The Application of Monte Carlo Simulation for Inventory Management: a Case Study of a Retail Store

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***Abstract* - This research aimed to find economic order quantity and reorder point of the inventory in a retail store under the uncertainty of lead time and demand. From the past, the store manager purchased a large amount of inventory to fulfill the customer demand without the appropriate techniques, which led to over-inventory. The store had lost more than THB 1 Million per year from the excess inventory. The Monte Carlo Simulation was applied in this research in order to determine the purchase order policy with the selected best sales goods. The inventory goods was classified by using ABC analysis. This research was only focus on the class A goods because they affected almost all of the inventory cost. As a result, 10 best sales goods in class A were selected. Then collecting the data of the sales for those goods for 12 months. After simulated the data for all selected goods and gained the optimal order quantity by using Monte Carlo Simulation, it was found that the new economic order quantity and reorder point would save the inventory cost, which was currently incurred from THB 1,462,281.77 to THB 371,142.73 per year or 74.62% of reduction. In addition, the inventory would reduce from 46,166,784 units to 2,638,808 units per year or 94.28% of reduction.**

***Keywords* - Monte Carlo Simulation, Inventory Management, Retail Store**

I. INTRODUCTION

Due to the business survivability in the present day, it is necessary to maintain service level and minimize cost. In the case of retail stores, the most important cost comes from inventory. To maintain the service level, goods must be available for customers at any time. In order to minimize inventory cost, the order quantity of goods must be equal to customers demand. If the order quantity is less than customers demand, the service level will be reduced. If the order quantity exceeds customers demand, there will be sunk cost of inventory, obsolescence of goods and excess storage cost. Therefore, inventory management is an important factor for business achievement of retail stores.

To do this research, a retail store has been chosen to be a case study. In the past, the store had lost more than THB 1 Million per year from the excess inventory. Therefore, it was needed to solve the problem. By collecting the data, there were 10,218 stock keeping unit (SKU) in the retail store that can be classified into three classes (A, B, and C) by using ABC analysis. Class A accounted for a large proportion of the overall sales but a small percentage of the number of items. Class B and class C had less overall sales but had a higher percentage of the number of items than class A respectively. As a result, there were 230 SKU (70% of sales) in class A, 1,496 SKU (20% of sales) in class B and 8,492 SKU

(10% of sales) in class C as shown in Fig. 1.

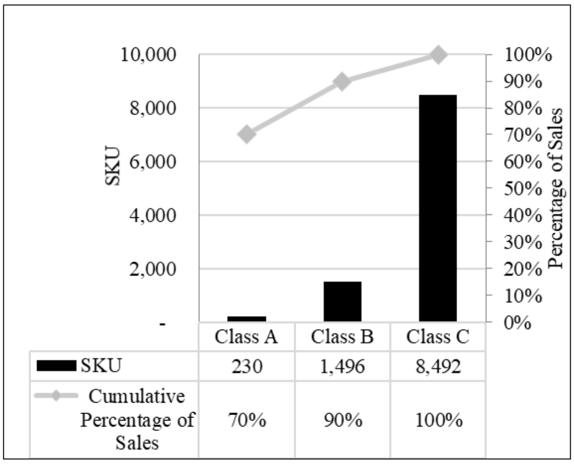

Fig. 1 Goods Classification by ABC Analysis

This research focused only 10 most sales goods (10 SKU) in class A which were A1008, B6011, C0414, D0613, E0803, F0797, G3002, H0483, I0377, and J0155 as shown in Table I. Customers demand and order quantity from August 2016 to July 2017 of each item are shown in Fig. 2.

TABLE I
FOCUSED GOODS (10 SKU)

Barcode of Goods	Representative Name
885099914**1008**	A1008
885199361**6011**	B6011
885479600**0414**	C0414
885238800**0613**	D0613
885017000**0803**	E0803
885017000**0797**	F0797
885099914**3002**	G3002
885017000**0483**	H0483
885479600**0377**	I0377
885017000**0155**	J0155

From Fig. 2, it can be concluded that the retail store ordered goods more than customer demand, which led to over-inventory. The total inventory for 10 goods was 151,057 units per year and the sunk cost of inventory was THB 7,871,650 per year as shown in Table II.

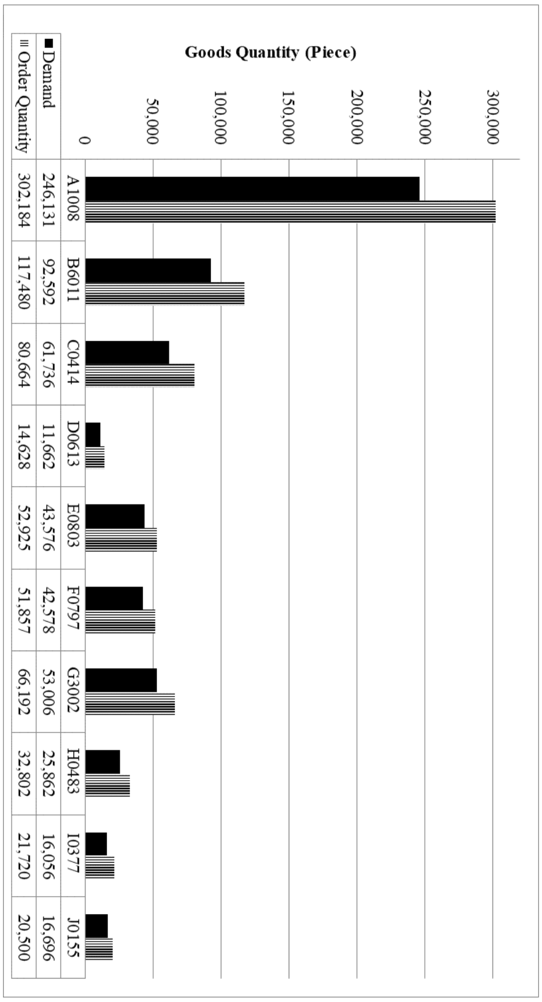

Fig. 2 Customers Demand and Order Quantity from August 2016 to July 2017

TABLE II
SUNK COST OF FOCUSED GOODS

No.	Goods	Quantity (Units)		Inventory (Units per year)	Sunk Cost (THB per year)
		Demand	Order Quantity		
1	A1008	246,131	302,184	56,053	2,662,518
2	B6011	92,592	117,480	24,888	1,178,032
3	C0414	61,736	80,664	18,928	928,261
4	D0613	11,662	14,628	2,966	672,046
5	E0803	43,576	52,925	9,349	384,137
6	F0797	42,578	51,857	9,279	425,906
7	G3002	53,006	66,192	13,186	393,932
8	H0483	25,862	32,802	6,940	400,438
9	I0377	16,056	21,720	5,664	518,256
10	J0155	16,696	20,500	3,804	308,124
Total		**609,895**	**760,952**	**151,057**	**7,871,650**

The data in Table II only showed sunk cost of 10 goods, the total sunk cost of all goods should be higher than that. Therefore, the improvement of inventory management is needed for this retail store.

II. LITERATURE REVIEWS

Inventory management is one of logistics activities, which can utilize the space for goods storage. The goal is to find the method to minimize the space but still meet the customers demand and service level. However, many firms decided to order a large amount of goods in order to get lower price even though only some of them could be sold. To decrease the unnecessary order, ABC Classification is an approach which has been applied to analyze the importance of each item of goods and prioritize them. Tanwari, Lakhiar, and Shaikh [1] applied ABC Classification to manage the spare parts in a warehouse, which could reduce the storage space of those spare parts. After that, Economic Order Quantity (EOQ) and reorder point (ROP) should be calculated to reach the goal of inventory management.

In real life, the customers demand and lead-time of goods are uncertainties. The company should have safety stock to feed customers. Statistical data is used to calculate safety stock based on seasonal demand or trend. Tamwai [2] calculated safety stock based on statistical seasonal demand, based on median absolute deviation varies over time, and based on highest demand. Then Monte Carlo technique was applied to simulate the sales behaviors. The simulation result showed that 56% of average inventory and holding cost could be cut. Total inventory cost could be calculated from ordering cost, unit cost, holding cost, and shortage cost. Sedtakomkul [3] and Vararittichai [4] applied ABC analysis and then calculated EOQ and ROP by implementing Monte Carlo Simulation. The result showed that 7.4% and 71% of total inventory cost per year was reduced comparing to the traditional purchasing policy respectively.

Monte Carlo Simulation has been widely used for inventory management by generate a large amount of random number to obtain numerical results. The key of simulation is to repeat random sampling many times to gain the least deviation [5]. Peterson, Sui and Heiser [6], Marcoulaki, Broulias and Chondrocoukis [7] and Tsige [8] simulated Monte Carlo Simulation to improve order-picking efficiency. Muansrichai [9] applied Monte Carlo Simulation to automotive industry to find the EOQ and ROP under uncertainties. As a result, the inventory cost was reduced approximately 26% per quarter comparing to the traditional purchasing policy. Phupha [10], Rujirawisarut [11], Manchu [12] and Chaimunin [13] also applied Monte Carlo Simulation to calculate EOQ of processed food industry, retail company, pallet-manufacturing factory, and petrochemical industry respectively. The total inventory cost was reduced by 38.35%, 54%, 9.28%, and 22% respectively.

From the reviews above, it can be concluded that Monte Carlo Simulation is an appropriate approach to calculate EOQ under uncertainty lead time and demand.

III. RESEARCH METHODOLOGY

The case study of this research had uncertainty demand and lead time as shown in Table III and Table IV. Therefore, Monte Carlo Simulation was applied to calculate EOQ and ROP.

Monte Carlo Simulation started by calculating the ranges of random number and then generating random number according to that range. The ranges of random number for daily demand and lead time of A1008 are shown in Table III and Table IV respectively.

From Table III, Probability of 153 units of demand of A1008 was 1 / 323 = 0.003096. Then did the same procedure for all daily demand to find the ranges of random number.

From Table IV, probability of 1-day lead time of A1008 was 41 / 121 = 0.33884. Then did the same procedure for all lead time to find the ranges of random number.

TABLE III
RANGES OF RANDOM NUMBER OF ANNUAL DEMAND

Daily Demand (Units per day)	Frequency (days)	Probability	Cumulative Probability	Ranges of Random Number (r)
153	1	0.003096	0.003096	0 < r <= 0.003096
199	1	0.003096	0.006192	0.003096 < r <= 0.006192
291	1	0.003096	0.009288	0.006192 < r <= 0.009288
.	.	.	.	.
407	2	0.006192	0.074303	0.068111 < r <= 0.074303
.	.	.	.	.
1800	1	0.003096	0.996904	0.993808 < r <= 0.996904
1914	1	0.003096	1	0.996904 < r <= 1
Total	**323**	**1**		

TABLE IV
RANGES OF RANDOM NUMBER OF LEAD TIME

Lead Time (Day)	Frequency (times)	Probability	Cumulative Probability	Ranges of Random Number (r)
1	41	0.33884	0.33884	0 < r <= 0.33884
2	15	0.12397	0.46281	0.33884 < r <= 0.46281
3	18	0.14876	0.61157	0.46281 < r <= 0.61157
.	.	.	.	.
5	12	0.09917	0.82645	0.72727 < r <= 0.82645
.	.	.	.	.
14	1	0.00826	1	0.99174 < r <= 1
Total	**121**	**1**		

To calculate ROP, Lordahl and Bookbinder's approach [14] was applied by resequencing the demand of customer from smallest to largest. The sequenced demand is shown in Table V.

The approach showed that if:

$$\left(n+1\right)P \geq n; ROP = X_y \quad (1)$$

$$\left(n+1\right)P < n;\ ROP = (1-\omega)X_y + \omega\left(X_{y+1}\right) \quad (2)$$

where

n is the number of data.

P denote customer service level (95%).

Xy is the demand of y^{th}.

ω is the decimal of *(n*+1)*P*.

From the data in Table V using (1) and (2):

$$\left(n+1\right)P = (323+1)\ x\ 0.95 = 307.8$$

Thus, $y = 307$ and $\omega = 0.8$.

$307.8 < 323$ So, $y + \omega < n$

$$ROP = (1-0.8)(1375) + 0.8(1426)$$
$$= 1415.8 \approx 1416 \text{ units}$$

Maximum, minimum and average of the data from Table V were calculated to be the input for Monte Carlo Simulation to find EOQ. From Table V, maximum, minimum and average of the data were 1,914, 153, and 762 units respectively.

After that, random number (20,000 times) was generated by using =RAND() in Microsoft Excel. Then, the ranges of random number in Table III and IV were used for identifying demand and lead time of that random number by using =VLOOKUP() in Microsoft Excel as shown in Table VI.

From Table VI, the first column is working day of a retail store. The second column shows the number of starting inventory of the day. The third column shows the EOQ from maximum, minimum and average value of Table V, but this table shows only the maximum value. The fourth column is random number of demand. The fifth column is the amount of demand according to Table III. The sixth column shows whether the amount of starting inventory is higher than demand or not. If the demand is higher than starting inventory, it will lead to shortage in the seventh column. The eighth column is the remaining inventory, which is the difference between starting inventory and demand. The ninth column shows the order decision. If the remaining inventory is less than ROP, the retail store has to order on amount of EOQ. The tenth column shows random number of lead time. The eleventh column is lead time according to Table IV. The twelfth column is the arrival day calculated by starting day plus lead time.

TABLE V
SMALLEST TO LARGEST SEQUENCED DEMAND

153	199	291	303	304	312	314	317	336	338	341	343	346	347
352	367	377	382	391	393	403	405	407	407	411	414	417	421
422	422	434	435	436	441	442	443	445	447	449	450	451	451
453	457	458	460	464	465	466	468	471	472	473	474	476	477
478	478	478	484	488	489	491	493	497	499	501	504	508	514
516	517	518	519	525	526	527	531	537	537	539	539	540	544
548	549	549	549	550	550	551	551	555	555	557	557	560	562
562	570	572	579	579	580	585	585	587	589	590	591	593	594
595	595	598	602	604	604	609	613	614	615	616	617	617	617
623	627	627	627	632	634	635	635	637	637	643	650	653	653
657	659	662	663	664	665	666	670	671	672	672	673	675	678
679	679	680	686	686	687	690	691	691	695	695	697	704	709
710	710	713	715	715	720	721	723	723	724	725	728	729	730
730	730	731	733	735	740	740	743	748	748	749	760	770	772
774	776	779	783	785	789	789	790	792	799	801	813	816	816
819	822	827	827	828	828	836	837	840	842	845	850	855	856
860	872	873	875	877	878	888	891	897	899	900	903	905	906
907	908	909	914	916	922	924	925	927	927	931	943	944	947
957	957	958	969	974	977	988	990	990	1010	1012	1025	1033	1046
1077	1081	1098	1109	1114	1116	1117	1117	1118	1123	1126	1131	1133	1144
1151	1154	1156	1161	1164	1165	1170	1176	1183	1184	1185	1195	1204	1211
1214	1218	1221	1238	1242	1275	1298	1307	1353	1354	1356	1356	1375	1426
1427	1449	1462	1484	1486	1503	1562	1583	1638	1645	1690	1718	1737	1800
1914													

The thirteenth column is total inventory cost, which can be calculated by:

$$TC = \left[\frac{DP}{Q}\right] + \left[\frac{QH}{2}\right] + nC_S \quad (3)$$

where

TC denotes total inventory cost [THB].

D denotes annual demand [unit/year].

P denotes setup or ordering cost for each order [THB].

Q denotes number of pieces per order [unit].

H denotes holding or carrying cost per unit per year [THB/unit*year].

n denotes shortages [unit].

C_S denotes shortage cost [THB/unit].

For item A1008, by substituting (3), ordering cost is 20.83 THB/order calculated from salary of employee and ordering time. Carrying cost equals 0.03 THB/unit calculated from salary of warehouse keepers. Shortage cost (C_S) equals 3 THB/unit calculated from the loss of profit. Total inventory cost after 20,000 replications of Monte Carlo Simulation is 140,133.09 THB/year.

To prove that 20,000 replications of simulation is not vary, the fourteenth and fifteenth column are used to find the cumulative error of each replication. Then, plot all 20,000 replications into a graph as shown in Fig. 3.

TABLE VI
MONTE CARLO SIMULATION OF A1008

Day	Inventory	Order	Random Number	Demand	Check	Shortage	Remaining Inventory	Order Decision	Random Number	Lead Time	Arrival Day	Total Cost	Average Cost	Cumulative Average Error
1	1914	0	0.08922	422	422	0	1492	0	0.26921	1	0	44.76	44.76	
2	1492	0	0.54476	723	723	0	769	1	0.893	6	8	43.9	44.33	0.43
3	769	0	0.74085	908	0	908	769	1	0.04736	1	4	2767.9	952.18667	-907.85667
4	769	1914	0.49842	690	690	0	1993	0	0.99545	14	0	59.79	729.0875	223.099167
5	1993	0	0.21494	514	514	0	1479	0	0.91635	6	0	44.37	592.144	136.9435
6	1479	0	0.96199	1462	1462	0	17	1	0.19229	1	7	21.34	497.01	95.134
7	17	1914	0.09394	434	0	434	1931	0	0.07258	1	0	1359.93	620.28429	-123.27429
8	1931	1914	0.25015	539	539	0	3306	0	0.55597	3	0	99.18	555.14625	65.1380357
9	3306	0	0.19442	491	491	0	2815	0	0.78756	5	0	84.45	502.84667	52.2995833
10	2815	0	0.40755	634	634	0	2181	0	0.43237	2	0	65.43	459.105	43.7416667
.	.		.	.	.	.	.	.	.		.	.	.	.
19995	541	0	0.63334	792	0	792	541	1	0.57214	3	19998	2413.06	590.39824	-0.0911604
19996	541	1914	0.61962	785	0	785	2455	0	0.30295	1	0	2428.65	590.49017	-0.091931
19997	2455	1914	0.73197	905	905	0	3464	0	0.72827	5	0	103.92	590.46583	0.02433216
19998	3464	1914	0.60526	772	772	0	4606	0	0.46163	2	0	138.18	590.44322	0.02261655
19999	4606	0	0.11301	445	445	0	4161	0	0.54578	3	0	124.83	590.41994	0.02328182
20000	4161	0	0.63395	792	792	0	3369	0	0.63852	4	0	101.07	590.39547	0.0244675

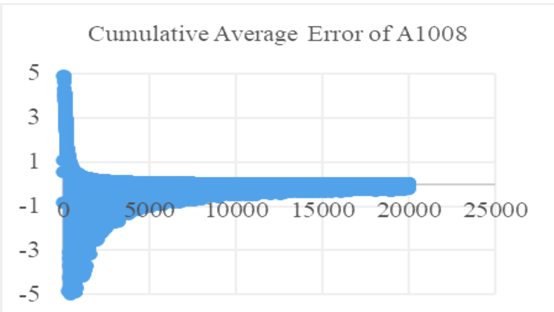

Fig. 3 Cumulative Average Error of A1008

Fig. 3, shows that the cumulative average error is convergence. The more number of simulation is performed, the less deviation of cumulative average error will occur. Therefore, the simulation of 20,000 replications is good enough to use in this model.

IV. RESULTS

After substituting the maximum value of Table V with difference EOQ policies (minimum and average value), total inventory cost could be changed as shown in Table VII. Also, do the same method to all focused goods (10SKU). The result is shown in Table VII.

After that, apply the appropriate EOQ policy to each focused goods by using the policy that incur the lowest cost. The result is shown in Table VIII.

TABLE VII
COMPARISON OF TOTAL INVENTORY COST FOR 3 EOQ POLICY

Goods	EOQ [unit/order] and Total Inventory Cost (TC) (THB/year)					
	Min	TC	Average	TC	Max	TC
A1008	153	634,960	762	253,031	1,914	140,133
B6011	37	344,264	287	128,682	842	63,458
C0414	45	210,588	191	90,253	468	56,826
D0613	1	88,087	37	31,447	183	48,239
E0803	3	136,346	135	38,717	435	13,637
F0797	1	133,978	132	37,872	362	14,598
G3002	1	113,585	164	35,988	794	13,216
H0483	13	98,777	82	36,117	238	15,679
I0377	1	86,915	50	29,862	161	15,463
J0155	2	40,224	52	16,525	159	6,686
Total Cost [THB per year]	1,887,724.29		698,493.54		387,935.20	

TABLE VIII
APPROPRIATE EOQ AND TOTAL INVENTORY COST FOR EACH FOCUSED GOODS

Goods	EOQ [unit/order]	TC [THB/year]
A1008	1914	140,133.09
B6011	842	63,457.69
C0414	468	56,826.16
D0613	37	31,446.95
E0803	435	13,636.84
F0797	362	14,598.36
G3002	794	13,215.75
H0483	238	15,678.93
I0377	161	15,463.44
J0155	159	6,685.52
Total cost [THB/year]		**371,142.73**

V. CONCLUSION AND DISCUSSION

If the case study retail store apply this new EOQ policy found by using Monte Carlo Simulation, it could reduce total inventory cost from THB 1,462,281.77 per year to THB 371,142.73 per year (74.62% reduction). Moreover, inventory could reduce from 46,166,784 units per year to 2,638,808 units per year (94.28% reduction). The retail store would have more space for doing other activities.

This research is only focus on the goods in class A. If apply the same method to all 10,218 SKU of goods, the case study retail store would reduce more money and inventory space. Moreover, space utilization of this store will be increased.

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(Arranged in the order of citation in the same fashion as the case of Footnotes.)

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