Integration of Quantity Discount Pricing into Newsvendor Model

Haryadi Sarjono#1, Jeff Fernandez#2, Randy Jeremiah#3, Randy Tjhie#4, Bachtiar H.Simamora*5

#Binus Business School, Bina Nusantara University, Palmerah, Jakarta Barat 11480, Indonesia

1Haryadi_s@binus.edu
2JeffFernandez.K@gmail.com
3RandyJeremiah20@gmail.com
4Randy.Tjhie@gmail.com
*5bsimamora@binus.edu

***Abstract*— This research was done with a purpose to find out the solution of supply shortage problem which often occurs in supplying companies in Indonesia, which resulted by non-optimized order quantity. Quantity Discount Pricing Integrated Newsvendor Model (this term will further be called as Extended Newsvendor) was examined then having its performance compared with subjective method which has already been used by the companies. The comparison was done to discover which method is able to reduce the potential shortage of supplies, total cost of each unit, age of inventory, and order frequency. Extended Newsvendor method was chosen to be examined in the first place due to its assumption which was deemed suitable with the actual condition that is encountered by the companies, where the demand happens stochastically, and quantity discount pricing policy is applied. The calculation that utilizes 5 years of the company historical data, this research find that the Extended Newsvendor method is generally able to improve the performance of the order quantity medium-sized companies but is unable to improve the performance of the order quantity of small-sized companies.**

***Keywords*—** *Newsvendor, Quantity Discount, Age of Inventory, Order Frequency*

1. Introduction

Indonesia is a country which is usually known as a developing country. However, along with the pace of the development and the improvement of the national indicators, Indonesia is shifting away from the “developing country” title. In the beginning of the second millennium, Indonesia, along with few other countries like Turkey, Thailand, and South Afrika started to bear the title of “Newly Industrialized Countries” instead of “Developing Countries” [5]. During the shifts, Indonesia heavily depends on physical development as one of its economic machines. The pace of the development gets faster in the 1990s. The importance of this sector is further proven with the increasing percentage of nominal GDP that it contributes to, relative to other sectors [10].

According to the last economic census which was held in 2006 [1], the construction sector is ranked the second largest among all sectors in Indonesian economy, where the processing sector is ranked the first. This number is considered shocking as it is able to beat other sectors which deemed to be the most important like mining and property. The large economic volume consequently results in the large business opportunity as well as the large needs of employment. This is a fact that the number of construction-related companies, like contractors, consultant, and suppliers, proliferate throughout the years. Indotrading, a business directory website records that there are at least three thousand construction material suppliers in a few major cities in Indonesia alone. This sector is also able to absorb a huge number of labor available in the market, ranging from the unskilled labors to skilled engineers [2]. However, despite its “visually” appealing nature, construction sector is not an easy sector to get into, let alone survive and thrive.

Construction sector is among the most competitive sectors, especially for small and medium sized companies. The recorded trend showed that the number of small and medium sized, construction-related companies has been shrinking during the previous years. This exhibits the inability for the small and medium business to compete against their larger counterparts in construction sector. Furthermore, the number of construction-related companies has also been shrinking, regardless the size despite the constantly increasing national construction volume [3]. From the perspective of business owners and managers, these companies exhibit the perception of uncertainty towards the

IJSCM, ISSN: 2050-7399 (Online), 2051-3771 (Print)

future of their business in the construction sector. This negative perception is further exacerbated with the general consensus that construction sector is an operationally problematic sector [4].

This paper then selected a few construction-related companies which are considered representative to the general situation. Two small-sized companies and two medium-sized companies are selected to represent two categories of construction-related company which deemed to be unable to compete in the construction sector. These four selected companies are similar in characteristics to a few extents, these companies are located in Jakarta and are all suppliers of construction material. Through some interviews done with the companies' representative, we found that the problems that often happens to these companies is supplies shortage – a situation where the company can no longer serve the demand due to the depletion of the supplies. This shortage is then further investigated and was found that these four companies do not use any scientific or mathematic method to determine the quantity of order that have to make every period. Instead, the person in charge for resupplying simply estimate the order quantity subjectively, based on the individual personal estimation.

This fact is then carried as a main problem of this research. This research aims to recommend such method that is able to minimize the occurring shortage. This method is also needed to have such assumptions that are matched to the actual situation of the companies. The situations that were found are that the monthly demands that the companies receive are random. This situation often causes shortage or overage of supplies, two conditions which are equally disadvantage the companies. Overage may slow down the cashflow of the companies, in extreme cases, the companies has to sell these remaining supplies below the purchasing price to keep the cash circulating. In the other hand, shortage does not directly incur losses to the companies, but it causes opportunity costs, a situation where a company could have sold more products but is unable to due to the limitation of supplies. Other situation that is encountered by these four companies are the quantity discount pricing policy that is imposed by the manufacturers – the more supplies the companies purchase, the lower the price will be. The minimum order quantity policy is also applied by the manufacturer, meaning that the company cannot order a little amount of supplies only to fulfil the demand in a period. Based on these actual situations, this research will propose the Extended Newsvendor method to be adopted by these four companies. This Extended Newsvendor method is basically a combination of classical newsvendor and quantity discount pricing. The research will then calculate the economic cost (total unit cost per supply) and non-economic cost (age of inventory and order frequency).

The problem of shortage becomes so important to the companies in the long term as it was found the historical data of order quantity of these four companies, that the frequent occurrences of shortage create such tendency where the order quantity slowly diminishes over time. The person who is in charge of resupplying become insensitive to the shortage that the order quantity gets increasingly underestimated time to time [13]. The decreasing amount of supplies implies the decreasing opportunity to create sales. This paper aims to assess whether the combination of Newsvendor Model and Quantity Discount Pricing is able to improve the performance of the order quantity, by means of reducing the cost, shortage, age of inventory, and order frequency.

2. Literature Study

The previous papers on the Newsvendor Model discovered that this method has several advantages. Newsvendor Model is found to be less sensitive compared to the common EOQ Model as it results in higher optimality when the applied order quantity is not exactly the same with the result of the calculation [12]. Newsvendor Model allows the users to deviate the order quantity to adjust with their actual situation without losing a lot of optimality [8]. Newsvendor Model is also found to be usable when there is only limited amount of historical data [7]. Newsvendor Model is deemed suitable to be applied to risk averse users who consider overage penalty, as well as risk seeking users who consider opportunity cost. When being applied to the risk averse users, the order quantity will be smaller, hence lowering its overage penalty. On the other hand, when the model is being applied to the risk seeking users, the order quantity will be larger, hence lowering its opportunity cost [11]. Other journal also addresses that the quantity discount pricing further allows the model to minimize the cost, not only from shortage and overage cost, but also by minimizing the product cost themselves [9].

3. Methodology

This research is a descriptive research that aims to describe a situation by collecting sets of appropriate data which correspond to the actual situation of a company. This research relies on secondary data, which was recorded by the companies, which are order quantity, demand volume, and multiple amount of price data. This research is also a noncontrived-field study with minimal interference, where the existence of the researcher in the company will not affect the records that are made by the company. The researcher will simply observe and record the occurrence. The data that will be analyzed is monthly data, where this research will limit the span of the data to the previous 5 years data only, thus temporally, this research is a cross-sectional research. All the data collected is in numbers, hence, quantitative data. These data are monthly sales, time and quantity of order, selling price, purchasing price, salvage price, shipping cost, and maximum quantity per shipping unit.

For the sake of brevity, the analysis will be categorized into five steps, which are:

1. Step 1: Forecast and A/F Ratio Calculation

   Forecasting the monthly demand that has happened during the past 5 years using naive approach, simple moving average, weighted moving average, exponential smoothing, and exponential smoothing with trend adjustment. This forecast is done as if a corresponding month is currently going. Then one forecasting technique that has the least MAE will be selected.

$$MAE = \frac{\sum_{i=1}^{n}\left|D_i - \widehat{D}_i\right|}{n} \quad (1)$$

   At this point, the researcher already has the value of actual demand and forecasted demand, then A/F ratio can be calculated for each forecasted month. A/F ratio is a ratio between the actual value and the forecasted value. The average and the standard deviations of these ratios will then be calculated.

$$\overline{\frac{A}{F} Ratio} = \frac{\sum_{i=1}^{n}\frac{A}{F} Ratio_i}{n} \quad (2)$$

$$\sigma_{A/F} = \sqrt{\frac{\sum_{i=1}^{n}(A/F_i - \overline{A/F})^2}{n}} \quad (3)$$

2. Step 2: Critical Ratio Calculation and Shortage-Overage Cost Minimization

   Critical ratio of each risk preference scenario and order quantity scenario will then calculated. Critical ratio is calculated with this following formula [6].

$$F(Q) = \frac{P - C}{P - V} \quad (4)$$

There will be numerous critical ratios that correspond to their own risk preference scenario and order quantity scenario. The purchasing price will be lower as the order quantity gets larger; vice versa. The salvage value gets lower as the companies gets more risk-averse; vice versa.

Table 1. Risk Preference Scenario and the Corresponding Salvage Value

Risk Preference Scenario	***Salvage Value* (Rupiah)**
No Preference (Risk-Neutral)	Actual salvage value
Avoid Overage Risk (Risk-Averse)	Zero
Avoid Shortage (Risk-Seeking)	Close to the purchasing value

Then the value of μ and σ are calculated with the forecast value, A/F ratio average and standard deviation which were calculated in the first step; these μ dan σ values will then use for the classical Newsvendor formula to minimize the shortage-overage cost [6].

$$\mu = \widehat{D} \times \overline{\frac{A}{F} Ratio} \quad (5)$$

$$\sigma = \widehat{D} \times \sigma_{A/F} \quad (6)$$

$$z = Normsinv(1 - F(Q)) \quad (7)$$

$$Q = \mu + z \times \sigma \quad (8)$$

Some of the classical Newsvendor result will not be applicable due to their quantities that are not matched to the quantity discount policy. Small number of quantities which are matched to the quantity discount policy will be used in the further steps.

3. Step 3: Order Quantity Adjustment Based on the Shipping Container Capacity

   The previous step has found a number of order quantities; however, the amount might not be a perfect multiple of a shipping container capacity. This step aims to create such order quantities that are perfect multiple of a shipping container capacity. Order quantities can be rounded up to fill the last container, which is not full, or rounded down to omit the last container. These steps will make sure that every container space is utilized.

$$Q_{round\ up} = \left\lceil \frac{Q}{Q_{1\ container}} \right\rceil \times Q_{1\ container} \quad (9)$$

$$Q_{round\ down} = \left\lfloor \frac{Q_{21}}{Q_{1\ container}} \right\rfloor \times Q_{1\ container} \quad (10)$$

4. Step 4: Total Cost per Unit, Potential Shortage and Overage, Order Frequency, and Age of Inventory Calculation
This step will calculate total cost per unit which is comprised of product purchasing cost, shipping cost, shortage cost, and overage cost [6].

$$z = \frac{Q - \mu}{\sigma} \quad (11)$$

$$L(z) = Normdist(z,0,1,0) - z * (1 - normdist(z,0,1,1))$$

$$L(Q) = L(z) \times \sigma \quad (12)$$

$$V(Q) = Q - (\mu - L(Q)) \quad (13)$$

$$Shortage\ Cost = \frac{|L(Q)| \times (P - C)}{Q} \quad (14)$$

$$Overage\ Cost = \frac{|V(Q)| \times (P - V)}{Q} \quad (15)$$

These costs will then be summed up and divided by the order quantity that are found in step 3 to get the total cost per unit. Then, age of inventory and order frequency of each order will be calculated.

$$Age\ of\ Inventory = \frac{Q}{\mu} \times 12 \quad (16)$$

$$Order\ Frequency = \frac{12}{Age\ of\ Inventory} \quad (17)$$

This step will find a set of order quantities with differing characteristics. Generally, larger order quantity will result in lower total cost per unit and less frequent order frequency, but longer age of inventory. On the other hand, smaller order quantity will result in shorter age of inventory, but higher total cost per unit and more order frequency. There is no general guideline on which of these quantities are the best due to the subjective difference on preference, some companies might find the economic factors to be more important, some might find the non-economic factors to be as important, if not, more important.

5. Step 5: Calculating Total Cost per Unit, Potential Shortage and Overage, Order Frequency, and Age of Inventory; and Comparison of Actual and Theoretical Calculation Result
This final step will redo step 4 on the actual order quantity data to find their total cost per unit, potential shortage and overage, order frequency and age of inventory. These variables are then compared to the variables that are resulted by the order quantity from Extended Newsvendor calculation.

4. Result

Green shading indicates better performance than actual order quantity, blue shading indicates on-par performance than actual order quantity, red shading indicates worse performance than actual order quantity:

Table 2. Comparison of Results on Company 2 – Medium-Sized Company 1

Month of Order	Cost/Unit (Rupiah)		Age of Inventory (Month)		Order Frequency		Shortage (L(Q))	
	Extended Newsvendor / Historical							
Jun-12	6,468	6,551	1.6	1.82	8	7	1,861.3	516.008
Sep-12	6,880	6,943	2.9	3.35	5	4	1.0514	0.0247
Dec-12	6,895	6,958	3.14	3.67	4	4	0.0112	0.0118
Mar-13	6,903	6,969	3.27	3.94	4	4	0.0205	0.0228
May-13	6,912	6,922	3.45	2.98	4	5	0.5412	17.5336
Jul-13	6,872	6,881	2.79	2.46	5	5	37.5477	248.219
Oct-13	7,092	7,110	3.41	3.05	4	4	0.1070	3.2205
Jan-14	7,083	7,072	3.23	2.53	4	5	0.3598	80.8248
Mar-14	7,065	7,028	2.92	2.09	5	6	4.4558	778.377
Jun-14	7,041	7,091	2.6	2.76	5	5	36.6691	11.1245
Aug-14	7,090	7,082	3.35	2.65	4	5	0.0060	23.3908
Nov-14	7,029	7,080	2.46	2.62	5	5	50.9097	14.9676
Mar-15	7,094	7,136	3.45	3.55	4	4	0.0319	0.0338
Jul-15	7,193	7,240	3.62	3.95	4	4	0.0365	0.0370
Oct-15	7,172	7,216	3.1	3.27	4	4	0.0423	0.0198
Jan-16	7,172	7,207	3.1	3.07	4	4	0.0187	0.0367

Table 3. Comparison of Results on Company 3 – Medium-Sized Company 2

Month of Order	Cost/Unit (Rupiah)		Age of Inventory (Month)		Order Frequency		Shortage (L(Q))	
	Extended Newsvendor / Historical							
Aug-12	7,082	7,129	3.5	3.41	4	4	5.3199	8.9069
Oct-12	7,011	7,028	2.83	2.58	5	5	154.939	480.999
Jan-13	7,690	7,727	2.98	2.85	5	5	26.5304	55.9155
Mar-13	7,661	7,686	2.77	2.58	5	5	22.9109	76.9561
Jul-13	7,699	7,712	3.06	2.74	4	5	5.1105	43.8979
Sep-13	7,684	7,713	2.93	2.76	5	5	4.2755	16.7262
Dec-13	7,688	7,776	2.97	3.26	5	4	0.9091	0.0158
Mar-14	7,814	7,887	2.94	3.08	5	4	1.5426	0.3811
May-14	7,797	7,957	2.82	3.79	5	4	31.2971	0.0559
Aug-14	7,785	7,815	2.74	2.59	5	5	166.613	335.735
Nov-14	8,226	8,208	2.78	2.39	5	6	125.353	720.908
Feb-15	8,234	8,270	2.83	2.71	5	5	75.7506	143.155
May-15	8,238	8,238	2.85	2.85	5	5	57.4078	57.4078
Aug-15	8,240	8,281	2.86	2.78	5	5	48.9774	80.2793
Oct-15	8,232	8,249	2.81	2.59	5	5	94.1809	283.396
Jan-16	8,236	8,308	2.84	2.96	5	5	82.3528	42.1099

Table 4. Comparison of Results on Company 4 – Small-Sized Company 1

Month of Order	Cost/Unit (Rupiah)		Age of Inventory (Month)		Order Frequency		Shortage (L(Q))	
	Extended Newsvendor / Historical							
Jul-12	6,548	6,121	2.18	2.93	6	5	0.03	0.00
Oct-12	6,461	6,090	1.67	2.23	8	6	273.72	31.46
Jan-13	6,595	6,139	2.62	3.56	5	4	0.22	0.02
Mar-13	6,088	6,084	2.21	2.14	6	6	8.21	12.99
Jun-13	6,750	6,730	2.31	2.06	6	6	11.90	50.47
Sep-13	6,873	6,772	2.00	2.64	7	5	59.18	1.01
Dec-13	6,950	6,858	1.81	2.42	7	5	175.49	10.86
Mar-14	7,012	6,878	2.36	2.76	6	5	9.43	0.53
Jun-14	7,658	7,371	2.27	2.63	6	5	13.54	1.02
Oct-14	7,680	7,402	2.47	3.29	5	4	3.01	0.03
Feb-15	7,699	7,414	2.67	3.66	5	4	0.32	0.03
Apr-15	7,356	7,335	2.39	2.11	6	6	12.63	56.51
Jul-15	7,867	7,863	2.34	2.31	6	6	16.48	19.83
Oct-15	8,018	7,902	2.30	2.72	6	5	18.10	1.19
Jan-16	7,872	7,896	2.38	2.63	6	5	9.93	1.82
Apr-16	7,872	7,873	2.38	2.40	6	6	10.81	9.98

Table 5. Comparison of Results on Company 5 – Small-Sized Company 2

Month of Order	Cost/Unit (Rupiah)		Age of Inventory (Month)		Order Frequency		Shortage (L(Q))	
	Extended Newsvendor / Historical							
Jul-12	6,965	6,862	2.29	4.51	6	3	0.0000	0.0000
Nov-12	7,061	6,959	2.24	4.28	6	3	1.3997	0.0089
Mar-13	7,056	6,957	2.17	4.16	6	3	0.1194	0.0010
Jun-13	6,994	6,935	1.58	3.05	8	4	58.566	0.0006
Okt-13	7,235	7,145	2.20	4.16	6	3	0.2237	0.0020
Feb-14	7,228	7,139	2.11	3.81	6	4	0.1253	0.0006
Jul-14	7,760	7,669	2.89	5.1	5	3	0.0004	0.0004
Dec-14	7,706	7,773	3.09	5.31	4	3	0.0002	0.0002
Jun-15	7,735	7,789	3.79	6.33	4	2	0.0001	0.0001
Sep-15	7,603	7,711	1.90	3.19	7	4	12.908	0.0039
Dec-15	7,749	7,709	3.64	3.15	4	4	0.0031	0.0031
Mar-16	7,880	8,001	2.08	3.61	6	4	1.1877	0.0025

The comparison of results above is then statistically presented, as follow:

Table 6. Statistical Comparison of Medium Sized Companies

Variable	Percentage			Hypothesis Test (α = 0.05)	Result
	Better Than	Worse Than	Par-With		
Cost per Unit	84.375%	12.500%	3.125%	Significantly Different (Sig = 0.00)	Extended Newsvendor performs better
Age of Inventory	40.625%	56.250%	3.125%	Indifferent (Sig = 0.493)	Extended Newsvendor performs similarly
Order Frequency	18.750%	15.625%	65.625 %	Indifferent (Sig = 0.763)	Extended Newsvendor performs similarly
Shortage	68.750%	28.125%	3.125%	Significantly Different (Sig = 0.024)	Extended Newsvendor performs better

Table 7. Statistical Comparison of Small Sized Companies

Variable	Percentage			Hypothesis Test (α = 0.05)	Result
	Better Than	Worse Than	Par-With		
Cost per Unit	17.857%	82.143%	0.000%	Significantly Different (Sig = 0.002)	Extended Newsvendor performs worse
Age of Inventory	82.143%	17.857%	0.000%	Significantly Different (Sig = 0.00)	Extended Newsvendor performs better
Order Frequency	0.000%	78.571%	21.429 %	Significantly Different (Sig = 0.00)	Extended Newsvendor performs worse
Shortage	7.143%	75.000%	17.857 %	Significantly Different (Sig = 0.018)	Extended Newsvendor performs worse

5. Conclusion

Based on the steps of data analysis which has been done, the conclusion that can be drawn is that the Extended Newsvendor method is generally able to improve the performance of order quantity when applied on the medium-sized company; but is unable to improve the performance of order quantity when applied on the instead-sized company, instead, it worsen the order quantity performance.

This research then suggests that medium-sized company should adopt the Extended Newsvendor which was found to be able to lower the total cost per unit and potential shortage. Although it is not able to lower the age of inventory and order frequency, at least, this method does not worsen the value of these two variables. On the other hand, the adoption of Extended Newsvendor is not recommended on small-sized company due to the finding that this method only worsen the performance, increases total cost per unit, potential shortage, and order frequency; unless the company feel that the age of inventory – which Extended Newsvendor lowers – is of the most important.

Limitation and Further Direction

This paper has addressed the problem on whether the combination of Newsvendor model and Quantity Discount Pricing works well when being applied on small scale company and medium scale company. However, to make suitable comparison, this paper synchronizes the components of cost per unit on the two categories of company; which might not represent the real cost structure as larger companies tend to have more complex cost structure. Further research has to account this reality, so that the proper cost components can be included to the calculation.

Acknowledgments

The authors declare that there is no conflict of interest during the process of the research and writing of this manuscript. This study is funded personally by the authors.

References

[1] Transaksi Total Atas Dasar Harga Pembeli Menurut 17 Produk, 2010 (Juta Rupiah), https://www.bps.go.id/linkTabelStatis/view/id/1895, 25-10-2018.

[2] Jumlah Profesi Tenaga Ahli di Perusahaan Konstruksi Menurut Provinsi dan Kualifikasi, 2014, https://www.bps.go.id/linkTableDinamis/view/id/941, 25-10-2018.

[3] Jumlah Perusahaan Konstruksi Menurut Provinsi dan Jenis Golongan Perusahaan, 2000 –2014, https://www.bps.go.id/linkTableDinamis/view/id/920, 15-11-2018.

[4] Konstruksi dalam Angka, https://www.bps.go.id/publication/2016/12/16/91f4964440483507ffc33f54/konstruksi-dalam-angka-2016.html, 15-11-2018.

[5] Pawel Bozyk, *Globalization and the Transformation of Foreign Economic Policy*, Farnham: Ashgate Pub Co, 2006.

[6] Gerard Cachon, Christian Terwiesch, *Matching Supply with Demand,* London: McGraw-Hill Education, 2012.

[7] Sibo Ding, S., "*Uncertain Newsboy Problem",* Journal of Intelligent and Fuzzy System, Vol 26, pp. 483-490, 2014.

[8] Avijit Khanra, Chetan Soman, "*Sensitivity Analysis of the Newsboy Model*", Operational Journal of Operational Research, Vol 239, No. 2, pp. 403-412, 2014.

[9] Zhenwei Luo, Jinting Wang, "*The Optimal Price Discount, Order Quantity, and Minimum Quantity in Newsvendor Model with Group Purchase*", Journal of Industrial and Management Optimization, Vol 11, pp. 1-11, 2015.

[10] OECD Economic Survey Overview, https://www.oecd.org/eco/surveys/indonesia-2016-OECD-economic-survey-overview-bahasa.pdf, 12-12- 2018.

[11] Jian Tan, "*Advertising and Order Quantity Decision Based on the Newsvendor Model*", International Journal of u- and e- Service, Science and Technology, Vol 8, pp. 161-170, 2015.

[12] Laquanda Leaven, Shengbin Wang, Linda Silver Coley, Silvanus Udoka, "*Achieving Optimal Safety Inventory Levels for Oil Companies using the CONWIP Approach*", International Journal of Supply Chain Management, Vol 6, No 4 pp. 17-21, 2017.

[13] BH Simamora, D Natalia, *Aggregate Planning for Minimizing Costs: A Case Study of PT XYZ in Indonesia,* International Business Management, Vol 8 (6), pp. 353-356, 2014