IE 562 Term Project

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Abstract: This paper is on Inventory Management. EOQ is used for basic inventory management. However EOQ is not suitable for actual situation. In actual situation, there are a lot of constraints such as set up time or limited area. So other methods such as GINO and LIMIT are used.

IE 562

Manufacturing Systems Management

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Term Project

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Introduction

In presence, inventory is one of the significant factors for business, both manufacturing and merchandising. The more inventory, the more cost. For this our project, we would like to show how to manage inventory. This project is based on case from case study book. However, problem is this project is not the same the problem from the original.

We use EOQ, basic for inventory management. However EOQ is not suitable for actual situation. In actual situation, we know that there are a lot of constraints such as set up time or limited area. So, we also use other method to manage the inventory. GINO and LIMIT (Lot-size Inventory Management Interpolation Technique) are our choice for other method.

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Problem Statement

The president of Spirit Bottling Company met with his newly vice president and manager of the Soft Drink Division, Donald Whitecomb. The president wanted to discuss several inventory problems. The main problem is that the Spirit Bottling Company has high level for inventory level. The company also pays a lot for holding cost. So, the management of this company wants to reduce inventory.

More information about the Spirit Bottling Company.

The Spirit Bottling Company bottled and marketed soft drink in franchise territory covering the southern half of Minnesota and portions of Wisconsin. Now the company consists of 14 distribution and three bottling plants. These are the product names of this company: Spirit, 11-up, Pep, Brite, Dr. Spice.

Mr. Donald gets information from visiting the three production plants and discusses product scheduling. He concludes that the manager tried to minimize downtime due to changeover. Moreover, after meeting, he knows that even though all managers want to reduce inventory, they also prefer to minimize setup time. There are two kinds of changeover : product changeovers (such as from Spirit to 11-up) and package changeovers (such as from 10 ounce to 16 ounce bottles).

Product Changeover Cost

Washdown expense

24 oz syrup @ $ 3.92 / gallon = 72 cent

Carbon dioxide and water = 6 cent

Total = 78 cent

Labor cost for mixing concentrate

1 man @ $ 8 / hour

Time required = 15 minutes

Labor cost = $ 2.00

Total cost = $ 2.78

Package Changeover cost

Labor cost for resetting machine

2 men @ $ 8 / hour

Time required = 35 minutes

Total cost = $ 9.34

Mr. Donald has a lot of information about inventory and he knew that Mankato distribution center was the representative of company wide inventory-to-sales level. So, he can get some idea of the company's inventory situation.

Item	Product package	Inventory (cases)	Demand (cases)	Days' supply (days)
1	6.5 oz Spirit	345	3056	3.5
2	10 oz Spirit	255	4941	1.6
3	10 oz 11-up	138	294	15.3
4	10 oz Pep	234	1168	6.1
5	10 oz Brite	86	923	2.8
6	16 oz Spirit	284	1418	6.2
7	1 lite Spirit	1208	856	43
8	1 lite 11-up	50	19	83
9	1 lite Pep	78	68	35.4
10	1 lite Brite	63	79	25.2
11	1 lite Dr. Spice	33	12	82.5

Table 1. Inventory and sales analysis (for 1 month), Spirit company : Mankato plant

The three production plants (located in Rochester, Minneapolis, and St. Cloud) produced and shipped the company products to 14 distribution centers that marketed and sold them in Spirit's franchise territory.

Item	Product	Minneapolis	Mankato	Red Wing	Rush City	Coon Rapids	St. Cloud	New ULM
1	6.5 oz Spirit							
2	10 oz Spirit							
3	10 oz 11-up							
4	10 oz Pep							
5	10 oz Brite							
6	16 oz Spirit		R			R		
7	1 lite Spirit	R	R	R	R	R	R	R
8	1 lite 11-up	R	R	R	R	R	R	R
9	1 lite Pep	R	R	R	R	R	R	R
10	1 lite Brite	R	R	R	R	R	R	R
11	1 lite Dr. Spice	R	R	R	R	R	R	R

Table 2. Production assignment for each distribution center (for 1 month)

Item	Product	Arkansaw Wis.	Rochester	St.Bonfacius	Sauk Center	Princeton	Hutchinson	Little Falls
1	6.5 oz Spirit		R	R	R	R	R	R
2	10 oz Spirit		R	R	R	R	R	R
3	10 oz 11-up		R	R	R	R	R	R
4	10 oz Pep		R	R	R	R	R	R
5	10 oz Brite		R	R	R	R	R	R
6	16 oz Spirit		R	R	R	R	R	R
7	1 lite Spirit		R	R	R	R	R	
8	1 lite 11-up		R	R	R	R	R	
9	1 lite Pep		R	R	R	R	R	
10	1 lite Brite		R	R	R	R	R	
11	1 lite Dr. Spice		R	R	R	R	R	

Table 2. Production assignment for each distribution center (continue)

R = Rochester

From table1, the inventory figures divided by average daily sales gave the number of days' supply "on the floor" for each product and package. Days' supply was the key factor in determining what and when to produce.

Although Spirit Bottling Company has three production plants, we will consider only the Rochester plant. Because, if we can have solution from this plant, we can apply this method to the others.

During May for example, the plant held 45,785 cases of finished product. Lack of space within the plant cost of company in several ways.

The Rochester operation, although generally well managed, had obvious problem. There was not enough warehouse space for raw material and finished goods.

The company was forced to store 86,334 cases of used returnable glass in cartons and cases outside in an open yard. The cases cover 24,500 square feet. When it rained the cardboard carton in a case was ruined . There was four cartons in a case, each costing 5 cent.

PLANT	LINE NUMBER	PACKAGE	LINE CAPACITY (per hour)
ROCHESTER	1	1 lite R	300
	2	6.5 oz or 10 oz R	1000
	2	16 oz R	938

Table 3. Line capacities of Rochester plant

Note. R = returnable bottles

From all information that the manager has, he decides to reduce inventory by finding the new order quantity.

Literature Review

The LIMIT (Lot-size Inventory Management Interpolation Technique) is designed to handle a family of items that passes over common manufacturing facilities.

LIMIT is a two phase technique

Trial economical lot-sizes are calculated for each item in chosen group using the standard EOQ equation. The total setup hour required for these economic lot sizes is then compared with the total setup required for the present lot sizes. New LIMIT order quantities are then calculated, which result in total of setup hours equals to the present total. The result is usually to reduce the total inventory very substantially without changing total setup hours. Thus the benefits from reduced inventory investment are obtained with no change in operation condition.

Aggregate Safety Stock Inventory

The balance between customer service and inventory investment is seldom the result of a well-thought-out policy in most business. It is not always recognized by management that there is a basic relationship between inventory level and customer service level and that these are not independent variables. The better the desired service to customers, the higher the finished-goods inventory must be in a business already using manufacturing-control system effectively.

Economic Ordering quantity

Because of the decision of management to balance between holding cost and setup cost, EOQ formula can indicate the economic lot size for this problem by assuming some conditions.

The EOQ concept applied under the following condition.

1. The item is replenished in lots or batches, either by purchasing or manufacturing, and it is not produced continuously.

2. Sale or usage rate are uniform and are low compared to the rate at which the item is normally produced so that there a significant amount of inventory.

Basic equation for EOQ

$$EOQ = \sqrt{(2\,A\,S / I)}$$

Where

A = the annual usage, in dollars

S = the setup or ordering cost, on dollars

I = the inventory holding cost

GINO software

This software is for non-linear programing problem. Many commands in GINO are identical in from and function to those in LINDO. However, there are a few difference between GINO and LINDO.

1) A MAX or MIN statement is not required in GINO model, but when it is used, it need not be the first line of the formulation.

2)The MAX or MIN must followed by and equal sign, thus;

MAX=<expression>

the multiplication operator must be explicit in GINO

4*X not 4X

4) Variables must be includes in the right hand side of a GINO expression

5) When entering a model, a " ;" (semicolon) is required to indicate the end of a row of a formation input; a carriage return maybe used to split lines.

Methodology

The LIMIT Technique

The LIMIT (Lot-size Inventory Management Interpolation Technique) is a technique that reduces the total inventory and total setup time. In this case, there is a problem with the inventory level in the Rochester plant.

First, we calculate a trial economic lot-sizes for each item in the group of product by using the standard EOQ equation. Then compare the total setup time required for the EOQ and the total setup time required for the present lot-sizes. The new LIMIT order quantities are calculated and the result in a total setup time equal to the present setup time. The result from the new LIMIT is to reduce the total setup time when compared with the EOQ lot-sizes without changing total setup time.

LIMIT procedure

This case involves with 11 items of soft drink in Rochester plant. These data are required for calculating the new LIMIT.

1. Monthly usage in units
2. Units cost
3. Present order quantity
4. Setup time per order
5. Setup cost per hour

Assumption

1. Returnable bottles are the major problem because the company was forced to storage them outside the plant. In this project, we will concern only returnable bottles.

2. Mankato is the representative of 14 distribution centers that means the Rochester plant sends the product (returnable bottle) to 14 distribution centers and each distribution center has the same demand and quantity to order as Mankato.

Item	Product	Minneapolis	Mankato	Red Wing	Rush City	Coon Rapids	St. Cloud	New ULM
1	6.5 oz Spirit							
2	10 oz Spirit							
3	10 oz 11-up							
4	10 oz Pep							
5	10 oz Brite							
6	16 oz Spirit		1418			1418		
7	1 lite Spirit	856		856	856	856	856	856
8	1 lite 11-up	19	19	19	19	19	19	19
9	1 lite Pep	68	68	68	68	68	68	68
10	1 lite Brite	79	79	79	79	79	79	79
11	1 lite Dr. Spice	12	12	12	12	12	12	12

Table 4. Monthly demand for each distribution center

Item	Product	Arkansaw Wis.	Rochester	St.Bonfacius	Sauk Center	Princeton	Hutchinson	Little Falls
1	6.5 oz Spirit		3056	3056	3056	3056	3056	3056
2	10 oz Spirit		4941	4941	4941	4941	4941	4941
3	10 oz 11-up		294	294	294	294	294	294
4	10 oz Pep		1168	1168	1168	1168	1168	1168
5	10 oz Brite		923	923	923	923	923	923
6	16 oz Spirit		1418	1418	1418	1418	1418	1418
7	1 lite Spirit		856	856	856	856	856	
8	1 lite 11-up		19	19	19	19	19	
9	1 lite Pep		68	68	68	68	68	
10	1 lite Brite		79	79	79	79	79	
11	1 lite Dr. Spice		12	12	12	12	12	

Table 4. Monthly demand for each distribution center (continue)

From the Table 4 we get the following table.

Item	Product package	Demand (cases)	Number of distribution center	Total demand
1	6.5 oz Spirit	3056	6	18336
2	10 oz Spirit	4941	6	29646
3	10 oz 11-up	294	6	1764
4	10 oz Pep	1168	6	7008
5	10 oz Brite	923	6	5538
6	16 oz Spirit	1418	8	11344
7	1 lite Spirit	856	12	10272
8	1 lite 11-up	19	12	228
9	1 lite Pep	68	12	816
10	1 lite Brite	79	12	948
11	1 lite Dr. Spice	12	12	144

Table 5. Monthly demand for Rochester plant

Note: Total demand = Monthly demand of Rochester

Item	Product	Minneapolis	Mankato	Red Wing	Rush City	Coon Rapids	St. Cloud	New ULM
1	6.5 oz Spirit							
2	10 oz Spirit							
3	10 oz 11-up							
4	10 oz Pep							
5	10 oz Brite							
6	16 oz Spirit		284			284		
7	1 lite Spirit	1208		1208	1208	1208	1208	1208
8	1 lite 11-up	50	50	50	50	50	50	50
9	1 lite Pep	78	78	78	78	78	78	78
10	1 lite Brite	63	63	63	63	63	63	63
11	1 lite Dr. Spice	33	33	33	33	33	33	33

Table 6. Order quantity for each distribution

Item	Product	Arkansaw Wis.	Rochester	St.Bonfacius	Sauk Center	Princeton	Hutchinson	Little Falls
1	6.5 oz Spirit		345	345	345	345	345	345
2	10 oz Spirit		255	255	255	255	255	255
3	10 oz 11-up		138	138	138	138	138	138
4	10 oz Pep		234	234	234	234	234	234
5	10 oz Brite		86	86	86	86	86	86
6	16 oz Spirit		284	284	284	284	284	284
7	1 lite Spirit		1208	1208	1208	1208	1208	
8	1 lite 11-up		50	50	50	50	50	
9	1 lite Pep		78	78	78	78	78	
10	1 lite Brite		63	63	63	63	63	
11	1 lite Dr. Spice		33	33	33	33	33	

Table 6. Order quantity for each distribution (continue)

From the table 6 we get the following table

Item	Product package	Inventory (cases)	Order quantity (cases)	Number of distribution center	Total order quantity (cases)
1	6.5 oz Spirit	345	690	6	4140
2	10 oz Spirit	255	510	6	3060
3	10 oz 11-up	138	276	6	1656
4	10 oz Pep	234	468	6	2808
5	10 oz Brite	86	172	6	1032
6	16 oz Spirit	284	568	8	4544
7	1 lite Spirit	1208	2416	12	28992
8	1 lite 11-up	50	100	12	1200
9	1 lite Pep	78	156	12	1872
10	1 lite Brite	63	126	12	1512
11	1 lite Dr. Spice	33	66	12	792

Table 7. Order quantity for Rochester plant

Note: Inventory = (order quantity)/2

thus order quantity = 2 * inventory

Total order quantity = Present order quantity for Rochester plant.

From table 5 and 7 we get

Item	Returnable (bottles)	Monthly usage	Present order quantity
1	6.5 oz Spirit	18336	4140
2	10 oz Spirit	29646	3060
3	10 oz 11-up	1764	1656
4	10 oz Pep	7008	2808
5	10 oz Brite	5538	1032
6	16 oz Spirit	11344	4544
7	1 lite Spirit	10272	28992
8	1 lite 11-up	228	1200
9	1 lite Pep	816	1872
10	1 lite Brite	948	1512
11	1 lite Dr. Spice	144	792
	Total	85,900	51,608

Table 8. Show Monthly usage (demand) in units (cases), Unit cost and Present order for Rochester plant

Setup time per order and setup cost per hour

When we want to change a product to another product, there are two steps of setup, product changeover and package changeover. We have two lines, line 2 and line 4, in production of returnable bottle.

Line number	Package
1	1 lite R
2	6.5 oz R, 10 oz R
2	16 oz R

Table 9. Production line

Note: R = returnable bottle

1. Product changeover

Change the different kind of product but the same size such as *10 oz Spirit* to *10 oz Pep.*

Washdown expense

24 oz syrup @ 3.92/gallon = 72 cent

Carbon dioxide and water = 6 cent

Total = 78 cent

Labor cost for mixing concentrate

1 man @ $8/hour

Time required = 15 minutes

Labor cost = $2.00

Total cost = $2.78

In line 1, we produce only 1 lite product thus item 7, 8, 9, 10, 11 (1 lite product) have only product changeover.

Setup time = 15 minute

= 0.25 hour

Setup cost = 2.78 per 15 minutes

= $11.12 per hour

2. Package changeover

Change the different kind and size of product such as *6.5 oz spirit* to *10 oz Pep.*

Labor cost for resetting machine

2 men @ $8/hour

Time required = 35 minutes

Total cost = $9.34

In line 2, we produce 6.5 oz, 10 oz and 16 oz thus item 1, 2, 3, 4, 5, 6 have product changeover and package changeover.

Setup time = 35 + 15 = 50 minutes

= 0.8333 hour

Setup cost = 2.78 + 9.34

= $12.12 per 50 minutes

= $14.544 per hour

Setup time per order for item 7, 8, 9, 10, 11 (line 1) equal to 0.25 hour

item 1, 2, 3, 4, 5, 6 (line 2) equal to 0.8333 hour

Setup cost per hour for item 7, 8, 9, 10, 11 (line 1) equal to $11.12 per hour

item 1, 2, 3, 4, 5, 6 (line 2)equal to $14.544 per hour

The setup requirement

Calculation to determine the present annual setup requirement for each part and the total setups for all 11 items are determined by dividing the monthly usage by the present order quantities to find the number of setups and then multiplying by the setup hours per order.

$$\frac{\text{monthly usage}}{\text{present order quantities}} \times (\text{setup hour per order}) = \text{monthly setup (hour)}$$

For example, 6.5 oz Spirit

monthly usage = 18336 cases

present order quantities = 4140 cases

setup hour per order = 0.8333 hour

monthly setup = (18336/4140) x (0.8333)

= 3.6907

Item	Returnable bottle	Monthly usage	Set up (hrs) per order	Present order	Monthly setup (hrs) present order
1	6.5 oz Spirit	18336	0.8333	4140	3.6907
2	10 oz Spirit	29646	0.8333	3060	8.0732
3	10 oz 11-up	1764	0.8333	1656	0.8876
4	10 oz Pep	7008	0.8333	2808	2.0797
5	10 oz Brite	5538	0.8333	1032	4.4717
6	16 oz Spirit	11344	0.8333	4544	2.0803
7	1 lite Spirit	10272	0.25	28992	0.0886
8	1 lite 11-up	228	0.25	1200	0.0475
9	1 lite Pep	816	0.25	1872	0.1090
10	1 lite Brite	948	0.25	1512	0.1567
11	1 lite Dr. Spice	144	0.25	792	0.0455
	Total	85,900		51,608	21.7305

Table 10. Monthly setup hours for each item

Trial order quantity (EOQ)

These data are calculated from the standard EOQ formula

$$EOQ = \sqrt{(2US)/(IC)}$$

where

U = monthly usage (cases)

S = setup cost per setup (setup hours per order * setup cost per hour)

I = inventory carrying cost expressed as a decimal fraction

C = cost per cases

Note: We use EOQ = TOQ (Trial order quantity)

$$TOQ = \frac{\sqrt{2 * (\text{monthly usage}) * (\text{setup hours per order}) * (\text{setup cost per hour})}}{\sqrt{(\text{inventory carrying cost}) * (\text{cost per case})}}$$

For item 1, 6.5 oz Spirit, the following answer is obtained for the trial order quantity (TOQ) using the EOQ formula while a carrying cost (I) and setup cost per hour equal to 0.15, $14.544 respectively.

monthly usage = 18336 cases

setup hours per order = 0.8333 hr

setup cost per hour = $27.1314

inventory carrying cost = 0.15

cost per case = $2

$$TOQ = \frac{\sqrt{2 * (18336) * (0.8333) * (27.1314)}}{\sqrt{(0.15) * (2)}}$$

$$= 1662.4304$$

We use this formula for all items and get the result in the following table.

Item	Returnable bottle	Monthly usage	Set up (hrs) per order	Unit cost	Trial order quantity
1	6.5 oz Spirit	18336	0.8333	2	1662.43
2	10 oz Spirit	29646	0.8333	2.5	1890.68
3	10 oz 11-up	1764	0.8333	2.5	461.19
4	10 oz Pep	7008	0.8333	2.5	919.24
5	10 oz Brite	5538	0.8333	2.5	817.17
6	16 oz Spirit	11344	0.8333	2.7	1125.40
7	1 lite Spirit	10272	0.25	3	356.25
8	1 lite 11-up	228	0.25	3	53.07
9	1 lite Pep	816	0.25	3	100.40
10	1 lite Brite	948	0.25	3	108.22
11	1 lite Dr. Spice	144	0.25	3	42.18
	Total	85,900			7,536.28

Table 11. Trial order quantity (EOQ)

The monthly setup hours resulting from the use of the trial order quantity.

$$\frac{\text{monthly usage}}{\text{the trial order quantities}} \times (\text{setup hour per order}) = \text{monthly setup (hour)}$$

monthly usage = 18336 cases

the trial order quantities = 1662.4304 cases

setup hour per order = 0.8333 hour

monthly setup = (18336/1662.4304) x (0.8333)

= 9.1910 hours

Likewise, we can derive solution for monthly setup for other products in the following table.

Item	Returnable bottle	Set up (hrs) per order	Unit cost	Trial order quantity	Monthly setup (hrs) trial order
1	6.5 oz Spirit	0.8333	2.00	1662.4304	9.1910
2	10 oz Spirit	0.8333	2.50	1890.6851	13.0662
3	10 oz 11-up	0.8333	2.50	461.1959	3.1872
4	10 oz Pep	0.8333	2.50	919.2491	6.3528
5	10 oz Brite	0.8333	2.50	817.1704	5.6473
6	16 oz Spirit	0.8333	2.70	1125.4012	8.3996
7	1 lite Spirit	0.25	3.00	356.2531	7.2084
8	1 lite 11-up	0.25	3.00	53.0760	1.0739
9	1 lite Pep	0.25	3.00	100.4098	2.0317
10	1 lite Brite	0.25	3.00	108.2269	2.1898
11	1 lite Dr. Spice	0.25	3.00	42.1806	0.8535
	Total	0.25		7,536.28	59.2014

Table 12. Monthly setup time for the trial order quantity

The LIMIT order quantity

Calculate the order quantities that will have the identical total monthly setup times to the present order quantities. The LIMIT order quantities are calculated from the following formula

LIMIT formula : $M = H_a / H_b$

where

H_b = total setup hours resulting from the present order quantities

H_a = total setup hours resulting from the trial order quantities

The LIMIT formula provides a multiplying factor M to convert trial order quantities to LIMIT order quantities. For example, 6.5 oz Spirit

H_b = 21.7305 hours

H_a = 59.2014 hours

M = (59.2014/21.7305)

= 2.7243

Using the multiplying factor M, the LIMIT order quantity for 6.5 oz Spirit is calculated

LIMIT order quantity = (Trial order quantity) * (multiplier factor)

= (1662.4304) * (2.7243)

= 4529.0336

The monthly setup hours resulting from the LIMIT order quantity

$$\frac{\text{monthly usage}}{\text{the LIMIT order quantities}} \times \text{(setup hour per order)} = \text{monthly setup (hour)}$$

For example the monthly setup hours for 6.5 oz Spirit

monthly usage = 18336 cases

the LIMIT order quantities = 4529.0336 cases

setup hour per order = 0.8333 hour

monthly setup = (18336/4529.0336) x (0.8333)

= 3.3737 hours

From above formula, we get the LIMIT order quantity for each item in the following table.

For production line 2.

Item no.	Returnable bottle	Monthly usage	Set up (hrs) per order	Present order quantity	Monthly setup (hrs) present	LIMIT order quantity	Monthly setup (hrs) LIMIT
1	6.5 oz Spirit	18336	0.8333	4140	3.6907	4529.0336	3.3737
2	10 oz Spirit	29646	0.8333	3060	8.0732	5150.8783	4.7961
3	10 oz 11-up	1764	0.8333	1656	0.8876	1256.4567	1.1699
4	10 oz Pep	7008	0.8333	2808	2.0797	2504.3515	2.3318
5	10 oz Brite	5538	0.8333	1032	4.4717	2226.2540	2.0729
6	16 oz Spirit	11344	0.8333	4544	2.0803	3065.9811	3.0832
	Total	73,636		17,240	21.2833	14,811.1819	21.2833

Table 13. LIMIT order quantity and monthly setup time

For production line 1.

Item no.	Returnable bottle	Monthly usage	Set up (hrs) per order	Present order quantity	Monthly setup (hrs) present	LIMIT order quantity	Monthly setup (hrs) LIMIT
7	1 lite Spirit	10272	0.25	28992	0.0886	970.5563	2.6459
8	1 lite 11-up	228	0.25	1200	0.0475	144.5975	0.3942
9	1 lite Pep	816	0.25	1872	0.1090	273.5510	0.7457
10	1 lite Brite	948	0.25	1512	0.1567	294.8475	0.8038
11	1 lite Dr. Spice	144	0.25	792	0.0455	114.9144	0.3133
	Total	12,264		34,368	0.4473	19,715.4596	0.4473

Table 13. LIMIT order quantity and monthly setup time (continue)

The monthly setup hours are calculated for each item. Notice that the monthly setup hours from the LIMIT order quantity and the monthly setup hours from the present order are the same value. In addition, the LIMIT quantities reduce the amount of order from the present order but still have the same setup hours.

GINO Software

GINO software can solve non-linear equation. By using GINO software, we can get the same solution from EOQ solution (if there is no constraints).

Let

Q1 = 6.5 oz Spirit
Q2 = 10 oz Spirit
Q3 = 10 oz 11-up
Q4 = 10 oz Pep
Q5 = 10 oz Brite
Q6 = 16 oz Spirit
Q7 = 1 lite Spirit
Q8 = 1 lite 11-up
Q9 = 1 lite Pep
Q10 = 1 lite Brite
Q11 = 1 lite Dr. Spice

1) Objective function

This objective function come from the basic equation of EOQ

Cost = (S * Q)/2 + (h* D)/Q

where

S = Setup cost

Q = Order quantity

h = Holding cost

D = Demand

So, we can derive objective function from above basic equation.

Qi	S	h	D	Set up time (hrs) per order
Q1	0.3	22.608596	18336	0.8333
Q2	0.375	22.608596	29646	0.8333
Q3	0.375	22.608596	1764	0.8333
Q4	0.375	22.608596	7008	0.8333
Q5	0.375	22.608596	5538	0.8333
Q6	0.405	22.608596	11344	0.8333
Q7	0.45	2.780000	10272	0.25
Q8	0.45	2.780000	228	0.25
Q9	0.45	2.780000	816	0.25
Q10	0.45	2.780000	948	0.25
Q11	0.45	2.780000	144	0.25

Table 14. Data for GINO

min = (0.3*Q1)/2+(22.608596*18336)/Q1+(0.375*Q2)/2+(22.608596*29646)/Q2+
(0.375*Q3)/2+(22.608596*1764)/Q3+ (0.375*Q4)/2+(22.608596*7008)/Q4+
(0.375*Q5)/2+(22.608596*5538)/Q5+ (0.405*Q6)/2+(22.608596*11344)/Q6+
(0.45*Q7)/2+(2.78*10272)/Q7+ (0.45*Q8)/2+(2.78*228)/Q8+ (0.45*Q9)/2
+(2.78*816)/Q9+ (0.45*Q10)/2+(2.78*948)/Q10+ (0.45*Q11)/2+(2.78*144)/Q11;

2) Constraint

2.1) Setup time

From the problem, we decide to minimize setup time and we also know that for the problem the managers minimize setup time for the the present method

Each item has setup time = (D /Q) * setup time for individual item

So, From above statement and table14 ., we can derive setup time constraint

(18336*0.8333)/Q1+(29646*0.8333)/Q2+(1764*0.8333)/Q3+(7008*0.8333)/Q4+
(5538*0.8333)/Q5+(11344*0.8333)/Q6+(10272*0.25)/Q7+(228*0.25)/Q8+
(816*0.25)/Q9+(948*0.25)/Q10+(144*0.25)/Q11<21.730

2.2) From problem, we know that 24, 500 square feet is for 86,634 cases

Assumption

I. The warehouse can consist 20 cases in vertical direction.

So, (volume of one case) * (total quantity of case) = volume of warehouse

let

v = height of one case

V= height of warehouse

But from assumption, V =20 v

Then, (area of one case) * (v) * (total quantity of cases) = area of warehouse * V

total quantity = 86,634 cases

area of warehouse = 24,500 square feet

Finally, area of one case = (24,500 * 20 * v) / (86,634 * v)

= 1.41

II. Each type of soft drink has the same area but is different in height. However, warehouse can store 20 cases in vertical direction.

III.. For the storage area, we use the present order quantity to calculate because we assume the plant has enough area to store average inventory from the present order.

average inventory = present order quantity / 2

average inventory from table 8 = 51608 / 2 = 25804 cases

From assumption II, 1 case has 1.41 square feet

So storage area for this plant = 1.41 * 25804

= 36383.64 square feet

From the assumption, the following equation shows constraint for storage area.

(1.41*Q1)/2+(1.41*Q2)/2+(1.41*Q3)/2+(1.41*Q4)/2+(1.41*Q5)/2+(1.41*Q6)/2+
(1.41*Q7)/2+(1.41*Q8)/2+(1.41*Q9)/2+(1.41*Q10)/2+(1.41*Q11)/2<36383.64;

3) For GINO software it is possible that some variable can be native so, we should force the variable not to be negative. Furthermore, we have to produce all product to meet the demand. For this constraint, we force by let each variable equal or more than their EOQ value

This is constraint to meet demand.

Q1>1163;

Q2>1890;

Q3>462;

Q4>920;

Q5>818;

Q6>1126;

Q7>357;

Q8>53;

Q9>100;

Q10>108;

Q11>44;

The result from GINO program show in table below

Item no.	Returnable bottle	GINO order quantity	Monthly setup (hrs) GINO
1	6.5 oz Spirit	4,188.27	3.6481
2	10 oz Spirit	4,773.40	5.1753
3	10 oz 11-up	1,165.38	1.2613
4	10 oz Pep	2,318.53	2.5187
5	10 oz Brite	2,060.84	2.2393
6	16 oz Spirit	2,840.52	3.3279
7	1 lite Spirit	1,338.49	1.9186
8	1 lite 11-up	198.79	0.2867
9	1 lite Pep	376.26	0.5422
10	1 lite Brite	405.61	0.5843
11	1 lite Dr. Spice	157.90	0.2280
	Total	19,824.02	21.7305

Table15. Result from GINO program

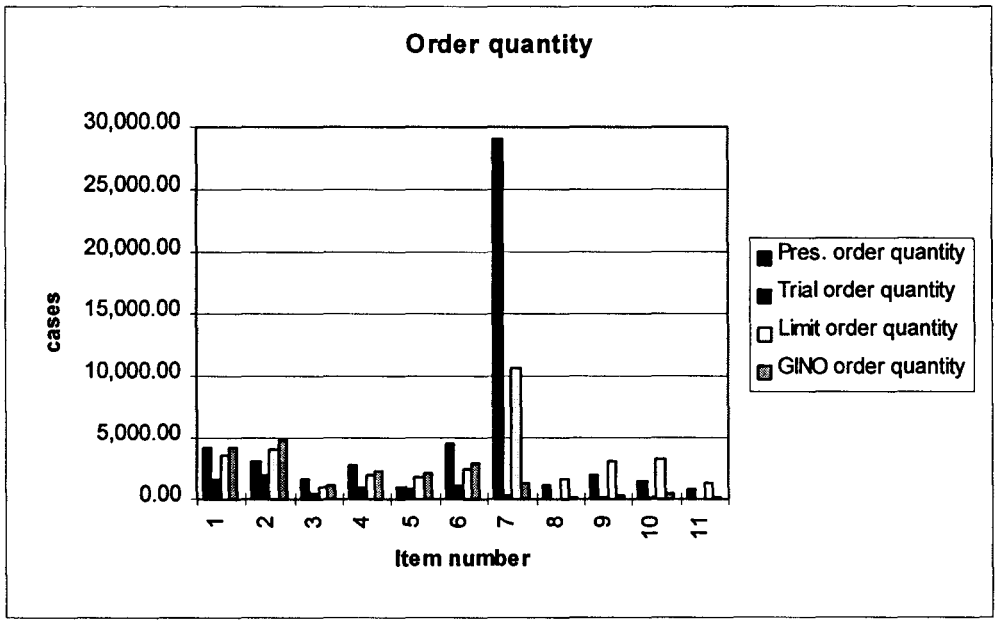

Figure 1. Order quantity for each order quantity

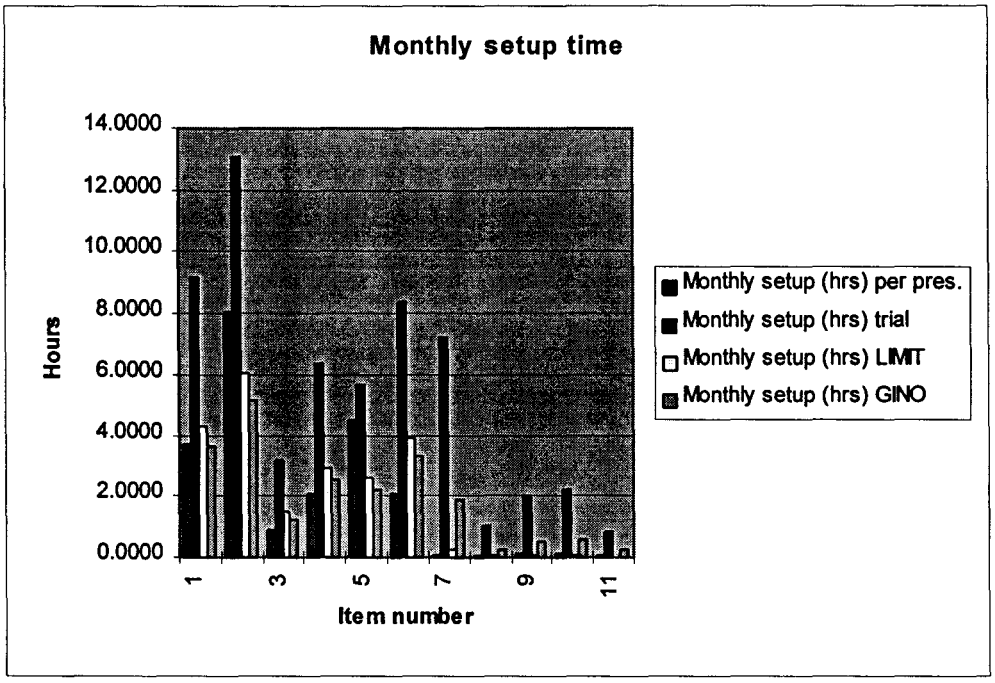

Figure 2. Monthly setup time for each order quantity

The inventory investment

Total inventory investment is

$$I = (cQ)/2$$

where

I = total inventory investment (dollar)

c = cost per case (dollar)

Q = order quantity (cases)

For example, item 1 6.5oz Spirit,

c = $2.00

Q = 4140 cases (for Present order quantity)

I = (2*4140)/2

= $4140

Item no.	Present quantity	Trial quantity	LIMIT quantity	GINO quantity	Unit cost	Inventory investment			
						Present	Trial	LIMIT	GINO
1	4,140.00	1,662.43	3,580.87	4,188.27	$2.00	$4,140.00	$1,662.43	$3,580.87	$4,188.27
2	3,060.00	1,890.69	4,072.53	4,773.40	$2.50	$3,825.00	$2,363.36	$5,090.67	$5,966.75
3	1,656.00	461.20	993.42	1,165.38	$2.50	$2,070.00	$576.49	$1,241.77	$1,456.73
4	2,808.00	919.25	1,980.06	2,318.53	$2.50	$3,510.00	$1,149.06	$2,475.08	$2,898.17
5	1,032.00	817.17	1,760.18	2,060.84	$2.50	$1,290.00	$1,021.46	$2,200.23	$2,576.05
6	4,544.00	1,125.40	2,424.11	2,840.52	$2.70	$6,134.40	$1,519.29	$3,272.55	$3,834.70
7	28,992.00	356.25	10,639.60	1,338.49	$3.00	$43,488.00	$534.38	$15,959.40	$2,007.74
8	1,200.00	53.08	1,585.13	198.79	$3.00	$1,800.00	$79.61	$2,377.70	$298.19
9	1,872.00	100.41	2,998.77	376.26	$3.00	$2,808.00	$150.61	$4,498.15	$564.39
10	1,512.00	108.23	3,232.23	405.61	$3.00	$2,268.00	$162.34	$4,848.34	$608.41
11	792.00	42.18	1,259.73	157.90	$3.00	$1,188.00	$63.27	$1,889.60	$236.85
Total	51,608.00	7,536.28	34,526.64	19,824.02		$72,521.40	$9,282.32	$47,434.36	$24,636.27

Table 16. Inventory investment

Conclusion

	Total order	Monthly setup time	Inventory investment
Present order	51,608.00	21.7305	72,251.40
Trial order	7,536.28	59.2014	9,282.32
LIMIT order	34,526.64	21.7305	47,434.36
GINO order	19,824.01	21.7305	24,636.27

Table 17. Compare result from each order quantity

1. When compare the results among the present order quantity, the trial order quantity (EOQ) quantity, the LIMIT order quantity, and GINO order quantity, we will see that the trial order has the best result. It has inventory level and inventory investment lower than the others but has maximum monthly setup time. Although the trial order has the best result in order quantity and inventory investment, it is not realistic because it has more setup time more than others. (EOQ formula apply to product to calculate the optimum solution based on some definite assumption.) Actually in the real situation, there are many constraints in the process such as the number of workers and machines. For example

I. The trial order has far more setup time than the others. The more setup time is required, the more people handle it. Sometimes in the department, there are no additional setup people to be hired in the area.

II. The training operators to setup machines will have required for a long period.

III. The company has to buy some machine parts from outside sources because the machine utilization will decrease dramatically result from the more setup time required by the trial order (EOQ).

IV. The workers are frequently disturbed by the amount of setup time that is required.

The results from the LIMIT order quantity show that the setups stay within the setup hour limitations that exist, equal to the present order. It is possible to reduce the present inventory level without increasing the setup cost.

Moreover, if we consider the result from GINO, we can know that even though GINO order quantity is worse than EOQ, GINO is more realistic.

2. If we consider the total setup time from GINO and LIMIT, we can see that both methods give the same solution. The reason is that LIMIT and GINO have constraint about setup time based on the present order quantity.

3. Both LIMIT and GINO method show that we can avoid the pitfall of EOQ (that is not realistic) by adding more actual situation in to both methods.

For all reasons, the manager should use GINO method to solve this problem by order the quantity followed the GINO result.

Item no.	Returnable bottle	GINO order quantity	Monthly setup (hrs) GINO
1	6.5 oz Spirit	4,188.27	3.6481
2	10 oz Spirit	4,773.40	5.1753
3	10 oz 11-up	1,165.38	1.2613
4	10 oz Pep	2,318.53	2.5187
5	10 oz Brite	2,060.84	2.2393
6	16 oz Spirit	2,840.52	3.3279
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8	1 lite 11-up	198.79	0.2867
9	1 lite Pep	376.26	0.5422
10	1 lite Brite	405.61	0.5843
11	1 lite Dr. Spice	157.90	0.2280
	Total	19,824.02	21.7305

Table 18. Result from GINO

Sensitivity Analysis

Estimating forecast error

Because forecast for demand is always error so, we will consider what is happen when demand is deviate from forecast

Assume that demand is a normal distribution and forecast is mean of this distribution. Then, we can find standard deviation for demand

Calculation

1) Standard deviation

$$\sigma = \sum (\mu - Xi)^2 / (n-1)$$

μ = mean of demand (demand forecast)

Xi = Demand in period i

n = A number period

2) Mean absolute deviation

$$MAD = | \mu - Xi | / n$$

In the actual situation, we should consider the divination of demand. How much it deviates from our forecast. We should keep service level for our customer. On the other hand, if we hold a high level for inventory, it means that we pay a lot for inventory cost.

This table shows relation between service level and a constant time of standard deviation and mean absolute deviation

PROBABILITY	SERVICE LEVEL	STANDARD DEVIATION	MEAN ABSOLUTE DEVIATION
0.50000	50.000	0.00	0.00
0.74857	74.857	0.67	0.84
0.79955	79.955	0.84	1.05
0.84134	84.134	1.00	1.25
0.85083	85.083	1.04	1.30
0.89435	89.435	1.25	1.56
0.89973	89.973	1.28	1.60
0.93319	93.319	1.50	1.88
0.94062	94.062	1.56	1.95
0.94520	94.520	1.60	2.00
0.95053	95.053	1.65	2.06
0.95994	95.994	1.75	2.19
0.96995	96.995	1.88	2.35
0.97725	97.725	2.00	2.50
0.97982	97.982	2.05	2.56
0.98610	98.610	2.20	2.75
0.99010	99.010	2.33	2.91
0.99180	99.180	2.40	3.00
0.99379	99.379	2.50	3.13
0.99492	99.492	2.57	3.20
0.99598	99.598	2.65	3.31
0.99702	99.702	2.75	3.44
0.99801	99.801	2.88	3.60
0.99865	99.865	3.00	3.75
0.99900	99.900	3.09	3.85
0.99931	99.931	3.20	4.00
0.99997	99.997	4.00	5.00

Table 19.

From the above table, we need 3 time of standard deviation for 99.9 % service level. So, This table gives us an idea that how to deter mine the level of safety stock.

For instance, if the management want to have 95 % service level they have to keep 3 time of standard deviation for safety stock

Safety stock

This is factor for safety stock

1. Service level that the management wants it
2. Standard deviation of demand (from the forecast)

Example

The reserve stock required for each service level can be calculated using the method show below

Number of exposure per year = annual forecast divided by order quantity

for example annual forecast = 2600

order quantity = 200

Number of exposure per year 2600 / 200 = 13

If want to have service level 9 time per year so,

Service fraction = 9 / 13

Service ratio = 9 / 13

= 63.2 %

Required number of MAD' s (table) = 0.75 (estimated)

Reserved stock required = 0.75 * MAD

= 0.75 * 209 = 157

From the previous table

Stockout per year	Exposure	Service fraction	Service ratio (%)	Required MAD	reserve
4	13	9/13	69.2	0.75	157
2	13	11/13	84.5	1.29	268
1	13	12/13	92.4	1.80	376
one in 2	26	25/26	96.1	2.20	460
one in 3	39	38/39	97.4	2.40	501
one in 4	52	51/52	98.1	2.60	544
one in 5	65	64/65	98.5	2.70	565
one in10	130	129/130	99.2	3.00	626
never			100	5.00	1044

Table 20. Example of safety stock for each level of stockout

This example will show safety stock for one product from the Spirit Bottling Company.

From table, monthly usage for 6.5 oz Spirit is 18336. This is forecast sale per month. However, in the real situation forecast sale is always error. So, we will assume that the standard deviation for this product is 1000 case. By using normal distribution random in Excel program we can get actual demand. (Assume that normal distribution random is actual.)

Month	Monthly forecast	Sales	Deviation
1	18336	18035.87	300.13
2	18336	17596.95	739.05
3	18336	18196.41	139.59
4	18336	18482.36	-146.36
5	18336	17138.13	1197.87
6	18336	18028.1	307.90
7	18336	17248.16	1087.84
8	18336	19093.46	-757.46
9	18336	18335.99	0.01
10	18336	18753.24	-417.24
11	18336	17650.72	685.28
12	18336	19640.22	-1304.22
		Total	1832.39

Table 21. A number of sale in each month (random by deoending on standrd deviation.)

Mean Absolute Deviation = average D = 1832.39 / 10

= 183.239

Annual forecast = 18336 * 12 = 220036

Order quantity = 4529.0336

Number of exposure per year 220036 / 4529.0036 = 45.58

about 46

So, we can estimate safety stock for any service ratio

This table shows safety stock for any service ration of 6.5 oz Spirit

Stockout	Exposure	Service fraction	Service ratio	Required MAD	reserve
8	46	38 / 46	82.61	1.177	215.67
4	46	42 / 46	91.3	1.711	313.52
2	46	44 / 46	95.65	2.142	392.50
1	46	45 / 46	97.83	2.777	508.85
one in 2	92	91 / 92	98.91	2.87	525.90
one in 3	138	137 / 138	99.28	3.065	561.63
one in 4	184	183 / 184	99.46	3.18	582.70
one in 5	230	229 / 230	99.57	3.281	601.21
never			100	5	916.20

Table 22. Show safety stock for each level of stockout

From this table, If the management want to have service ratio 82.61 % (it means that there is stockout only once in the year), They should have reserve stock about 215.67 cases

Moreover, if they want to have service ratio 100 % (it means that there is no stockout), they should have safety stock 916.20 cases

However, the management should realize that the more safety stock, the more inventory and the more inventory investment. So, they should consider that which service ratio is suitable for their company.

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