in the event of any stock-out due to other factors. This paper maintains the inventory level at 40~110 units whilst Company T keeps it at 50~145 units. Therefore, the new system created by this paper assumes lower inventory costs than the original system implemented by Company T.

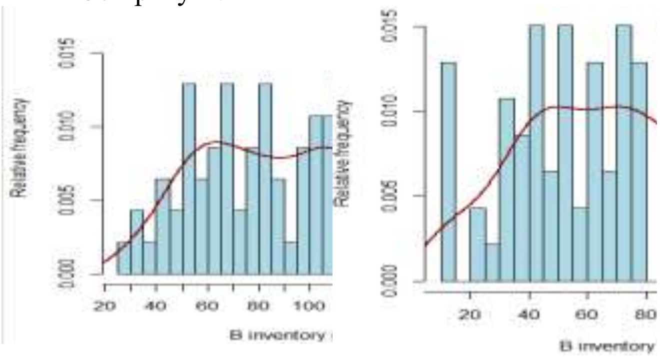


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Figure 4.6: Comparison of Inventory Records for Face Masks for Adults (B)

- Order volume:
  The new system planned by this paper sets the order volume at 96 units (4 boxes), 24 units (1 box) fewer than the fixed volume of 120 units (5 boxed) under the previous system in Company T. There was no stock-out during the three months. The reorder point and the safety margin of inventory under the old system are both higher than those in the new scheme. If Company T does not wish to adopt the parameters proposed by this paper, it may still reduce the order volume by 24 units (1 box) to reduce procurement costs.

- Inventory monitoring:
  The old system in Company T keeps a close eye on inventory levels whilst this paper suggests a relaxed approach by inspecting inventory levels once per week. This is because Product Group B is not as important as Product Group A and it is not necessary to constantly maintain comprehensive and accurate inventory information. What is needed is a complete record of inventory data.

(3) Traffic cones (C)

- Order method:
  Company T sets the maximum level of inventory at 25 units based on experience. Reorders are made at the reorder points for the volume equivalent to the delta between the maximum level of inventory and the existing level of inventory. This paper adopts the fixed-time period model by ordering once every two weeks, for the volume equivalent to the maximum level of inventory minus the current level of inventory. The maximum level of inventory is predetermined at 34 units.

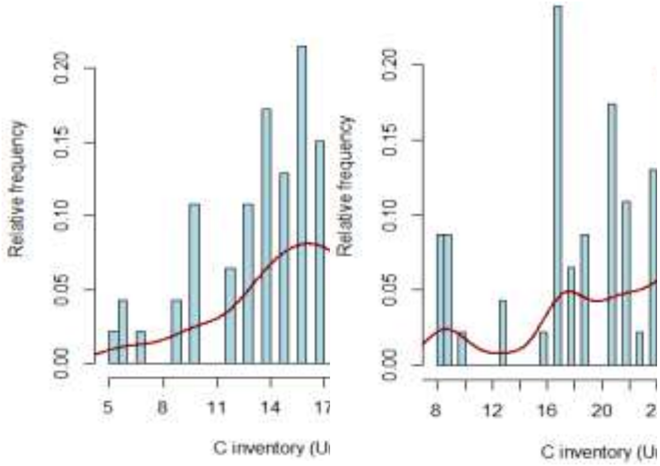
- Appendix 3-Table 3 (based on Table 4.17) highlights the difference in the ordering pattern between the heuristic style of Company T and the fixed-time period model suggested by this paper for traffic cones (C) during the first three months.

Table 4.17 Order Method Comparison for Traffic Cones (C)

Product	No. of orders	No. of stock-outs
Traffic cones (C)	9 / 6	0

- Product Group C comes in a large variety, low values and low degrees of importance. Bulk purchases are often made in order to gain quantity discounts and reduce ordering costs. Without considering discounts or cost reductions, this paper advises ordering once every two weeks, at a volume lower than originally set up by Company T at reorder points.

- As shown in Figure 4.12, the inventory level is higher in the new system suggested by this paper than under the old method run by Company T. This paper replaces the robust control administered by Company T by increasing inventory levels to reduce the time required for inventory management of Product Group C. The purpose is to allow more time to be allocated on relatively important products.



Old System in Company T New System by This Paper

Figure 4.7: Comparison of Inventory Records for Traffic Cones (C)

- Order volume:
  Both the new system designed by this paper and the old system managed by Company T order for the volumes equivalent to the maximum level of inventory less the current level of inventory. This paper orders for the volume required for two weeks so the inventory costs will be higher than under the original system run by Company T.

- Inventory monitoring:
  Company T keeps a close eye on inventory levels whilst this paper suggests a more slack approach by inspecting inventory levels only before any reorders. It will not be possible to find out any problems until the next inspections under the new system.

5 Conclusion and Suggestions

5.1 Conclusion

1. Activity-based Classification

After extensive discussions with Company T, this paper recoded all the products from letters A to Z and regrouped them according to activity-based classification method. Table 4.3, Table 4.4 and Table 4.5 show the product items classified into Product Group A, Product Group B and Product Group C. Figure 4.1 illustrates the distribution of the quantities and annual sales of Product Groups A, B and C.

5.2 Simulation Forecasts and Inventory Control

Simulation forecasts can be used in the situations where it is difficult to obtain sales data. Simulations can produce forecasts based on expectations or assumptions for future sales. The results can serve as a reference for management planning. The forecasts can also be adjusted by changing input parameters or by the desired management styles.

This paper conducts simulation forecasts for each product from Product Group A, Product Group B and Product Group C of Company T. According to Table 4.13, the simulation results came quite close to the actual sales. This suggests that the parameters used by this paper for simulations are realistic. The next step is to introduce the appropriate inventory control methods and compare the results with the previous system managed by Company T. The comparison suggests that the new approach can dramatically improve the inventory levels and costs for Company T. It is suggested that different control mechanisms should be implemented according to the relative importance of products so as to facilitate the appropriate allocations of time and efforts, instead of a uniform approach for each and every product. Finally, this paper summarizes the pros and cons of the new system in Table 5.1. The workflows for improvement and integration of benefits are depicted in Figure 5.1.

Table 5.1: Benefits of Implementing Different Inventory Control Methods for Product Groups A, B and C

<table>
<tr><th>Importance / Item</th><th>Product Group A</th><th>Product Group B</th><th>Product Group C</th></tr>
<tr><td>Management time</td><td>The time saved from managing Product Groups B and C allowing for more time to manage Product Group A</td><td>Reduction of management time at a small percentage</td><td>Dramatic reduction of management time</td></tr>
<tr><td>Order cost</td><td colspan="2">Higher order costs (associated with transportation, ordering and delivering) due to more frequent orders</td><td>Significant reduction of order costs due to reduced frequency of ordering</td></tr>
<tr><td>Inventory levels</td><td colspan="2" rowspan="2">According to Figures 4.10 and 4.11, the range of inventory levels for Product Group A and Product Group B under the fixed-order quantity model are slower than before. As a result, inventory levels and costs will drop significantly.</td><td rowspan="2">The new system designed by this paper increases inventory levels to avoid extensive management. Hence, inventory levels and costs will rise.</td></tr>
<tr><td>Inventory costs</td></tr>
<tr><td>Inventory monitoring</td><td>Strictly monitoring inventory levels under the new and old systems, so as to maintain comprehensive and accurate inventory information</td><td>The new system slightly relaxes the monitoring with inspections once per week. Complete inventory records are still required.</td><td>The new system greatly relaxes the monitoring with inspections only before reorders.</td></tr>
</table>

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