Improving the Silica Stock Level on Controlling Raw Material Inventories Using the Periodic Review Power Approximation Method in Indonesian Leading Tire Manufacturer

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Abstract*—Competition in the industrial world is getting tighter, every manufacturing company must work quickly to meet market demand and as much as possible avoid missing opportunities in business. Poor raw material inventory control triggers an increase in the amount of raw material inventory and an increase in the total cost of inventory. This research was conducted to study the performance of raw material inventory control at leading tire manufacturers in Indonesia. It is expected that these results can evaluate the performance of raw material inventory control (silica) so that it can provide an alternative solution that is effective and efficient. The research was conducted by collecting data on silica needs and inventory cost data. The data that has been collected is processed using the "Periodic Review (R, s, S)" approach. The research results show that the performance of silica inventory control at Indonesian Leading Tire Manufacturer can be improved by implementing the proposed periodic review (R, s, S) policy parameters and can provide savings in the total cost of silica supplies by 3% or IDR 1,714,891,079 from the existing conditions and the service level value of 99.96%.

Keywords*—periodic review, raw material, inventory costs.

I. INTRODUCTION

The company is an organization that has various purposes. The activities of a company in achieving these goals require the management of production factors consisting of natural resources, human resources, capital, raw materials, machinery, and technology [1]. Companies must always pay attention to the linkages between these production factors, thus the company is required to properly manage these factors so that the company's performance becomes more effective and efficient.

In line with the increasingly fierce competition in the tire manufacturing industry, Indonesian leading tire manufacturers are required to maintain product quality and have a high commitment to meet current market needs.

In every business, there are certain costs needed for the production process and to support the production process according to the needs of each business [2]. The costs in question include production costs, raw material use costs, labor costs, energy costs, and storage costs as shown in Fig. 1.

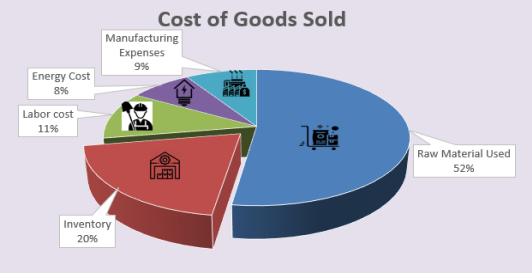

Fig. 1. Cost of Goods Sold in the Company

At this time the inventory system has an important role in the success of a company. Inventory is directly related to the level of availability of goods to meet customer demand. But the current storage value of 20% is considered large because it does not comply with the global standard of inventory. Global Standard for Inventory cost to COGS is 4%.

The largest stock and highest stock in Indonesia leading tire manufacturer are the filler category. Some of the filler categories include Carbon Black and Silica.

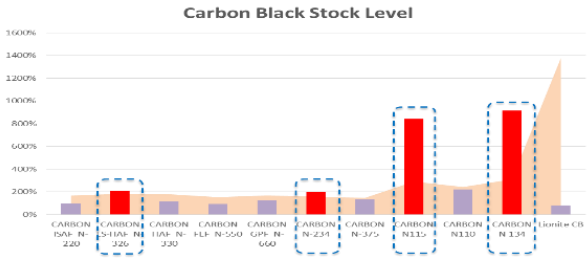

Fig. 2. Carbon black stock level data

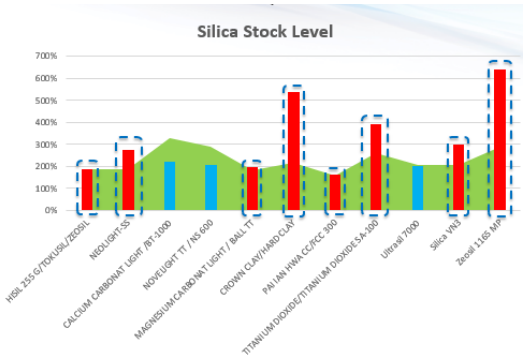

Fig. 3. Silica stock level data

Fig. 2 shows that currently there are 4 items of carbon black material that exceed the maximum ideal stock. Fig. 3 shows that currently 8 silica items exceed the maximum ideal stock. From the two figures, it can be concluded that Silica material has the most items that exceed the maximum ideal stock compared to carbon black. This supply problem is caused by a variety of complex activities.

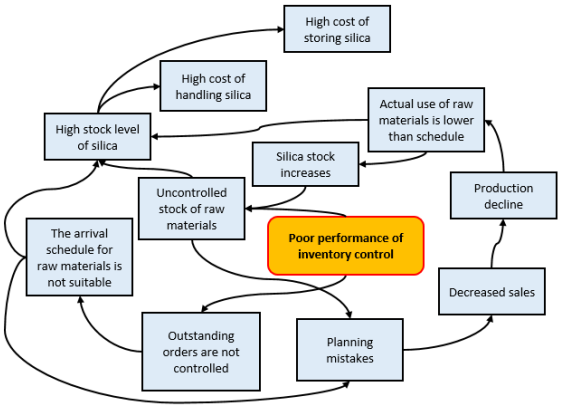

Fig. 4. Interrelationship diagram on inventory problems

Based on Fig. 4, poor performance of inventory control results in an increase in the amount of raw material stock and an increase in the total storage costs that must be incurred by the company. Because the increasing number of raw material stock, inventory control theory is an important aspect for analyzing and solving problems that occur in inventory. By applying inventory control theory, the characteristics of the raw material inventory can be used as a basis for decision making to achieve better conditions. In this research, a study was conducted to study the performance of raw material inventory control in Indonesian leading tire manufacturers. It is expected that these results can evaluate the performance of controlling the raw material inventory (silica) so that it can provide an alternative solution that is effective and efficient.

In an inventory control company, it is very important to reduce waste in inventory costs. The objective of this research is "Designing improved silica inventory control system to improve its performance".

II. LITERATURE REVIEW

A comparative study literature review is shown in Table 1 and Table 2.

TABLE I
COMPARISON OF LITERATURE REVIEW

Authors	Challenge	EOQ	MRP	Periodic Review	Others	Number of Products	Demand Type	Country	Industry	Finding
Tariq, 2018	The relationship between inventory management and company performance is determined based on inventory days and analysis of return on assets (ROA).		√			Multi	Deterministic	India	Steel	Find the amount of inventory that will meet demand, avoiding excess inventory
Oliveira, 2018	Propose a formulation to generalize the consideration of initial inventory in a way that is perfectly consistent with the periodic review policy			√		Single	Stochastic	Brazil	Retail	Optimal periodic-review inventory control policies under demand uncertainty with the possibility of considering partial backorder.
Wan, Q. W, 2020	Computes discrete-time cost accounting that evaluates storage costs and shortages at one or more discrete points in the reorder interval as a special case.			√	√	Single	Deterministic	China	Retail	Develop a model for evaluating and optimizing serial inventory systems.
Bafruei, M. D., 2020	Two echelons of SC with one supplier as leader and one retailer as follower and only one product type with stochastic demand considered and a periodic inventory review system is used by the retailer to control inventory.			√		Single	Stochastic	Iran	Retail	Reducing GHG emissions in two echelons of the Supply Chain (SC) used a periodic inventory review
Hanafi, 2019	Classifying the inventory held by SSM into easy to manage groups	√				Multi	Deterministic	Indonesia	Automotive	Optimal Inventory Cost
Proposed Model	Reducing inventory costs by optimizing supplies using a periodic review power approach (R, s, S) which is influenced by uncertain demand			√		Multi	Stochastic	Indonesia	Tire Manufacture	Designing improved inventory control system to improve its performance

Abbreviations:
EOQ : Economic Order Quantity
MRP : Material Requirement Planning

TABLE II
COMPARISON OF INVENTORY CONTROL METHODS

Method	Demand Type	Purchase period	Review interval
Economic Order Quantity (EOQ)	Deterministic	Uncertain	Nothing
Material Requirement Planning (MRP)	Stochastic	Uncertain	Nothing
Periodic Review	Stochastic	Uncertain	Determined

To control the supply of raw materials, the type of demand greatly affects the availability of raw materials. Uncertainty in demand for raw materials will affect the availability of raw materials, this can lead to shortages and excess stock of raw materials, so there is a need for periodic reviews to balance the ever-changing stock and demand for raw materials. The Periodic Review method is very suitable to be used to anticipate these problems.

A. *Inventory Costs*

In calculating the cost of the inventory itself, all costs that are fixed in nature do not have to be involved in the calculation because they will not affect the optimal results obtained. The cost of the inventory itself consists of several components such as purchase costs, ordering costs, storage costs, inventory shortages, and systemic costs [3].

With the calculation of Inventory costs as follows [5]:

$$Ot = Ob + Op + Os + Ok \quad (1)$$

Where:
Ot = Total Inventory Cost (IDR)
Ob = Purchase Costs (IDR)
Op = Ordering Costs (IDR)
Os = Storing and Handling Costs (IDR)
Ok = Shortage Costs (IDR)

B. *Periodic Review (R, s, S)*

To find the review interval value or the order interval, it is searched using the iterative method using the Hadley-Within method as follows [5]:
Calculating the value of T_0

$$T_0 = \sqrt{\frac{2.A}{D.h}} \quad (2)$$

Calculating the Probability of losing inventory (α) and Maximum Inventory (S)

$$\alpha = \frac{\mathbf{T_0 \, x \, h}}{\mathbf{Cu}} \quad (3)$$

$$\mathbf{S = D.T_0 + D.L + z\alpha \, (\sqrt{T_0 + L})} \quad (4)$$

Calculate the total cost of inventory (Ot)

$$\mathbf{N = Stdev\left(\sqrt{T_0 + L}\,[f(z\alpha) - z\alpha \; x \; \psi(z\alpha)]\right)} \quad (5)$$

$$\mathbf{Ot = DP + \frac{A}{T_0} + h\left(S - D.L + \frac{D.T}{2}\right) + \frac{Cu}{T_0}.N} \quad (6)$$

Information:

T_0 : Review Interval (/5 months)
D : Demand (Kg/5 months)
A : Order fees (IDR)
h : Operation costs (storage + handling) (IDR/kg/5 months)
Cu : Shortage costs (IDR/kg)
Stdv : Standard deviation (Kg)
L : Lead time (month)
S : Maximum Inventory (Kg)
N : Inventory Shortage (Kg)
α : Probability of Inventory Shortage

C. *Approximation Algorithm*

The following is the algorithm formulation for calculating the reorder point (s) and maximum level (S) parameters:

Stage 1

$$Q_p = 1{,}3 \; x \; \bar{x}_R{}^{0{,}494} \left(\frac{A}{Pr}\right)^{0{,}506} \left(1 + \frac{\sigma^2{}_{R+L}}{\bar{x}_R{}^2}\right)^{0{,}116} \quad (7)$$

$$S_p = 0.973 \; \bar{x}_{R+L} + \sigma_{R+L}\left(\frac{0{,}183}{z} + 1{,}063 - 2{,}192z\right) \quad (8)$$

Where:

$$z = \sqrt{\frac{Q_p h}{\sigma_{R+L} Cu}} \quad (9)$$

$$\sigma_{R+L} = D(R + L) \quad (10)$$

Stage 2 if $\frac{Q_p}{\bar{x}_R} > 1{,}5$, then

$$S = S_p \quad (11)$$

$$S = S_p + Q_p \quad (12)$$

If not, then proceed to stage 3.

$$S_0 = \bar{x}_{R+L} + k\sigma_{R+L} \quad (13)$$

With

$$P_\mu \geq (k) = \frac{h}{Cu+h} \quad (14)$$

So that the parameter values are obtained as follows.

$$s = minimum\,\{S_p, S_0\} \quad (15)$$

$$S = minimum\,\{S_p + Q_p, S_0\} \quad (16)$$

Information:

R : Review Interval
D : Demand (Kg/5 month)
L : Lead time (month)
A : Order fees (IDR)
h : Operation costs (storage + handling) (IDR/kg/5 month)
Cu : Shortage costs (IDR/kg)
P : Price (IDR/Kg)
$P_\mu \geq (k)$: Probability of Inventory Shortage
σR+L : Standard deviation during review time and lead time (Kg)
$XR+L$: Average demand during review time and lead time (Kg)
XR : Average demand during review time (Kg)
Qp : Order quantity perspective (Kg)
Sp + Qp : Maximum limit point (Kg)
S0 : Minimum limit point (Kg)

III. RESEARCH METHODOLOGY

This research is a quantitative approach consisting of problem formulation, compiling models, obtaining data, finding solutions, analyzing results, and implementing the results [7].

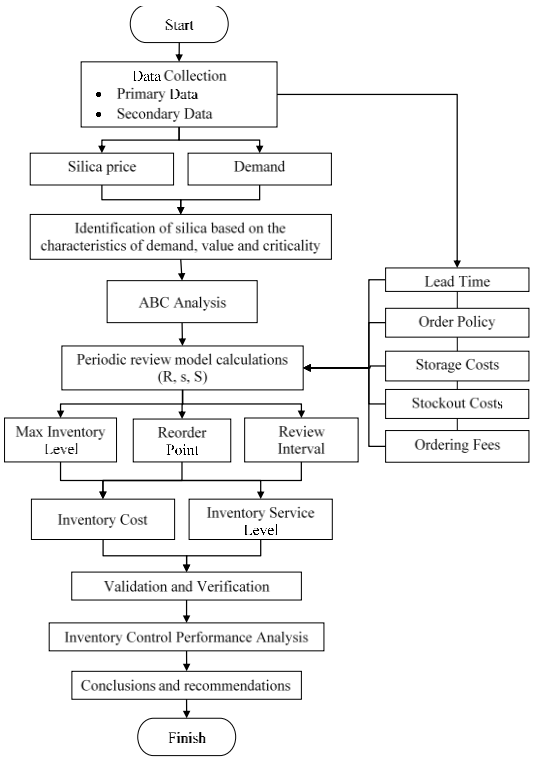

Fig. 5. Research flow and mindset

IV. RESULTS AND DISCUSSIONS

A. *Existing Inventory Cost of Silica*

The total cost of silica inventory is currently the cost incurred by the company to store silica for 5 months. The results are obtained from the sum of the purchase costs, storage costs, handling fees, ordering costs, and shortage costs.

Fig. 6. Total costs of inventory silica

Fig. 6 shows the largest total inventory cost is Ultrasil 7000. The total inventory cost of Ultrasil 7000 reached IDR 21,749,771,643 in 5 months. Next is Pai Ian Hwa CC of IDR 15,510,535,937 and Silica VN3 of IDR 5,922,980,318.

B. ABC Analysis for Silica

TABLE III
ABC ANALYSIS FOR SILICA

Description	Total Cost of Inventory	Percentage	Classification
Ultrasil 7000	21,749,771,643	39.97%	A
Pai Ian Hwa CC	15,510,535,937	28.51%	A
Silica VN3	5,922,980,318	10.89%	A
Zeosil 1165 MP	3,589,921,442	6.60%	B
Hisil 255 G	2,600,452,740	4.78%	B
Titanium Dioxide SA-100	2,194,340,222	4.03%	B
Neolight-SS	1,194,052,060	2.19%	C
Magnesium Carbonat Light	936,071,903	1.72%	C
Crown Clay	384,594,353	0.71%	C
Novelight TT	318,751,306	0.59%	C
Calcium Carbonat Light	8,425,207	0.02%	C

Based on Table 3, there are 3 items of silica with an inventory cost of> 5 billion, 3 items of silica with an inventory cost of 2-5 billion and 5 items of silica with an inventory cost of <2 billion.

C. Proposed Inventory Policy

1) Calculation of T0 Parameters or Review Interval (R)

At this stage, it aims to find the most optimal parameter of the periodic review inventory system R (Review Interval) or T0 using the Hadley-Within method. Because the Ultrasil item has the largest inventory cost, the calculation example uses the Ultrasil 7000 item.

D : 1,142,800 Kg/5 months
P : IDR 17,684/Kg
A : IDR 85,700
h : IDR 1,759.5/Kg/5 months
Cu : IDR 19,011 /Kg
L : 4.23 months
Stdv : 27,207 Kg

LITERATION 1

1. Calculating the value of T0

$$T_0 = \sqrt{\frac{2.A}{D.h}} = \sqrt{\frac{2 \text{ x } 85{,}700}{1{,}142{,}800 \text{ x } 1{,}759.5}} = 0.009$$

2. Calculating the Probability of losing inventory (α) and Maximum Inventory (S)

$$\alpha = \frac{\mathbf{T_0 \text{ x } h}}{\mathbf{Cu}} = \frac{\mathbf{0.009 \text{ x } 1{,}759.5}}{\mathbf{19{,}011}} = \mathbf{0.0009}$$

$\alpha = \mathbf{0.0009}$; $\mathbf{z\alpha = 3.11}$; $\mathbf{f(z\alpha) = 0.0032}$; $\boldsymbol{\psi}\mathbf{(z\alpha) = 0.0031}$ (From Table)

$$\mathbf{S = D.T_0 + D.L + z\alpha\left(\sqrt{T_0 + L}\right)}$$
$$\mathbf{S = (1{,}142{,}800 \text{ x } 0.009) + (1{,}142{,}800 \text{ x } 4{,}23) + 3.11\left(\sqrt{0.009 + 4.23}\right) = 4{,}848{,}411 \text{ Kg}}$$

3. Calculate the total cost of inventory (Ot)

$$\mathbf{N = Stdv\left(\sqrt{T_0 + L}\,[f(z\alpha) - z\alpha \text{ x } \psi(z\alpha)]\right)}$$
$$\mathbf{N = 27{,}207\left(\sqrt{0.009 + 4.23}\,[0.0032 - 3.11 \text{ x } 0.0031]\right) = 361 \text{ Kg}}$$
$$\mathbf{Ot = DP + \frac{A}{T_0} + h\left(S - D.L + \frac{D.T}{2}\right) + \frac{Cu}{T_0}.N}$$
$$\mathbf{Ot = (1{,}142{,}800 \text{ x } 17{,}684) + \frac{85{,}700}{0.009} + 1{,}759.5\left(4{,}848{,}411 - 1{,}142{,}800 \text{ x } 4.23 + \frac{1{,}142{,}800 \text{ x } 0.009}{2}\right) + \frac{19{,}011}{0.009} \text{ x } 361}$$
$$\mathbf{Ot = IDR\ 20{,}990{,}070{,}284}$$

The calculation is performed using 6 literacies with the following literacy values:

TABLE IV
PROPOSE AN R VALUE

Literacy 1	T0
Literacy 2	T0-0,001
Literacy 3	T0-0,002
Literacy 4	T0+0,001
Literacy 5	T0+0,002
Literacy 6	T0+0,003

The literacy calculation for the Ultrasil 7000 that has been carried out is then compared with the existing inventory costs. The comparison results can be seen in Fig. 7.

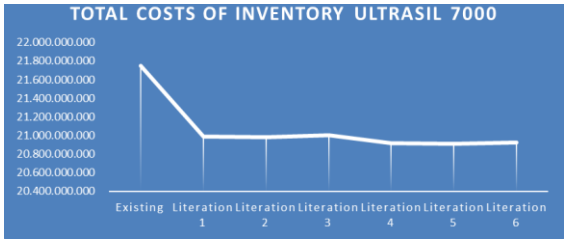

Fig. 7. Total costs of proposed inventory Ultrasil 7000

Based on Fig. 7, after calculating up to the sixth literacy, the optimal calculation result to determine the periodic review is literacy 5 with the proposed total cost of supplies of Ultrasil 7000 IDR 20,912,872,424 compared to the others.

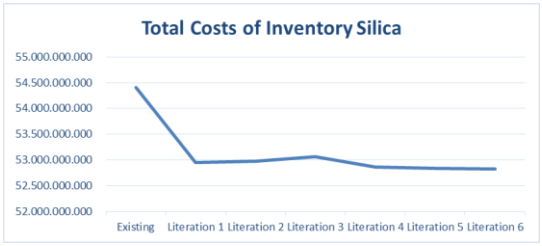

Fig. 8. Total costs of proposed inventory silica

Based on Fig. 8, after calculating up to the sixth literacy, the optimal calculation result to determine the periodic review is literacy 6 with the total cost of the proposed silica supply of IDR 52,821,664,202 which is the most optimal compared to the others.

2) Parameter Calculation (s,S)

At this stage, it aims to find the parameters of the periodic review inventory system s (Reorder Point) and S (Maximum Stock). Because the Ultrasil item has the largest inventory cost, an example of calculating the Ultrasil 7000 item using equations 7 to 16 is obtained as in Table 5.

TABLE V
RESULT PARAMETERS (R, S, S) PROPOSED CONDITIONS

Description	Classification	Proposed		
		Review Interval (Days)	Reorder point (Kg)	Maximum Stock (Kg)
Ultrasil 7000	A	2	1.142.175	1.142.175
Pai Ian Hwa CC	A	1	2.164.876	2.164.876
Silica VN3	A	3	262.234	281.134
Hisil 255 G	B	5	95.169	114.069
Titanium Dioxide SA-100	B	8	36.058	46.058
Zeosil 1165 MP	B	4	151.713	168.213
Neolight-SS	C	4	121.344	137.344
Calcium Carbonat Light	C	32	1.460	1.631
Novelight TT	C	6	34.968	54.968
Magnesium Carbonat Light	C	10	14.622	19.622
Crown Clay	C	9	15.563	25.563

D. Proposed Service Level

The level of service is influenced by several factors, including the amount of incoming goods, average inventory, and safety stock. After obtaining the periodic review parameters (R, s, S), then calculating the service level for each silica item. The Ultrasil 7000 service level calculation is used as a sample to calculate the service level of the proposed condition.

N : 432 Kg
XR+L : 981,550 Kg

$$\eta = 1 - \frac{N}{XR + L} x100\%$$

$$\eta = 1 - \frac{432\ Kg}{981{,}550\ Kg} x100\%$$

$$\eta = 99.96\ \%$$

TABLE VI
PROPOSED SERVICE LEVEL

Description	Inventory Shortage (N)	Average Demand During Review Time and Lead time (XR+L)	Service Level (η)
	Kg	Kg	%
Ultrasil 7000	432	981,550	99.96%
Pai Ian Hwa CC	876	2,095,937	99.96%
Silica VN3	179	243,113	99.93%
Zeosil 1165 MP	187	115,671	99.84%
Hisil 255 G	109	90,187	99.88%
Titanium Dioxide SA-100	44	28,000	99.84%
Neolight-SS	202	124,166	99.84%
Magnesium Carbonat Light	30	12,178	99.75%
Crown Clay	191	15,393	98.76%
Novelight TT	420	40,845	98.97%
Calcium Carbonat Light	9	1,375	99.35%
Average			99.64%

From Table 6, it can be concluded that with the periodic review method (R, s, S) the suggested service level value is 99.64%.

E. Analysis of Total Cost of Existing Inventories and Proposals

After obtaining the results of the periodic review (R, s, S) proposed inventory policy parameters, the next step is to calculate the total cost of the proposed inventory which then becomes a comparison of the total cost of the existing inventory.

1) Ordering Costs

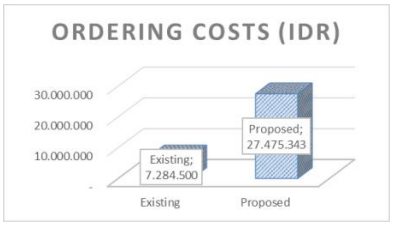

Fig. 9. Comparison of the cost of ordering between the existing and proposed conditions

Fig. 9 shows the comparison of the cost of existing and proposed orders. The total value of the reservation cost for the existing condition is IDR 7,284,500, while the total cost for the proposed order is IDR 27,475,343. The total cost of ordering increased 277.18% from existing conditions.

2) Storage and Handling Costs

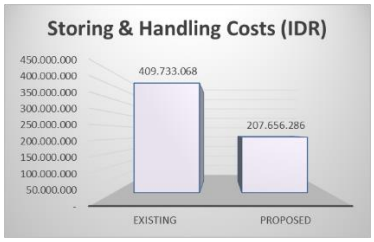

Fig. 10. Comparison of the Cost of Storing & Handling between the Existing and Proposed Conditions

Fig. 10 shows a comparison of the storage and handling costs between the existing and proposed conditions. The total value of storage and handling costs in the existing conditions is IDR 409,733,068, while the total cost of the proposed order is IDR 207,656,286. There is a saving and handling cost savings of 49.32% from existing conditions.

3) Shortage Costs

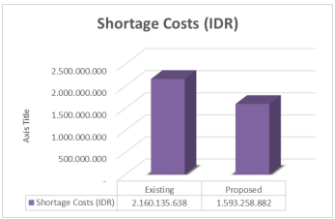

Fig. 11. Comparison of the cost of shortage between the existing and proposed conditions

Fig. 11 shows a comparison of the cost of shortages between the existing and proposed conditions. The total cost of shortages in the existing conditions is IDR 2,160,135,638, while the total cost of the proposed order is IDR 1,593,258,882. There is a shortage cost, savings of 26.24% from existing conditions.

4) Total Inventory Costs

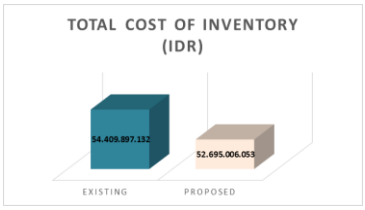

Fig. 12. Comparison of the total cost of inventory between the existing and proposed conditions

Fig. 12 shows a comparison of the total cost of inventory between the existing and proposed conditions. The total cost of inventory in existing conditions is IDR 54,409,897,132, while the total cost of the proposed inventory is IDR 52,695,006,053. There is a total cost savings of 3.15% from existing conditions or IDR 1,714,891,079.

V. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

This research made based on the theories that have been studied. From the results of the study and data analysis carried out, it can be concluded that the performance of silica inventory control at Indonesian Leading Tire Manufacturer can be improved by implementing periodic review (R, s, S) policy parameters as shown in table V for each silica item. The proposed periodic review (R, s, S) policy can provide savings in the total inventory costs of silica by 3.15% or IDR 1,714,891,079 from existing conditions and a service level value of 99.96%.

B. Recommendations

- Creating an Android-based application that can assist companies in controlling the inventory level of raw material products.
- Creating a supplier database so that the company can find out a list of suppliers for each material before procuring materials.
- Researchers expect further studies on the performance of inventory control in the spare parts warehouse to improve the performance of controlling spare parts inventories.

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