CHAPTER 5

DISSCUSSION OF RESULTS

According to group ordering method, inventory management system, and truck loading algorithm in Chapter 4, major suppliers and minor suppliers are considered to study. For Siam cement group, the products are grey cement and white cement. They are usually ordered only one type (one item). For example, grey tiger brand cement is only one item ordered and loaded into truck for transportation. That is not suitable for group of items for ordering. For minor suppliers, the products have less frequency of daily transaction of sales data than major products. In addition, The transportation costs of minor suppliers including Nawaplastic industry, Thai ceramic, Siam Sanitary ware. and Siam Nawaphan are free of charge. These minor suppliers are deal with transportation for the distributor. Therefore. two product groups: Siam fiber-cement group and Siam gypsum industry group are selected and studied an inventory management system and truck loading algorithm. Data collection is made from year 2000. Descriptions of these two product groups are presented in Table A.1-Table A.2 in Appendix A.

5.1 Results of the Inventory Management System

5.1.1 Input to the Inventory Management System

There are many input parameters for the output inventory management system: order quantity (EOQ), order point (s), and order-up-to-level (S).

1. Demand (r) or sales of each item. It is assumed as constant and deterministic. The monthly demand and standard deviation of usage during lead time (σ) are shown in Table 5.1-Table 5.2.

2. Inventory holding cost (h). It is calculated by expense of holding costs per year divided by value of average inventory levels per year. It is 18.00 per cent. (see Chapter 4, section 4.4: parameter estimation of inventory holding cost).

3. Ordering cost (k). Transportation cost is only considered for ordering cost. The transportation cost is fixed by 2,600 baht per trip.

4. Unit cost. In Table A.1 – Table A.2 in Appendix A show unit cost of each item of two product groups.

5. Lead time (L). All items of two product groups have three days lead time.

6. Number of standard deviation for a specified level (z). It is defined as a safety stock factor 1.65 (see Table 4.4).

Table 5.1

Product Group: Siam Fiber-Cement

Item	Product Code	Demand (pieces / month)												Total demand (pieces)	Average demand (pieces / month)	SD. (pieces / month)
		Jan.	Feb.	Mar	April	May	Jun	July	Aug.	Sept.	Oct.	Nov.	Dec.			
1	2000120	2934	1186	5174	726	857	536	412	2244	1690	1016	1340	2056	20,171	1680.92	1332.96
2	2000150	178	8	218	53	314	55	66	68	7	0	15	102	1,084	90.33	97.9
3	2013120	2050	1397	3615	1415	1184	350	500	461	280	1602	244	300	13,398	1,116.50	1,002.13
4	2015120	1000	0	517	460	25	0	5	435	450	25	0	165	3,082	256.83	317.31
5	2017120	1100	695	498	1310	415	0	0	36	0	59	16	0	4,129	344.08	466.82
6	2011121	0	0	0	0	0	0	2060	250	300	760	500	287	4,157	346.42	592.84
7	2019120	120	755	1282	1825	598	400	0	150	298	300	0	0	5,728	477.33	567.56
8	2090121	0	0	645	0	40	320	896	731	1242	126	52	3210	7,262	605.17	920.86
9	2020120	0	0	180	0	0	13	4	0	30	0	0	700	927	77.25	204.2
10	2064040	330	12	1605	164	0	42	27	37	0	172	20	920	3,329	277.42	492.55
11	2064240	455	174	217	93	48	57	234	109	60	40	48	14	1,549	129.08	125.4
12	2066240	0	131	135	0	213	140	51	15	0	0	3	0	688	57.33	76.12

Table: 5.2

Product Group: Siam Gypsum Industry

Item	Product Code	Demand (pieces / month)												Total demand (pieces)	Average demand (pieces / month)	SD. (pieces / month)
		Jan.	Feb.	Mar.	April	May	Jun	July	Aug.	Sept.	Oct.	Nov.	Dec.			
1	G201000	2	61	184	48	26	138	16	92	55	5	13	0	640	53.33	58.32
2	G202000	0	210	109	48	55	141	205	84	43	109	20	0	1,024	85.33	72
3	G211000	0	0	25	0	30	0	10	0	0	0	0	0	65	5.42	10.76
4	G212000	0	0	11	16	47	0	33	0	0	0	7	0	114	9.5	15.49
5	G231000	0	66	0	6	0	0	20	0	15	0	0	0	107	8.92	19.22
6	G232000	0	0	20	10	0	0	6	0	0	0	0	0	36	3	6.24

5.1.2 Process to the Inventory Management System

According to (s, S) system, the concept of EOQ, order point, and order-up-to-level will be described respectively.

5.1.2.1 Economic Order Quantity (EOQ)

The assumption of EOQ concept includes:

1. The demand is constant and deterministic. (r)
2. Inventory holding cost (h)
3. Ordering or setup cost (k)

$$EOQ = \sqrt{2kr/h}$$

EOQ values of each items are defined as an integer value.

Example of EOQ calculation of Roman Tile uncolor, product code: 2000120 is shown below.

- From Table 5.1, Demand   r = 20,171 per year

- Inventory holding cost h = 38 x 0.18
                                                = 6.84

   - Unit variable cost = 38 baht
   - Inventory holding cost = 18.00%

- Transportation cost k = 2,600 baht

Therefore,

$$EOQ = \sqrt{2x2600x20,171/6.84}$$

$$= 3,915.95 = 3,916 \text{ pieces}$$

5.1.2.2 Safety Stock Level

$$SS = z\sigma_L$$

The term $z\sigma_L$ is the amount of safety stock

Where

L   =   Lead time in days (time between placing
an order and receiving the items)

z   =   Number of standard deviations for
a specified service level (safety stock factor)

σ =   Standard deviation of usage during
lead time

The best estimate of population standard deviation of each item is calculated by formula shown below.

$$\sigma = \sqrt{\frac{\sum(r - \bar{r})^2}{n-1}}$$

r = demand rate of each item

n = a number of months in one year = 12

Therefore,

$$SS = z\sigma_L$$

Standard deviation of usage during lead time(σ_L) can be calculated by standard deviation of usage per day that demands or sales per day are independent each other. In this case, variance value is additive. So variance per lead time is equal to lead time times of variance per day.

$$\sigma^2_L = L(\sigma^2)$$

or

$$\sigma_L = \sqrt{L}(\sigma)$$

$$SS = z\sqrt{L}\sigma$$

Example of Safety Stock calculation of Roman Tile uncolor, product code: 2000120 is shown below.

- Lead time is equal to three days for all product groups of items.

- The specified service level is defined as 95 per cent. From table 4.4, the safety stock factor (z) is equal to 1.65.

- From Table 5.1, the standard deviation per month is equal to 1,332.96, so the standard deviation per day is equal to 44.43.

Therefore,

$$SS = z\sigma_l$$

$$SS = z\sqrt{L}\,\sigma$$

$$= 1.65\sqrt{3}x44.43$$

$$= 126.97$$

5.1.2.3 Order Point

Where

s	=	Order point
$\bar{d}$	=	Average daily demand
L	=	Lead time in days (time between placing an order and receiving the items)
SS	=	Safety Stock

The order point values of each items are defined as an integer value.

Example of order point (minimum level) calculation of Roman Tile uncolor, product code: 2000120 is shown below.

- From Table 5.1, the average monthly demand is equal to 1,680.92 so the average daily demand is equal to 56.03.

- Lead time is equal to three days.

- Safety Stock (SS) is equal to 126.97.

Therefore,

$$s = \bar{d} L + SS$$

$$= 56.03 \times 3 + 126.97$$

$$= 295.06 = 295 \text{ pieces}$$

5.1.2.4 Order-Up-To-Level

$$S = s + EOQ$$

Where

$$s = \text{Order point}$$

$$EOQ = \text{Economic Order Quantity}$$

The order-up-to-level values of each items are defined as an integer value.

Example of order-up-to-level (maximum level) calculation of Roman Tile uncolor, product code: 2000120 is shown below.

Therefore,

$$S = s + EOQ$$

$$= 295 + 3,916$$

$$= 4,211 \text{ pieces}$$

The Roman Tile uncolor, product code: 2000120 has three values as follows:

1. Economic Order Quantity (EOQ)   = 3,916 pieces

2. Order point (s)   = 295   pieces

3. Order-up-to-level (S)   = 4,211 pieces

5.1.3 Output to the Inventory Management System

In Table 5.3 – Table 5.4 show output of (s, S) inventory management system. Each table presents product code, order quantity (EOQ), order point (s), and order-up-to-level (S).

Product group: Siam Fiber-Cement

Item	Product Code	Order quantity (EOQ) (pieces)	Order point (s) (pieces)	Order-up-to-level (S) (pieces)
1	2000120	3,916	295	4,211
2	2000150	791	18	809
3	2013120	2,728	207	2,935
4	2015120	1,309	56	1,365
5	2017120	1,515	82	1,597
6	2011121	1,520	91	1,611
7	2019120	1,784	102	1,886
8	2090121	2,841	148	1,989
9	2020120	862	27	889
10	2064040	1.148	75	1,123
11	2064240	580	25	605
12	2066240	313	13	326

Table 5.3: (s, S) system output of Siam fiber-cement group.

Product group: Siam Gypsum Industry

Item	Product Code	Order quantity (EOQ) (pieces)	Order point (s) (pieces)	Order-up-to-level (S) (pieces)
1	G201000	316	11	327
2	G202000	400	15	415
3	G211000	88	2	90
4	G212000	116	2	118
5	G231000	112	3	115
6	G232000	65	1	66

Table 5.4: (s, S) system output of Siam gypsum industry group.

5.2 Results of the Truck Loading Algorithm

From (s, S) system, three values of order quantity (EOQ), order point, and order-up-to-level (S) have defined. Truck loading algorithm is used to select the items in each group products for ordering. Both Siam fiber-cement and Siam gypsum industry supplier is used the same a set of decision rules of truck loading algorithm. Any item in product group drops to order point (s), that item is ordered and loaded into 10-wheel truck. Other items are considered by Ratio To Order (RTO). Inventory position that is on hand inventory plus on order is considered for order point and RTO. Month in March, April, May is used to study like simulation for truck loading algorithm.

5.2.1 Input to the Truck Loading Algorithm

Two groups of product: Siam fiber-cement and Siam gypsum industry are used to study the truck loading algorithm. There are several inputs to consider as shown below.

1. Daily demand or sales of each item in three months (March, April, May). See Table B.1 – B.54 in Appendix B.

2. On hand inventory. It is stock available in a warehouse. See Table B.1 – B.54 in Appendix B.

3. On order. It is stock that is ordered. See Table B.1 – B54 in Appendix B.

4. Inventory position. It is on hand inventory plus on order inventory. See Table B.1 – B.54 in Appendix B.

5. Order point (s), order-up-to-level (S), and Order quantity (EOQ) are considered for ordering. See Table 5.3 – Table 5.4.

6. Unit weight. Each item has its own weight. See Table A.1 – Table A.2 in Appendix A.

5.2.2 Process to the Truck Loading Algorithm

Example of Siam fiber-cement group is shown for truck loading algorithm. Three months (March, April, May) are used to study.

On March 28, the inventory position of product code: 2015120 (roman tile green) falls to order point (56), see Table B.10 in Appendix B, so this item is ordered by order quantity (Max - Min). Other items in this Siam fiber-cement group are

considered by RTO. Other items are loaded into 10-wheel truck that the weights of ordered items must not exceed the maximum loading capacity.

March 28,

Product code: 2015120 is ordered by order quantity (Max- Min)

Order quantity = Max – Min = EOQ = 1,309 pieces

Unit weight   = 6.2 kgs

Total weight of this item   = 1,309 x 6.2 = 8,115.8 kgs

Other items in this group include 11 items. Ratio To Order (RTO) is used to considered these items.

Product Code	RTO = $\dfrac{\text{Inventory position - Min}}{\text{Max – Min}}$	
2000120	$= \dfrac{2,023-295}{3,916}$	= 0.441
2000150	$= \dfrac{402-18}{791}$	= 0.485
2013120	$= \dfrac{1,203-207}{2,728}$	= 0.365
2017120	$= \dfrac{1,807-82}{1,515}$	= 1.139
2011121	$= \dfrac{780-91}{1,520}$	= 0.453
2019120	$= \dfrac{2,658-102}{1,784}$	= 1.433
2090121	$= \dfrac{1,155-148}{2,841}$	= 0.354
2020120	$= \dfrac{61-27}{862}$	= 0.039
2064040	$= \dfrac{522-75}{1,148}$	= 0.389
2064240	$= \dfrac{336-25}{580}$	= 0.536
2066240	$= \dfrac{84-13}{313}$	= 0.227

The item has lower RTO than other items, it is considered for ordering. The priorities of RTO items are shown in table 5.5 below.

Priority	Product Code	RTO
1.	2020120	0.039
2.	2066240	0.227
3.	2090121	0.354
4.	2013120	0.365
5.	2064040	0.441
6.	2000120	0.453
7.	2011121	0.485
8.	2000150	0.536
9.	2064240	1.139
10.	2017120	1.218
11.	2019120	1.433

Table 5.5: RTO priority of Siam fiber-cement group.

Product code: 2020120 is the first priority to consider.

Order quantity = Max – inventory position

= 889 - 61

= 828

Unit weight   = 5.4 kgs

Total weight of this item = 828 x 5.4 = 4,471.2 kgs

Now, two items are ordered and loaded into truck with weight 8,115.8 + 4,471.2 = 12,587 kgs. Maximum loading capacity is equal to 13,000 kgs or 13 tons. So 413 kgs are available for loading.

Product code: 2066240 is the second priority to consider.

Order quantity = Max – inventory position

= 326 – 84

= 242

Unit weight   = 30.3 kgs

Total weight of this item = 242 x 30.3 = 7,332.6 kgs

Sum weights of three items = 12,587 + 7332.6 = 19,919.6 kgs.

Total weight of product code: 2066240 (7.332.6 kgs) makes sum of weight of three items exceed truck loading capacity (13 tons). So order quantity of product code 2066240 has to be reduced.

Order quantity = 13 x 30.3 = 393.9 kgs

Grand total weights of ordered three items = 12,587 + 393.9
= 12,980.9 kgs or 12.98 tons

Product code: 2090121 that is the third priority cannot be ordered because of exceeding truck loading capacity.

Therefore, product code: 2015120, 2020120, and 2066240 are ordered as one purchase order and grand total weights are 12,980.9 kgs or 12.98 tons as shown in table 5.6

Item	Product Code	Order quantity (pieces)	Total weight (kgs)
1.	2015120	1,309	8,115.8
2.	2020120	828	4,471.2
3.	2066240	13	393.9

Table 5.6: Ordered items of Siam fiber-cement group.

This example presented above is truck loading algorithm study for ordering. Other product groups are used in the same way of this example.

5.2.3 Output to the Truck Loading Algorithm

According to the proposed truck loading algorithm, the output of ordered items of two product groups are presented. Siam fiber-cement group has to order three times in March and May (see Table 5.7 – Table 5.9). Siam gypsum industry has to order only one time in March (see Table 5.10).

Product group: Siam fiber-cement
Month: March 28

Item	Product Code	Order quantity (pieces)	Total weight (kgs)
1.	2015120	1,309	8,115.8
2.	2020120	828	4,471.2
3.	2066240	13	393.9

Grand total weights 12,980.9 kgs or ≈13.00 tons

Table 5.7: Ordered items of Siam fiber-cement group in March.

Product group: Siam fiber-cement
Month: May 9

Item	Product Code	Order quantity (pieces)	Total weight (kgs)
1.	2017120	1,515	9,393.0
2.	2064040	357	3,605.7

Grand total weights 12,998.7 kgs or ≈13.00 tons

Table 5.8: Ordered items of Siam-fiber cement group in May.

Product group: Siam fiber-cement
Month: May 26

Item	Product Code	Order quantity (pieces)	Total weight (kgs)
1.	2066240	313	9,483.9
2.	2000120	567	3,515.4

Grand total weights 12,999.3 kgs or ≈13.00 tons

Table 5.9. Ordered items of Siam-fiber cement group in May.

Product group: Siam gypsum industry
Month: March 26

Item	Product Code	Order quantity (pieces)	Total weight (kgs)
1.	G202000	400	8,000
2.	G232000	56	1,232
3.	G231000	65	1,430
4.	G211000	35	700
5.	G201000	81	1,620

Grand total weights 12,982 kgs or ≈13.00 tons

Table 5.10: Ordered items of Siam gypsum industry group in March.

From the truck loading algorithm for ordering. The items have ordered, so the inventory position has been changed. Table 5.11 – Table 5.12 show the sum of inventory position between actual system and proposed system of two product groups.

Product Group: Siam fiber-cement

Product Code	Inventory position of Actual system (pieces)			Inventory position of Proposed system (pieces)		
	March	April	May	March	April	May
1. 2000120	82,776	56,386	46,339	82,776	56,386	46,140
2. 2000150	13,682	12,749	28,483	13,682	12,749	28,483
3. 2013120	40,163	77,180	130,608	40,163	77,180	130,608
4. 2015120	13,587	10,935	11,096	18,119	27,554	27,780
5. 2017120	61,729	53,370	33,330	61,729	53,370	39,927
6. 2011121	24,180	23,400	24,180	24,180	23,400	24,180
7. 2019120	77,293	76,302	38,094	77,293	76,302	38,094
8. 2090121	41,340	34,650	35,725	41,340	34,650	35,725
9. 2020120	2,951	14,767	6,191	6,263	26,670	27,559
10. 2064040	33,852	12,252	11,098	33,852	12,252	18,952
11. 2064240	12,755	10,695	20,692	12,755	10,695	20,692
12. 2066240	2,272	3,800	6,428	2,501	2,910	4,137

Table 5.11: Inventory position of Siam fiber-cement group in three months.

Product Group: Siam Gypsum Industry

Product Code	Inventory position of Actual system (pieces)			Inventory position of Proposed system (pieces)		
	March	April	May	March	April	May
1. G201000	6,533	8,723	13,757	7,079	8,093	7,108
2. G202000	2,175	11,167	9,073	4,575	12,154	10,653
3. G211000	1,530	1,650	1,025	1,740	2,700	2,110
4. G212000	2,046	2,544	1,641	2,046	2,544	1,641
5. G231000	1,550	2,516	2,374	1,940	3,366	3,379
6. G232000	450	2,280	3,720	786	1,860	1,736

Table 5.12: Inventory position of Siam gypsum industry group in three months.

5.3 Comparison of Results

Two product groups of Siam fiber-cement and Siam gypsum industry in three months (March, April, May) are tested in comparing between actual system and proposed system. The costs incurred from both actual and proposed systems are included holding cost and transportation cost. The holding costs of two group products both actual and proposed systems are presented. From Table 5.11 – Table 5.12, the sum of inventory position of an item is divided by a number of days in month. There are average inventory levels of items. Inventory holding cost of each item = average inventory level x unit weight x inventory holding cost (1,420 baht/ton/year). Table 5.13- Table 5.18 show inventory holding cost in each item both actual and proposed systems of two product groups.

Month: March
Product group Siam fiber-cement

Item	Product Code	Actual system		Proposed system	
		Average inventory level (pieces)	Inventory holding cost (baht)	Average inventory level (pieces)	Inventory holding cost (baht)
1	2000120	2,670.19	23,508.38	2,670.19	23,508.38
2	2000150	441.35	4,825.77	441.35	4,825.77
3	2013120	1,295.58	11,406.29	1,295.58	11,406.29
4	2015120	438.29	3,858.71	584.48	5,145.76
5	2017120	1,991.26	17,531.04	1,991.26	17,531.04
6	2011121	780.00	6,867.12	780.00	6,867.12
7	2019120	2,493.32	21,951.21	2,493.32	21,951.21
8	2090121	1,333.55	9,468.19	1,333.55	9,468.19
9	2020120	95.19	729.94	202.03	1,549.18
10	2064040	1,092.00	15,661.46	1,092.00	15,661.46
11	2064240	411.45	11,802.08	411.45	11,802.08
12	2066240	73.29	3,153.39	80.68	3,471.23

Table 5.13: Inventory holding cost of Siam fiber-cement group in March.

From the table 5.13, average inventory levels of item 1, 2, 3, 5, 6, 7, 8, 10, and 11 of actual system are equal to a proposed system because they are not ordered. These mean inventory holding costs of actual system are equal to proposed system. Meanwhile, average inventory levels of item 4, 9, and 12 are increased in comparison with an actual system. Item 4:- product code: 2015120 is trigger item, so an order quantity can cause a higher inventory level and inventory holding cost as well. Item 9-: product code: 2020120 and item 12:- product code: 2066240 are ordered by Ratio To Order (RTO) causing higher inventory levels and inventory holding costs.

Month: April
Product group: Siam fiber-cement

Item	Product Code	Actual system		Proposed system	
		Average inventory level (pieces)	Inventory holding cost (baht)	Average inventory level (pieces)	Inventory holding cost (baht)
1	2000120	1,879.53	16,547.41	1,879.53	16,547.41
2	2000150	424.97	4,646.59	424.97	4,646.59
3	2013120	2,572.67	22,649.79	2,572.67	22,649.79
4	2015120	364.50	3,209.08	918.46	8,086.02
5	2017120	1,779.00	15,662.32	1,779.00	15,662.32
6	201112!	780.00	6,867.12	780.00	6,867.12
/	2019120	2,543.40	22,392.09	2,543.40	22,392.09
8	209012!	1,155.00	8,200.50	1,155.00	8,200.50
9	2020120	492.33	3,774.47	889.00	6,816.85
10	2064040	408.40	5,857.27	408.40	5,857.27
11	2064240	356.50	10,255.85	356.50	10,225.85
12	2066240	126.67	5,449.96	97.00	4,173.52

Table 5.14: Inventory holding cost of Siam fiber-cement group in April.

From table 5.14, average inventory levels of item 1, 2, 3, 5, 6, 7, 8, 10, and 11 of actual system are equal to a proposed system. There is no ordering in April. Average inventory levels of item 4, 9, and 12 are increased in comparison with an actual system because of ordering in March. Inventory holding costs also are increased.

Month: May
Product group: Siam fiber-cement

Item	Product Code	Actual system		Proposed system	
		Average inventory level (pieces)	Inventory holding cost (baht)	Average inventory level (pieces)	Inventory holding cost (baht)
1	2000120	1,494.81	13,160.28	1,488.39	13,103.79
2	2000150	918.81	10,046.23	918.81	10,046.23
3	2013120	4,213.16	37,092.67	4,213.16	37,092.67
4	2015120	357.94	3,151.26	896.13	7,889.52
5	2017120	1,075.16	9,465.71	1,287.97	11,339.27
6	2011121	780.00	6,867.12	780.00	6,867.12
7	2019120	1,228.84	10,818.70	1,228.84	10,818.70
8	2090121	1,152.42	8,182.18	1,152.42	8,182.18
9	2020120	199.71	1,531.37	889.00	6,816.85
10	2064040	358.00	5,134.44	611.35	8,768.05
11	2064240	667.48	19,146.11	667.48	19,146.11
12	2066240	207.35	8,921.65	133.45	5,741.82

Table 5.15: Inventory holding cost of Siam fiber-cement group in May.

From the table 5.15, average inventory levels of item 2, 3, 6, 7, 8, and 11 of actual system and inventory holding cost of actual system are equal to a proposed system because they are not ordered. Average inventory levels of item 4, 5, 9, and 10 are increased, but item 1 and 12 are decreased. Item 5:- product code 2017120 is trigger item, so an order quantity can cause a higher inventory level and inventory holding cost as well. Item 12:- product code: 2066240 is also trigger item, but inventory holding cost of proposed system is less than an actual system. It may cause that a greater number of orders of actual system can cause a higher average inventory level and inventory holding cost in comparison with a proposed system. That is the same result of item 1:- product code: 2000120 that inventory holding cost of proposed system is less than actual system. For item 10:- product code: 2064040, inventory holding cost of proposed system is greater than actual system due to ordering from ratio to order. Increasing average inventory levels of item 4:- product code: 2015120 and item 9:- product code: 2020120 are in a result of ordering in March.

Month: March
Product group: Siam gypsum industry

Item	Product Code	Actual system		Proposed system	
		Average inventory level (pieces)	Inventory holding cost (baht)	Average inventory level (pieces)	Inventory holding cost (baht)
1	G201000	210.74	5,985.07	228.55	6,485.28
2	G202000	70.16	1,992.58	147.58	4,191.29
3	G211000	49.35	1,401.68	56.13	1,594.06
4	G212000	66.00	1,874.40	66.00	1,874.40
5	G231000	50.00	1,562.00	62.58	1,955.02
6	G232000	14.52	453.48	25.35	792.09

Table 5.16: Inventory holding cost of Siam gypsum industry group in March.

From table 5.16, average inventory levels and inventory holding costs of five items of proposed system are increased. Item 2:- product code: G202000 is trigger item. Other items are ordered by Ratio To Order (RTO). These can cause higher average inventory levels and inventory holding costs. For item 4:- product code: G212000, average inventory level and inventory holding cost of actual system are equal to proposed system because it is not ordered.

Month: April
Product group: Siam gypsum industry

Item	Product Code	Actual system		Proposed system	
		Average inventory level (pieces)	Inventory holding cost (baht)	Average inventory level (pieces)	Inventory holding cost (baht)
1	G201000	290.77	8,257.77	269.77	7,661.37
2	G202000	272.23	10,571.33	405.13	11,505.79
3	G211000	55.00	1,562.00	90.00	2,556.00
4	G212000	84.80	2,408.32	84.80	2,408.32
5	G231000	83.87	2,620.10	112.20	3,505.13
6	G232000	76.00	2,374.24	62.00	1,936.88

Table 5.17: Inventory holding cost of Siam gypsum industry group in April.

From table 5.17, average inventory levels and inventory holding costs of item 2, 3, 5,and 6 of proposed system are increased. On the other hand, average inventory levels and inventory holding costs of item 1 of proposed system are decreased. A greater number of orders of actual system can cause higher average inventory levels and inventory holding costs in comparison with a proposed system. For item 4, average inventory level and inventory holding cost of actual system are equal to proposed system because it is not ordered.

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Month: May
Product group: Siam gypsum industry

Item	Product Code	Actual system		Proposed system	
		Average inventory level (pieces)	Inventory holding cost (baht)	Average inventory level (pieces)	Inventory holding cost (baht)
1	G201000	443.77	12,603.19	229.29	6,511.85
2	G202000	292.70	8,312.68	343.65	9,759.52
3	G211000	33.06	939.03	68.06	1,933.03
4	G212000	52.94	1,503.37	52.94	1,503.37
5	G231000	76.58	2,392.36	109.00	3,405.16
6	G232000	120.00	3,748.80	56.00	1,749.44

Table 5.18: Inventory holding cost of Siam gypsum industry group in May.

From table 5.18, average inventory levels and inventory holding costs of item 2, 3, and 5 of proposed system are increased. On the other hand, average inventory levels and inventory holding costs of item 1 and item 6 of proposed system are decreased. Higher average inventory level and inventory holding cost of actual system in May is a result of ordering of actual system in April. For item 4, average inventory level and inventory holding cost of actual system are equal to proposed system because it is not ordered.

Table 5.19 shows transportation costs of actual system of two product groups. A number of trips and transportation cost are derived from a purchase order considered only ordered items from the same supplier for these two product groups. Ordered items of these two product groups are often combined with other items from the different suppliers and total weights of ordered items are both not exceed loading capacity and exceed loading capacity. They have to share cost of transportation. For Siam fiber-cement group, there are six trips included in March 9.78 ton or 72.07% of total weight 13.57 ton and 7.76 ton or 78.74% of total weight 7.76 ton, in April 4.95 ton or 59.64% of total weight 8.30 ton, and in May 5.56 ton or 78.75% of total weight 7.06 ton, 4.54 ton or 31.07% of total weight 14.61 ton, and 5.87 ton or 57.44% of total weight 10.22 ton. For Siam gypsum industry, there are two trips included in March 6.10 ton or 78.01% of total weight 7.82 ton, and in April 5.61 ton or 54.95% of total weight 10.21 ton.

Product Group	Transportation cost (baht)		
	March	April	May
1 Siam fiber-cement	3,921.06	1,550.64	4,348.76
2. Siam gypsum industry	2,028.26	1,428.70	0

Table 5.19: Transportation cost of actual system of two product groups in three months.

Table 5.20 – table 5.21 show holding cost and transportation cost in three months both actual and proposed system of two product groups.

Month	Holding cost (baht)		Transportation cost (baht)	
	Actual system	Proposed system	Actual system	Proposed system
March	131,663.63	132,287.73	9,321.06	2,600
April	125,482.44	126,255.96	1,550.64	0
May	133,517.71	133,812.31	4,348.76	5,200
Total	390,663.78	392,356.00	9,820.46	7,800

Table 5.20: The costs of Siam fiber-cement group.

Month	Holding cost (baht)		Transportation cost (baht)	
	Actual system	Proposed system	Actual system	Proposed system
March	13,269.91	16,892.14	2,028.26	2.600
April	27,766.76	29,573.49	1,428.70	0
May	29,499.43	24,862.37	0	0
Total	70,536.10	71,328.00	3,456.96	2,600

Table 5.21: The costs of Siam gypsum industry group.

From table 5.20, the holding cost of proposed system of Siam fiber-cement group in three months is higher than actual system, but the transportation cost of proposed system is less than actual system because of decreasing of a number of trips. From table 5.21, the holding cost of Siam gypsum industry group is also higher than actual system, but transportation cost of proposed system is less than actual system. However, holding cost of proposed system of Siam gypsum industry group in May (Table 5.21) is less than actual system. It causes that some items (G201000 and G232000) in actual system have much more number of orders than proposed system (See Table 5.18). It means a number of trips for transportation of actual system is greater than proposed system. So holding cost of actual system is higher than proposed system.

Table 5.22 – table 5.24 show the three months holding costs, transportation costs, and total costs both actual and proposed systems of two product groups.

Product group	Holding cost actual system	Holding cost proposed system	Increased cost (baht)	Increased cost (%)
1. Siam fiber-cement	390,663.78	392,356.00	1,692.22	0.43%
2. Siam gypsum industry	70.536.10	71,328.00	791.90	1.12%
Total	461,199.88	463,684.00	2,484.12	0.54%

Table 5.22: Holding cost between actual and proposed system in three months.

From table 5.22, holding cost of proposed system of Siam fiber-cement group is higher than holding cost of actual system 1,692.22 baht or 0.43 per cent in three months. For Siam gypsum industry group, holding cost of proposed system is also higher than holding cost of actual system 791.90 baht or 1.12 per cent in three months. The less demands of items of Siam gypsum industry group in April and May can cause to higher percentage of increase cost of holding cost proposed system. Order quantities of truck loading algorithm can lead to higher holding cost of proposed system of two product groups. Holding cost of proposed system of two product groups is increased 2,484.12 baht or 0.54 per cent in three months.

Product group	Transportation cost actual system	Transportation cost proposed system	Reduced cost (baht)	Reduced cost (%)
1. Siam fiber-cement	9,820.46	7,800	2,020.46	20.57%
2. Siam gypsum industry	3,456.96	2,600	856.96	24.79%
Total	13,277.42	10,400	2,877.42	21.67%

Table 5.23: Transportation cost between actual and proposed system in three months.

From table 5.23, transportation cost of proposed system of Siam fiber-cement group can be reduced 2,020.46 baht or 20.57 per cent in three months. For Siam gypsum industry group, transportation cost of proposed system can reduce cost 856.96 baht or 24.79 per cent in three months. Transportation costs of two product groups are reduced. It can be seen that proposed system is far superior to actual system, with an average cost savings 2,877.42 bath or 21.67 per cent in three months.

Product group	Total cost actual system	Total cost proposed system	Reduced cost (baht)	Reduced cost (%)
1. Siam fiber-cement	400,484.24	400,156.00	328.24	0.08%
2. Siam gypsum industry	73,993.06	73,928.00	65.06	0.09%
Total	474,477.30	474,084.00	393.30	0.08%

Table 5.24: Total cost between actual and proposed system in three months

From table 5.24, total cost of proposed system of Siam fiber-cement group is reduced 328.24 baht or 0.08 per cent in three months. For Siam gypsum industry group, total cost of proposed system can be reduced 65.06 baht or 0.09 per cent in three months. So total cost of proposed system of two product groups is reduced in three months only 393.30 baht or 0.08 per cent. Due to algorithm of truck loading followed by the Ratio To Order (RTO), total cost of proposed system of two product groups can save cost only 0.08 per cent. However, transportation cost of proposed system of two product groups can save cost 21.67 per cent and systematic operation is proposed instead of human assistance.

5.4 Inventory Turnover

Inventory turnover is used to measure an inventory performance. It is defined as the ratio of the cost of units sold to average inventory.

$$\text{Inventory turnover} = \frac{\text{cost of annual sales}}{\text{value of average inventory}}$$

Due to study truck loading algorithm in three months (March, April, May), the cost of sales in three months and value of average inventory level in three months will be tested instead of annual unit. In addition, the cost of sales of proposed system is assumed by equal to actual system.

This study has two product groups of Siam fiber cement group and Siam gypsum industry group. Inventory turnover is calculated by separation two product groups and combination of two product groups and it is compared between actual system and proposed system in three months

Actual system

1. Siam fiber cement group

Cost of sales	= 1,241,189.00	baht
Value of average inventory level	= 2,031,253.15	baht
Inventory turnover	= 1,241,189.00 / 2,031,253.15	
	= 0.61	

2. Siam gypsum industry group

Cost of sales	= 127,117.00	baht
Value of average inventory level	= 496,902.31	baht
Inventory turnover	= 127,117.00 / 496,902.31	
	= 0.26	

3. Two product groups

Cost of sales	= 1,368,306.00	baht
Value of average inventory level	= 2,528,155.46	baht
Inventory turnover	= 1,368,306.00 / 2,515,752.33	
	= 0.54	

Proposed system

1. Siam fiber cement group

Cost of sales	=	1,241,189.00	baht
Value of average inventory level	=	2,118,049.18	baht
Inventory turnover	=	1,241,189.00 / 2,118,049.18	
	=	0.59	

2. Siam gypsum industry group

Cost of sales	=	127,117.00	baht
Value of average inventory level	=	506,602.87	baht
Inventory turnover	=	127,117.00 / 506,602.87	
	=	0.25	

3. Two product groups

Cost of sales	=	1,368,306.00	baht
Value of average inventory level	=	2,631,147.96	baht
Inventory turnover	=	1,368,306.00 / 2,624,652.05	
	=	0.52	

Inventory turnover of Siam fiber-cement group of actual system and proposed system is 0.61 and 0.59 respectively. Inventory turnover of proposed system is decreased. It means that inventory performance of proposed system is reduced due to higher value of average inventory level. In the same way, inventory turnover of Siam gypsum industry group of proposed system is decreased from 0.26 to 0.25. Inventory performance of proposed system is reduced. For sum of two product groups, inventory turnover of actual system is 0.54 and proposed system is 0.52. Inventory performance of proposed system is reduced due to higher value of average inventory level. In addition, heuristic truck loading algorithm can cause to higher inventory level and lead to higher value of average inventory level.

5.5 <u>Sensitivity Analysis</u>

Sensitivity analysis is considered on the effects of changes in the input data. Due to a heuristic truck loading algorithm studied, holding cost of proposed system is higher than actual system. To determine the effect of the input parameter of interest rate of interest on capital that may change over time, sensitivity analysis is performed. The original value of interest rate of interest on capital of inventory holding cost is set at 18%. The changing of interest rate that is at a decrement of 4 per cent (at 14% and 10%) will certainly have effects on the values of inventory system, holding cost, and total cost.

The results of changing with an interest rate at 14% and 10% of only Siam gypsum industry supplier are presented in Table 5.25 – Table 5.34.

Observation of made from the sensitivity analysis conducted on only Siam gypsum industry supplier and the other suppliers can be summarized as follows:

1. As the value of interest rate is decreased, inventory holding cost in weight unit is decreased from 1.420 baht/ton/year of interest rate 18% to 1,100 baht/ton/year of interest rate 14% and 790 baht/ton/year of interest rate 10%. At the same time, inventory holding cost in percentage of value of average inventory level is decreased from 18.00% of interest rate 18% to 14.00% of interest rate 14% and 10.00% of interest rate 10%.

2. As the value of interest rate is decreased, the values of order quantity (EOQ) and order-up-to-level (maximum) are increased, but the value of order point (minimum) is not changed. (See Table 5.4, 5.25, and 5.26)

4. From number 2, the holding costs both actual and proposed system of three months are decreased. The percentages of increase cost are also decreased in comparison with actual system that is to be expected. (From 1.12% of increased cost of interest rate at 18% to 0.97% of interest rate at 14% and 0.57% of interest rate at 10% in three months). Transportation costs of actual and proposed system are not changed. (See Table 5.33)

5. Total costs of proposed system are decreased. The percentages of reduced cost are increased in comparison with actual system. (From 0.09% of reduced cost of interest rate at 18% to 0.54% of reduced cost of interest rate at 14% and 1.37% of reduced cost of interest rate at 10% in three months). (See Table 5.34)

The results show that the changing of interest rate parameter of interest on capital of inventory holding cost is sensitive to the inventory holding cost and total cost.

Sensitivity analysis: The (s, S) system output of Siam gypsum industry group
Interest rate = 14%, Inventory holding cost = 14.00%

Item	Product Code	Order quantity (EOQ) (pieces)	Order point (s) (pieces)	Order-up-to-level (S) (pieces)
1	G201000	358	11	369
2	G202000	453	15	468
3	G211000	100	2	102
4	G212000	132	2	134
5	G231000	127	3	130
6	G232000	74	1	75

Table 5.25: (s, S) system output of interest rate 14%.

Sensitivity analysis: The (s, S) system output of Siam gypsum industry group
Interest rate = 10%, Inventory holding cost = 10.00%

Item	Product Code	Order quantity (EOQ) (pieces)	Order point (s) (pieces)	Order-up-to-level (S) (pieces)
1	G201000	424	11	435
2	G202000	536	15	551
3	G211000	118	2	120
4	G212000	156	2	158
5	G231000	151	3	154
6	G232000	87	1	88

Table 5.26: (s, S) system output of interest rate 10%.

**Sensitivity analysis: Truck loading algorithm output of
Siam gypsum industry group
Interest rate = 14%**

Item	Product Code	Order quantity (pieces)	Total weight (kgs)
1.	G202000	453	9,060
2.	G232000	65	1,430
3.	G231000	80	1,760
4.	G211000	37	740

Total weights: 12,990 kgs. or ≈ 13.00 tons

Table 5.27: Truck loading algorithm output of interest rate 14%.

**Sensitivity analysis: Truck loading algorithm output of
Siam gypsum industry group
Interest rate – 10%**

Item	Product Code	Order quantity (pieces)	Total weight (kgs)
1.	G202000	536	10,720
2.	G232000	78	1,716
3.	G231000	25	550

Total weights: 12,986 kgs. or ≈ 13.00 tons

Table 5.28: Truck loading algorithm output of interest rate 10%.

Sensitivity analysis: Inventory position of Siam gypsum industry group
Interest rate = 14%

Product Code	Inventory position of actual system (pieces)			Inventory position of proposed system (pieces)		
	March	April	May	March	April	May
1. G201000	6,533	8,723	13,757	6,533	8,723	13,757
2 G202000	2,175	11,167	7,982	4,893	13,744	12,296
3 G211000	1,530	1,650	1,025	1,752	2,760	2,172
4 G212000	2,046	2,544	1,641	2,046	2,544	1,641
5 G231000	1,550	2,516	2,375	2,030	3,816	3,844
6 G232000	450	2,280	3,720	840	2,130	2,015

Table 5.29: Inventory position of actual and proposed system in three
months of interest rate 14%.

Sensitivity analysis: Inventory position of Siam gypsum industry group
Interest rate = 10%

Product Code	Inventory position of actual system (pieces)			Inventory position of proposed system (pieces)		
	March	April	May	March	April	May
1. G201000	6,533	8,723	13,757	6,533	8,723	13,757
2. G202000	2,175	11,167	7,982	5,391	16,234	14,869
3. G211000	1,530	1,650	1,025	1,530	1,650	1,025
4. G212000	2,046	2,544	1,641	2,046	2,544	1,641
5. G231000	1,550	2,516	2,375	1,700	2,166	2,139
6. G232000	450	2,280	3,720	918	2,520	2,418

Table 5.30: Inventory position of actual and proposed system in three
months of interest rate 10%.

Sensitivity analysis: Holding cost and Transportation cost of
Siam gypsum industry group
Interest rate = 14%, Inventory holding cost = 1,100 baht/ton/year

Month	Holding cost (baht)		Transportation cost (baht)	
	Actual system	Proposed system	Actual system	Proposed system
March	11,278.97	13,044.58	2,028.26	2,600
April	21,629.51	23,161.84	1,428.70	0
May	22,530.48	20,769.03	0	0
Total	55,438.96	55,975.45	3,456.96	2,600

Table 5.31: The costs in three months of interest rate 14%.

**Sensitivity analysis: Holding cost and Transportation cost of
Siam gypsum industry group
Interest rate = 10%, Inventory holding cost = 790 baht/ton/year**

Month	Holding cost (baht)		Transportation cost (baht)	
	Actual system	Proposed system	Actual system	Proposed system
March	7,382.17	9,367.77	2.028.26	2,600
April	16,462.72	17,067.62	1,428.70	0
May	17,855.81	15,503.69	0	0
Total	41,700.70	41,939.08	3,456.96	2,600

Table 5.32: The costs in three months of interest rate 10%.

**Holding cost in three months of Siam gypsum industry group,
Interest rate = 18%, 14%, and 10%,
Inventory holding cost = 1,420, 1,100 and 790 baht/ton/year**

Interest rate	Holding cost actual system	Holding cost proposed system	Increased cost (baht)	Increased cost (%)
1. 18%	70,536.10	71,328.00	791.90	1.12%
2. 14%	55,438.96	55,975.45	536.49	0.97%
3. 10%	41,700.70	41,939.08	238.38	0.57%

Table 5.33: Holding cost between actual and proposed system in three months of
interest rate 18%, 14%, and 10%.

**Total cost in three months of Siam gypsum industry group,
Interest rate = 18%, 14% and 10%,
Inventory holding cost = 1,420, 1,100 and 790 baht/ton/year**

Interest rate	Total cost actual system	Total cost proposed system	Reduced cost (baht)	Reduced cost (%)
1. 18%	73,993.06	73,928.00	65.06	0.09%
2. 14%	58,895.92	58,575.45	320.47	0.54%
3. 10%	45,157.66	44,539.00	618.58	1.37%

Table 5.34: Total cost between actual and proposed system in three months of
interest rate 18%, 14%, and 10%.