Inventory Control for Electrical and Instrumentation Spare Parts in Cement Industries

Imran and Iwan Vanany
Departement of Industrial and System Engineering
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
Imranst22@gmail.com, vanany@ie.its.ac.id

Abstract

Managing and controlling the spare parts inventory in industries including cement industries is critical activity. In this case study, the out of stock incidents especially spare parts in the electrical and instrumentation category were often occurring and significantly affecting the maintenance program based on observation and preliminary data collection. The purpose of this study is to minimize stock out for electrical and instrumentation spare part in cement industry. The lumpy phenomena were happened in some spare parts based on ADI-CV matrix methods and the probabilistic methods is needed to manage spare parts. The continuous review method (s, S) policy is selected to determine the number of orders (Q), reorder point (ROP) and total inventory costs. The Monte Carlo simulation method is used to analyse the inventory performance such as inventory costs and service level. The main result of this study is to determine the improvement action for managerial to reduce stock out and inventory costs. The main practical implication of this study is to increase the service level from 61% - 84% up to 88% - 95% in order to reduce the production losses due to stock out of spare parts.

Keywords
Continous Review, Inventory Cost, Spare Parts, Monte Carlo Simulation, Service Level

1. Introduction
Inventory management is significant function in logistics system that is responsible for all decision about stock in an organization including raw material, work in process, finished good, and spare parts. It is critical to makes decision for policies, activities and procedures to make sure the right amount of each item kept in stock. The main purpose of a stock is to provide a buffer between demand and supply. Spare part is an important part in logistics management and supply chain management. This safeguard spare part is very essential to ensure smooth operation and to enable operations to be more efficient and productive. Spare part inventory is needed for maintenance and repair final product, vehicle, industrial machine and equipment. Inventory management is complex due to the large number of differential items and low demand. Inventory influences operating costs - and therefore produces profits, return on assets, return on inventory, and almost all other financial performance measures (Octaviana et al. 2018).

Inventory can have a bad impact if it is not managed properly. The first reason for time, which is to deal with operational conditions that are not in accordance with planning, where the work unit continues to be held responsible for the production process. The second reason is the uncertainty in dealing with demand and supply. And the last reason is the economics of scale, that companies are able to achieve economic value in the production process and the procurement process. There are several types of inventory that make a difference between companies. Pipeline or transit inventory is the inventory that arises because of the long delivery time from one place to another. Cycle stock is type of inventory that has a cycle in its movement. The amount of inventory of this type will decrease little by little due to being used up or sold out. Safety stock is the one that serves as an anticipation of late delivery. Anticipation stock is inventory to anticipate the increase in demand due to the seasonal nature of the demand for a product (Octaviana et al. 2018)0.
Based on PT X (one of the leading cement company in Indonesia) observations, there is no clear theoretical basis in determining and planning the needs of spare parts of each controlling unit. In determining the number of requests, it is still solely based on estimation, the history of existing requests, or quantity requested by each maintenance unit who is informed when making an order. Even when the requesting unit makes an order, sometimes the item is already needed at that time also so the ideal condition is that there is already a stock in the warehouse. Based on the history of

the goods issued from the spare part warehouse in the last 3 years (2017-2019) there were 44338 times activity of goods/spare parts issued from the warehouse. Of the 44338 times, it consists of 6187 types of items. The most frequent material issued is the spare part that is included in the classification (based on the distribution of material types in SAP) of Electrical, Instrument & General Use, that is 32433 times issued with a total type of equipment of 3461.

For electrical and instrumentation spare parts, the information is obtained that there is still an imbalance between demand and stock. The level of inventory for these spare parts was found many stockout events as shown in Figure 1 below. Stock out condition has negative implications to the company which can result in loss of potential production and profits. For example, if motor equipment is burned/damaged and no spare parts is available at that time, one unit of the plant will shut down (for example, Finish Mill II units) where this unit produces cement with a capacity of 100 tons/day. So, the potential for loss of production is 100 tons/day. Then, if the selling price of cement per sack (40 kg) is Rp48,000 with a profit margin of ± 20%, thus there will be a potential loss of sales of Rp120,000,000 per day with the potential loss of profit Rp24,000,000 per day. Not to mention the presence of potential competitors entering if the cement stock is not available in the market. Therefore, the analysis of spare parts control for electrical and instrumentation items needs to be analyzed comprehensively. Efforts to determine the number of orders and reorder points by considering the cost of the inventory. It is expected that the stock out can be reduced. The practical implication expected for the inventory and warehouse department management is to reduce the potential loss due to interruption in production due to the absence of spare parts needed by the equipment.

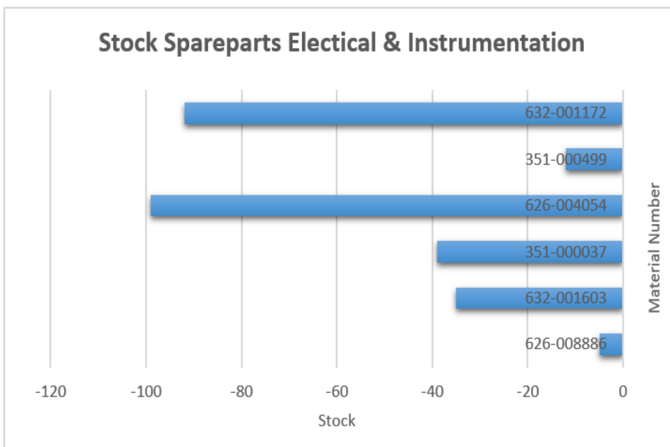

Figure 1. Actual condition (stock out) for electrical & instrumentation spare part

Several previous study in maintenance and other research topics were conducted in cement industries particularly in Indonesian (Graisa and Al-Habaibeh 2018). Research from Graisa and Al-Habaibeh (Graisa and Al-Habaibeh 2018) studied the current production challenges facing the Libyan cement industry and the need for Innovative Total Productive Maintenance (TPM) strategy. Other like Santarisi and Almomay (Santarisi and Almomany 2005) had done a research for mathematic modelling of wear rate of non-repairable part and their replacement strategies (case study: cement mill liners). Research discuss about spare part management is not too much founded. Study reviews current relevant literature and develops a conceptual framework (an integrated group decision support system) for selecting the most effective warehousing option for the process industry using the analytic hierarchy process (AHP) done by Mukherjee, Nilanjan and Dey, Prasanta. There has not yet been any research related to spare part electrical and instrumentation type in the cement industry which has occurred stock out such as explained in the previous paragraph.

2. Research Method

The focus of this research is to determine the optimal inventory policy strategy to minimize stock out in electrical and instrumentation spare parts inventory in the company. The first stage in this research is to classify spare parts by using ABC analysis for each of electrical spare part type and instrumentation type. ABC Analysis follows the 80-20 principle or pareto law, where 80% of the total value of material inventory is represented by 20% of inventory material (Octaviana et al. 2018). Second stage is, selecting A class spare part from ABC analysis for further analysis both electrical and instrumentation type. The next stage is to classify the spare parts based on the characteristics of the arrival of the request by using ADI - CV analysis. ADI-CV analysis is used to classify spare parts based on the characteristics of the requests through the time interval of the request arrival, and the diversity of levels of the incoming requests. This is performed to determine the appropriate spare part control strategy. Next step is calculating inventory policy using continuous review method (s, S) because company's procurement policy can be done at any time. The Monte Carlo simulation is performed to determine the repair parameters.

The calculation is started from collecting real condition of electrical and instrumentation spare part (both for consumable and not consumable) demand for 33 months (January 2017 - September 2019). Furthermore, this data becomes an input for inventory control policy makers using the continuous review (S, s) calculation method. It is found that for electrical spare parts, there were 805 items used during this period, 23 item consumable category, and 782 item spare part category. Meanwhile, for the type of instrumentation found there were 250 items spare part category. This spare part usage in production unit with machine ages ranging from 6 years to 39 years, as shown in Table 1.

Table 1. Electrical spare parts data

No	Material Number	Category	Quantity	Usage	Years
1	**602-000197**	***spare parts***	**1**	**Raw Mill 3**	**34**
2	**602-002875**	***spare parts***	**1,000**	**Finish Mill 5**	**6**
3	**602-002970**	***spare parts***	**2**	**Raw Mill 3**	**34**
4	**602-004055**	***spare parts***	**1**	**Settle Pond**	**2**
5	**602-004059**	***spare parts***	**1**	**Finish Mill 5**	**6**
….	**……..**	**……….**	**……**	**……**	**…**
489	**627-000118**	***consumable***	**5**	**Coal Mill 4**	**4**
490	**627-000127**	***consumable***	**18**	**Crusher 2**	**39**
….	**……..**	**……….**	**……**	**……**	**…**
805	**SI00004019**	***spare parts***	**30**	**Packer Bks**	**23**

Those spare parts will be classified using ABC analysis. Spare parts in A class from ABC analysis will be selected for further analysis both electrical and instrumentation type. In this paper, only four item that have stock out history will be selected for further analysis. The following Table 2 shows usage data for selected spare parts sample which will be used for inventory control calculations. This data is taken from the usage history recorded in the SAP system used by the company.

The classification of selected parts will be based on the ADI - CV value. The results obtained from the ADI-CV calculation will determine the inventory calculation policy method whether or not to use the continuous review method (s, S).

Table 2. Selected spare parts usage data and stock out for the period of 2015 – 2019

No	Material Number	Category	Period								Service Level
			1	2	3	4	5	…	59	60	
1	**631-000490**	**E - S**	**0**	**0**	**0**	**350**	**0**	**…**	**0**	**0**	**61%**
2	**602-001378**	**E - S**	**200**	**0**	**0**	**300**	**0**	**….**	**250**	**50**	**60%**
3	**627-000279**	**E - C**	**0**	**0**	**0**	**0**	**0**	**….**	**0**	**40**	**84%**
4	**632-001172**	**I - S**	**0**	**0**	**0**	**0**	**0**	**….**	**0**	**10**	**84%**

Table 3. Spare parts usage for spare part 631-000490 (Jan 2015 – Des 2019 / 60 period)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
-	-	-	350	-	-	-	240	-	-	-	-	-	500	320	-	-	-	-	-
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
6760	-	-	-	-	-	1000	-	-	-	-	-	-	1500	-	-	-	120	-	-
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
-	-	-	-	-	-	-	-	-	-	42	-	-	-	-	-	-	-	-	-

For calculation example, spare parts 631-000490 ADI calculations can be using the equation:

$$ADI = \frac{\sum_{N}^{i=1} t_i}{N} = \frac{60}{9} = 6.67$$

While the CV value can be searched using the equation as follows:

$$= \frac{\sum_{N}^{i=1} \quad i}{N} = \frac{(350+240+\cdots+42)}{60} = 180.53$$

$$CV = \frac{\sqrt{\frac{\Sigma_{i=1}^{i}(\varepsilon_i - \varepsilon)^2}{Ncv}}}{\varepsilon} = \frac{874,44}{180,53} = 4.84$$

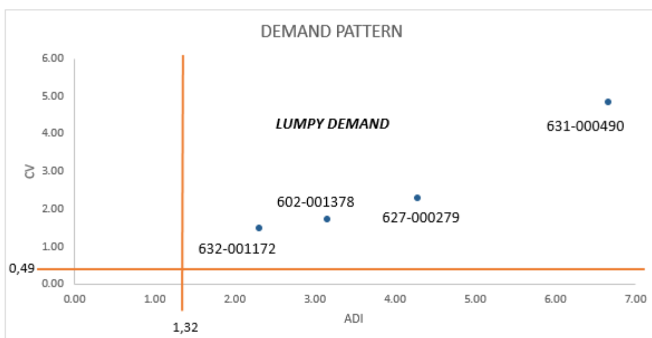

Figure 2. ADI – CV calculation

From the Figure 2, it can be seen in the demand pattern of all selected spare parts have a lumpy demand pattern. Where for this demand pattern is suitable to use probabilistic method (continuous review & periodic review) for calculating inventory policy, continuous review is selected because company's procurement policy can be done at any time. Other data that is also needed to be recorded is price and lead time data. For example, material number 602-001378 has a purchasing price of Rp380,000 and lead time of 137 days. Inventory costs are also taken into account, which consist of ordering, holding cost, and shortage cost. Ordering cost are obtained from the cost of assets used in the procurement unit such as laptop with price of Rp12,000,000 per unit, employee salaries such as procurement staff (Rp11,000,000), asset depreciation such us laptop (Rp700,000 per month), and other cost (electricity, communication, administration) with amount Rp5,500,000 per month. Therefore, the recapitulation of the ordering cost each item is Rp710,582, which obtained an average number of orders (purchase orders) each month by 128 times. Holding cost is the cost of holding one unit of item in inventory for a period of time. That cost will be calculated through the depreciation of assets from supporting facilities used to support inventories such as forklift, along with the human resources that manage these inventories and the cost of capital also needs to be considered. So that the holding costs for material such as material number 632-000490 is a combination of salary costs, depreciation, and the cost of capital, which in total is Rp1,400,405. For the calculation of shortage costs uses the costs that must be paid when the machine is damaged and no replacement parts are available, so that the equipment cannot run as it should such as material number 632-0001172 has shortage cost Rp2,948,307,692.

All data above will be used in the calculation of inventory policy using continuous review (s, S) method. The formula to use:

$$SS = Z\alpha \, \sigma_D \sqrt{L} \quad (1)$$

$$S = q' + r' \quad (2)$$

$$q = \sqrt{\frac{2AD}{h}} \quad (3)$$

$$\alpha = \frac{h \, q_0}{Cu \, D} \quad (4)$$

$$N = \int_{r'}^{\infty} (x - r')f(x)dx = \sigma_{DL}[f(Z\alpha) - Z\alpha\varphi(Z\alpha)] \quad (5)$$

$$r_1' = DL + Z\alpha \, \sigma_D \sqrt{L} \quad (6)$$

q = Order quantity S = Maximum Stock
D = Total Demand A = Order Cost
L = Lead Time h = *Holding cost*
Cu = Shortage Cost r' = Reorder Point
σ_D = Standard deviation Demand SS = Safety Stock

3. Result and Discussion

Inventory and ordering calculation with existing conditions will be performed on four samples of spare parts data according to the previous chapter. The following Table 4 below are the existing inventory indicator that will be compared with indicator after applying continuous review inventory policy. From the calculation of input parameters, it will be known how much recommendation for reorder points (ROP) and maximum stock. These input parameters shown in Table 5 will be used as initial input from simulations of inventory and ordering spare parts. Then a simulation of inventory policy calculation will be carried out with a continuous review (s, S) system method. This simulation is conducted to find out the best input parameters (s and S) that can reduce the stock out that occurs.

Table 4. Summary of existing inventory indicators

No	Material No.	s	S	Total Cost existing (Rp.)	Service level
1	**631-000490**	-	-	7,455,546,477	61%
2	**602-001378**	-	-	1,939,506,604	60%
3	**627-000279**	-	-	651,253,446	84%
4	**632-001172**	-	-	233,533,342	84%

Table 5. Summary parameters of inventory analysis

No	Material No.	s	S
1	**631-000490**	6311	13891
2	**602-001378**	633	1828
3	**627-000279**	115	303
4	**632-001172**	42	80

First step of this simulation is to generate random number with Monte Carlo approach. The step to generate random number are as follows:

- Observe the parameter to be modeled
- Calculate the frequency of each parameter
- Calculate the cumulative frequency distribution and cumulative probability distribution
- Pair the class value of each parameter with random number in the range 1 – 100

- Drag a random number using generate random in Microsoft excel application
- Get the appropriate parameter value by pairing the generate random number

Table 6. Generate random number result for material no. 632-001172

	Replica 1		Replica 2		Replica 3		…..	Replica 100	
No	Random Number	Demand	Random Number	Demand	Random Number	Demand	……	Random Number	Demand
1	**37**	**0**	**96**	**28**	**86**	**15**	……	**90**	**20**
2	**22**	**0**	**97**	**28**	**44**	**0**	……	**29**	**0**
3	**22**	**0**	**42**	**0**	**86**	**15**	……	**67**	**4**
4	**0**	**0**	**37**	**0**	**77**	**7**	……	**29**	**0**
…	…	…	…	…	…	…	…..	…	…
59	**80**	**8**	**94**	**25**	**9**	**0**	……	**77**	**7**
60	**34**	**0**	**40**	**0**	**19**	**0**	……	**21**	**0**

Next, it is necessary to do a t-test to validate that demand data that have been raised previously in this simulation to check whether or not it is already approaching the real condition. The following are the t-test result.

Table 7. Model validation results with the t-test material no. 632-001172

Replica	t Stat	t Critical	Result
1	**0.027**	**1.658**	**t Stat < t Critical**
2	**-0.200**	**1.658**	**t Stat < t Critical**
3	**1.012**	**1.658**	**t Stat < t Critical**
4	**0.132**	**1.658**	**t Stat < t Critical**
5	**1.596**	**1.658**	**t Stat < t Critical**
6	**0.069**	**1.658**	**t Stat < t Critical**
7	**-0.149**	**1.658**	**t Stat < t Critical**
….	……	……	……..
99	**-0.783**	**1.658**	**t Stat < t Critical**
100	**-1.204**	**1.658**	**t Stat < t Critical**

t-Test: Two-Sample Assuming Equal Variances

	Eksisting	*Replication-1*
Mean	16.4	16.2
Variance	1620.7525	1660.061017
Observations	60	60
Pooled Variance	1640.4068	
Hypothesized Mean Difference	0	
df	118	
t Stat	0.0270467	
P(T<=t) one-tail	0.4892341	
t Critical one-tail	1.6578695	
P(T<=t) two-tail	0.9784681	
t Critical two-tail	1.9802722	

From the results of the Table 6 and Table 7 above, it shows that the value of t stat <t critical. So, it can be concluded that the model is approaching the real condition.

Table 8. Calculation result for recommendation for improvement 627-000279 (s=155, S=303)

Replication	Holding Cost (Rp.)	Ordering Cost (Rp.)	Purchase Cost (Rp.)	Total Cost (Rp.)	Service Level
1	**1,398,071,009**	**3,552,908**	**649,513,836**	**2,051,137,754**	**84%**
2	**1,570,673,817**	**4,263,490**	**689,781,602**	**2,264,718,909**	**84%**
3	**1,380,470,451**	**2,131,745**	**431,963,308**	**1,814,565,504**	**86%**
4	**1,429,400,003**	**3,552,908**	**540,738,572**	**1,973,691,483**	**81%**
5	**1,696,576,477**	**1,421,163**	**284,489,152**	**1,982,486,792**	**95%**
…	**…………**	**…………**	**…………**	**……………**	**......**
99	**1,430,690,710**	**4,974,072**	**759,335,016**	**2,194,999,798**	**100%**
100	**1,219,601,349**	**4,974,072**	**981,592,166**	**2,206,167,586**	**92%**
Average	**1,371,318,161**	**3,439,215**	**625,708,788**	**2,000,466,164**	**90%**

Recommendations for improvements that is going to be proposed to the company will be conducted using a combination of values of s and S. By using continues review method, those 4 spare parts will be simulated in this paper. Spare parts to be used in this simulation include 60 data generated by the Monte Carlo simulation method with 100 replications. This simulation aims to evaluate the proposed policy so that later the results obtained in the form of inventory parameters, total costs, and the value of service level. Later, the results of this calculation simulation will be compared with existing policies and analyzed which policies are better in terms of service level value and total costs. Table 8 show the calculation result for Material No. 627-000279. By doing simulation calculations using a combination of input parameter values (s and S) and demand combinations (the results of generating random numbers with Monte Carlo simulations), the best results are obtained at the equivalent parameter values of s=155 & S= 700 can be seen in Table 9.

Table 9. Scenarios for recommendation for improvement 627-000279

Experiment	s	S	Average Total Cost (Rp.)	Average Service Level
Existing	**-**	**-**	**651,253,446**	**84%**
1	**115**	**303**	**2,000,446,164**	**90%**
2	**115**	**900**	**4,618,956,768**	**95%**
3	**115**	**800**	**4,122,921,948**	**95%**
4	**115**	**700**	**3,729,283,753**	**95%**
5	**115**	**600**	**3,216,606,282**	**94%**
6	**115**	**500**	**2,773,426,917**	**93%**
7	**115**	**400**	**2,416,952,159**	**93%**
8	**110**	**303**	**1,991,566,428**	**91%**
9	**105**	**303**	**1,970,443,411**	**90%**
10	**100**	**303**	**1,954,647,085**	**89%**
11	**95**	**303**	**1,941,851,018**	**89%**
12	**90**	**303**	**1,927,893,151**	**89%**
13	**85**	**303**	**1,904,102,792**	**89%**
14	**80**	**303**	**1,877,652,038**	**88%**
15	**75**	**303**	**1,867,200,696**	**88%**

With the same method, for other material result for recommendation of improvement can be seen in Table 10 below.

Table 10. Resume scenarios for recommendation for improvement

No	Material No.	s		S		Total Cost existing (Rp.)		Service level existing	
		Exis-ting	**Simu-lation**	**Exis-ting**	**Simu-lation**	**Existing**	**Simulation**	**Exis-ting**	**Simu-lation**
1	**631-000490**	-	10000	-	13891	7,455,546,477	82,816,400,435	61%	88%
2	**602-001378**	-	900	-	1828	1,939,506,604	9,696,702,891	60%	95%
3	**627-000279**	-	115	-	700	651,253,446	3,729,283,753	84%	95%
4	**632-001172**	-	42	-	120	233,533,342	645,797,715	84%	92%

From the above simulation Table 10 above it can be seen that the result shows an increase in service level from existing condition. Total cost also raises as result of increasing the service level.

4. Conclusion

The main purpose of this study is to determine reorder point, maximum inventory level, service level and inventory cost. Increased service level is more prioritized over inventory cost because the unavailability of spare part can cause high production losses. For example, in spare part 631-000490, service level increase from 61% to 88%, but the consequence is the cost of inventory increased from Rp7,455,546,477 to Rp82,816,400,435, this is due to an increase in the number of orders and the amount of stock in order to reduce shortage.

Practical implications with the existence of this study can improve service level. Then spare part already has an ABC classification in SAP system that did not exist before. Stock out is decreasing, this can be seen from the higher service level. Losses due to engine breakdown can be reduce so that the loss of production can be reduce as well. The limitation of this study is this study does not take into account the age of equipment and also period of major maintenance. Therefore, future research can take into account the age of equipment and consider the period of major maintenance that company has been scheduled every year.

References

Graisa, M., and Al-Habaibeh, A., An Investigation Into Current Production Challenges Facing The Libyan Cement Industry and the Need for Innovative Total Productive Maintenance (TPM) strategy, *Journal of Manufacturing Technology Management*, vol. 22, no. 4, pp 541–558, 2011.

Octaviana, M., Baihaqi, I., and Bramanti G.W., Penetapan Kebijakan Persediaan Spare Parts: Studi Kasus Pabrik Perakitan Sepeda Motor, *Jurnal Teknik ITS*, vol. 7, no. 1, pp 2337-3520, 2018.

Santarisi, N.S., and Almomany, R.M., Mathematical Modeling of Wear Rate of Non-Repairable Parts and Their Replacement Strategies, *Journal of Quality in Maintenance Engineering*, vol. 11, no. 1, pp 68–81, 2005.