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PURCHASING CONSORTIUM SYSTEM USING *COMMON REPLENISHMENT EPOCH* (CRE) MODEL BY DESIGNING MOBILE INFORMATION SYSTEM FOR SMALL and MEDIUM ENTERPRISES (SMEs)

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ABSTRACT

Purchasing consortium is a strategy to improve the purchasing competitiveness of a company. It's known in this research that the parameter that mostly affect the total amount of purchasing system is the amount of member's demand, the number of members, and the discount fraction. Besides that, the allocation of saving that is given to SMEs is 51.57% and 21.22% for agent due to the reduction of coordination cost in this research. This research has produced mobile information system which is able to help in coordination and database saving for consortium agent and SMEs. This information system is able to provide information in the form of best replenishment time for SMEs based on the theory of Common Replenishment Epoch (CRE).

Keywords: purchasing consortium, CRE, mobile information system

1. INTRODUCTION

Purchasing Consortium (PC), or commonly known as buying consortium, is a kind of horizontal cooperation system to aggregate demand of a good to do single ordering to reach the purpose. By doing single order in big amount, the consortium agent that represent SMEs will be able to purchase raw materials in an economic scale and have big bargaining power to negotiate the price with supplier.

Unfortunately, there's a problem in implementing purchasing consortium due to the different criteria of suppliers owned by each SME. Besides that, Heijboer (2003) emphasized that there's a tendency in purchasing consortium that one member will feel exploited by other member. This tendency is caused by the lack of trust between SMEs. Therefore, to minimize that tendency, an independent consortium is needed to communicate and coordinate each SME so they will agree to do cooperation through supply coordination.

This problem can be solved using *Common Replenishment Epoch* (CRE) model. CRE is a coordination policy of a factory or vendor that has some buyer/retailers to do replenishment at the same time. Therefore, vendor can combine replenishment order for buyer that has the same interval replenishment so it can reduce transportation costs, order processing costs, and delivery costs.

To support purchasing consortium system, a mobile information system design is needed as a tool for decision making and database that can support the activity of consortium agent so hopefully, the efficiency, effectivity, and productivity will be increased by doing purchasing Consortium (PC) system.

2. THEORETICAL BACKGROUND

2.1 Purchasing Consortium

The cooperation form that mostly done in increasing purchasing efficiency is supplier coordination or vertical integration. The horizontal cooperation within buyers hasn't been a main focus for industrial sectors (Essig, 2000). One of the forms of horizontal integration is implementing purchasing consortium.

Nowadays, the development of purchasing concept for strategic activities will affect to the development of PC concept. Essig (2000) stated that the cooperation concept in purchasing has to shift to strategic perspective which is consortium sourcing. Essig (2000) defines consortium sourcing consept as a combination between symbiosis and strategy. The symbiosis explains the beneficial cooperative relation, while strategy shows the strategic level of purchasing

activity. So, the consortium sourcing concept can be defined as a form of strategic cooperation between PC members in more than one level activity in purchasing. The concept of consortium sourcing is shown in the figure below.

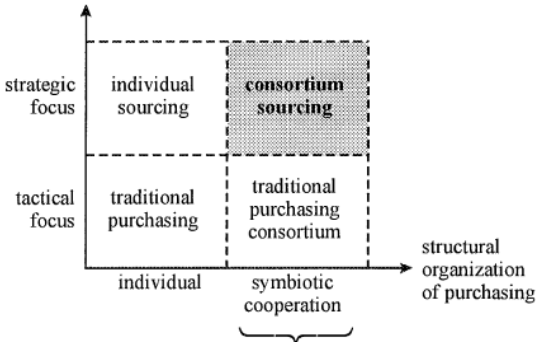

Figure 1 Cooperation Concept in Purchasing Consortium
Source: Michael Essig, 2000

2.2 Cost Concept in Purchasing Coordination

Based on Tersine (1994) in *Principles of Inventory and Material Management*, total cost in purchasing consists of 3 components, those are purchase cost, order cost, and holding cost which can be formulated as the sample below.

$$\text{Total Cost (TC)} = \text{purchase cost} + \text{order cost} + \text{holding cost}$$

$$TC(T) = PR + mC + \frac{PFR}{2m} = PR + \frac{C}{T} + \frac{PFRT}{2} \qquad (1)$$

Whereas:
P : purchasing price per item
R : amount of items purchased in a year
C: ordering cost for each ordering
$T = \frac{1}{m}$: interval of ordering period
m : amount of order in a year
F : holding cost per year which is the fraction of purchasing price (*P*)

The first differential of total cost to ordering time interval (T) is set to be zero to get the minimum total cost formula. This differential will result the T optimum formula (T*) which is called Economic Order Interval (EOI). The formula of EOI is formulated below:

$$T^* = \sqrt{\frac{2C}{PFR}} \qquad (2)$$

After getting the optimum interval ordering period, the optimum amount of items purchased (Q*) for each order is formulated below:

$$Q^* = RT^* = R\sqrt{\frac{2C}{PFR}} = \sqrt{\frac{2CR}{PF}} \qquad (3)$$

The formula above can be applied only when the parameter such as price, number of purchased items, and cost of each order are known and have constant value.

Purchasing coordination also can occur when supplier offers discount for purchasing in big amount. In this condition, the opportunity of inter-buyer coordination in purchasing will increase. The consolidation of purchased items will decrease the price of product and automatically decrease the purchasing price. Fazel et al (1998) in Krichen et al (2010) formulated the discount concept where the decreasing of price is linear to amount of purchased items as follow:

$$P = \begin{cases} P_0 & Q_i = 0 \\ P_0 - p \times Q_i & 0 < Q_i \leq Q_{max} \\ P_{min} & Q_i > Q_{max} \end{cases} \qquad (4)$$

Whereas P_0 is price per unit product in the market, p is discount rate given for purchasing more than 0 - Q_{max} unit products. More than Q_{max} purchasing will get the minimum price P_{min} because supplier is no longer able to give more discount. From the previous formula, Q_{max} can be formulated below:

$$Q_{max} = \frac{P_0 - P_{min}}{p} \qquad (5)$$

The purchasing cooperation can be broaden by doing cooperation in product delivery. Sarmaha et al (2008) modelled the purchasing coordination cost between one supplier with many heterogenic buyers. The *common replenishment time* scenario used to get saving for the same vehicle usage to deliver items from supplier to all buyers where the delivery costs will be paid by buyers. The amount of saving obtained is shown form the difference between total purchasing costs with coordination and total purchasing costs without coordination. The model of total purchasing costs where the delivery costs charged to buyer according to Sarmaha et al (2008) is formulated as follow:

TC = Ordering costs + Holding costs + Delivery costs

$$TC = \sum_{i=1}^{n} \frac{A_i}{T} + \frac{1}{2}\sum_{i=1}^{n} h_{bi} D_i T + \frac{C_c}{T} \qquad (6)$$

Where the optimum purchasing period with coordination is formulated as follow:

$$T^* = \sqrt{\frac{2(\sum_{i=1}^{n} A_i + C_C)}{\sum_{i=1}^{n} h_{bi} D_i}} \quad (7)$$

Whereas:

A_i : ordering cost paid to supplier for each order for buyer i

T : purchasing period with coordination (*common replenishment time*)

T^* : optimum purchasing period with coordination (*common replenishment time*)

h_{bi} : holding cost for each product per year for buyer i

D_i : demand per year for *buyer* i

C_c : biaya transportasi per pengiriman

This model assumed that there are so many buyers with small order quantity for each buyer. There's only one transportation cost for each delivery without considering the order quantity and delivery distance.

2.3 Common Replenishment Epoch

Nowadays, companies started to realize the importance of being focus in supply chain management.

This is happened because the inventory management with supply chain management concept will result more efficient in cooperation and coordination. One of the approaches based on cooperation and coordination is Common Replenishment Epoch (CRE) which is developed by S.Viswanathan and Rajesh Piplani. CRE includes in single vendor multiple buyer system. The Common Replenishment Epoch concept aimed to do coordination in inventory management between buyer/retailer in order to have the same replenishment time. The vendor will decide the basic interval replenishment (T0) where (T0) is minimum interval time to buyer to do replenishment order. Replenishment order can be done daily, weekly, or monthly (x/365, /x/52, x/12). Therefore, vendor will have opportunity to merge *replenishment order* from *buyer* that has the same interval *replenishment* so there will be saving in transportation cost, ordering cost, and delivery cost, and also set up cost.

The amount of discount and basic interval replenishment time stated by vendor so buyer will receive *Common Replenishment Epoch* strategy as formulated below:

$$Ming_O^C = \mathrm{A_s}/\ \mathrm{T_o} + \sum_{i=1}^{m} (DiZ + (\frac{Ai}{niTo}) \quad (8)$$

The formula developed by Viwanathan and Piplani above only applicable when the demand is *deterministic*. In the following journal, Feng and Viswanathan developed a formula that is applicable for stochastic demand. For the stochastic demand, the total costs formulation given for SME after *Common Replenishment Epoch* application is:

$$g_i^C = \frac{K_i}{n_i T_0} + \frac{1}{2} n_i T_0 \mu_i h_i + h_i z_i \sigma_i \sqrt{LT_i + n_i T_0} \quad (9)$$

While the discount given for each SME will follow the formulation below.

$$Z_i = \frac{1}{\mu_i}\left(\frac{K_i}{n_i T_0} + \frac{1}{2} n_i T_0 \mu_i h_i + h_i z_i \sigma_i \sqrt{LT_i + n_i T_0}\right) - (1 - S)\left(\sqrt{2\mu_i K_i h_i} + h_i z_i \sigma_i \sqrt{LT_i}\right) \quad (10)$$

2. 4 Information System Design

The helper tools are needed in designing an information system to describe the mechanism of the information system. The helper tools information system design used in this research are *data flow diagram*, *entity relationship diagram, use case diagram*, and *activity diagram*.

- The data flow diagram is used to develop a basic concept of an information system Data flow diagram is illustrated due to the data flow in system (Kendall, 2005). Data *flow diagram* will make the conceptual model building easier and will make easier to know the relationship between element and data.
- *Entity Relationship Diagram* (ERD) is a diagram that explains the involvement of inter-data relation in a group of database (Kadir, 2002).
- *Use case diagram* is used to build information system model based on user's point of view (Azis, 2005).
- *Activity diagram* is used to draw the business process and operational flow of a system. Activity diagram usually shows the demand of operation, steps in business process, or overall business process

3. RESEARCH METHODOLOGY

The notation used in purchasing strategy model development in Purchasing Consortium (PC) are as follows:

o Index for *supplier*

i, j Index for *buyer*, $i \neq j$

N	Members of PC
R_i	Demand amount of member *i*
R	Total demand of PC member
μ	Average demand
σ_i	Standard deviation of member *i* demand
σ	Standard deviation of aggregate demand of PC
Po	Basic price per unit of product
P_{min}	Minimum product price offered by supplier
p	Discount rate given by supplier
P	Price per unit of product
C_o	*Order-preparation cost* (*supplier*)
C_p	*Order-preparation cost* by PC
C	PC Agent operational cost
H_b	Holding costs for member
Q_i	*Order quantity* for member *i*
Q	*Order quantity* for PC
S	Fixed costs for vehicle rent
s	*Rate* of delivery variable cost
D_{oi}	Distance between *supplier* and member *i*
D	Delivery distance
L_o	*Lead time* of processing *supplier*
L_i	*Lead time* of processing to PC
B	Cost per *backorder* unit
$E(X-r)^+$	The expectation of inventory shortage/ cycle
L	The penalty of different *replenishment* time
1-β	*Service level* of member *i*
$1-\beta_P$	*Service level* of PC

In the first strategy (pooled pricing), the PC member can decide the *order quantity* and optimum *replenishment* freely, so there will be no Penalty Cost due to the lateness (BL). Here are the formulas used for 1st strategy:

- Purchasing cost (BB)
  For $0 < Q \leq Q_{max}$
  $$BB_i = PQ_i = (P_0 - pQ_i)R_i$$
  For $Q > Q_{max}$
  $$BB_i = PQ_i = P_{min}R_i \quad (11)$$
- Ordering Cost (BP)
  $$BP_i = m_i(C_o + C_p) = \frac{R_i}{Q_i}(C_o + C_p) \quad (12)$$
- Delivery Cost (D)
  $$BD_i = m_i(S + s\,.2d) = \frac{R_i}{Q_i}(S + s\,.2d_{0i}) \quad (13)$$
- Holding Cost (BS)
  $$BS_i = H_b\left(\frac{Q_i}{2} + k\sigma\sqrt{L_o + L_i}\right) \quad (14)$$
- Shortage Cost (BK)
  $$BK_i = B\frac{R_i}{Q_i}E(X-r)^+ = BGu(k)\frac{R_i}{Q_i}\sigma\sqrt{L} \quad (15)$$
- Operational Cost (BO)
  $$BO_i = \frac{c}{n} \quad (16)$$

The total purchasing cost for member i when applying the 1st strategy is formulated as

$$(TC_i) = \mathrm{BB} + \mathrm{BO} + \mathrm{BP} + \mathrm{D} + \mathrm{BS} + \mathrm{BK} \quad (17)$$

While in the 2nd strategy, which is pooled purchasing, there might be Penalty Cos due to the lateness created by the difference between early *replenishment* member and *replenishment* period in PC.

When the 1st strategy, the counting of total cost is done separately in each member, then the total cost in the 2nd strategy is counted together by aggregating all member's demand. Here are the formulas used in 2nd strategy:

- Purchasing Cost (BB) and Ordering Cost (BP)
  For $0 < Q \leq Q_{max}$
  $$BB = PR = (P_0 - pQ_i)\sum_i^n R_i \quad (18)$$
  For $Q > Q_{max}$
  $$BB = PR = P_{min}\sum_i^n R_i \quad (19)$$
  $$BP = \sum_{i=1}^n \frac{c}{n} + \frac{\sum_{i=1}^n R_i}{Q}(C_o + nC_p) \quad (20)$$
- Delivery Cost (BD)
  $$BD = \frac{R}{Q}(n.S + s\,.2d) = \frac{\sum_i^n R_i}{Q}(n.S + s\,.2\sum_i^n d_{0i}) \quad (21)$$
- Holding Cost (BS) dan Shortage Cost (BK)
  $$BS = H_b \times I = H_b\left(\frac{Q}{2} + k\sigma\sqrt{L_o + \sum_{i=1}^n L_i}\right) = H_b\left(\frac{Q}{2} + k\sigma\sqrt{L_o + nL_i}\right) \quad (22)$$
  $$BK = BGu(k)\frac{R}{Q}\sigma\sqrt{L_o + \sum_{i=1}^n L_i} = BGu(k)\frac{R}{Q}\sigma\sqrt{L_o + nL_i} \quad (23)$$
- Lateness Penalty Cost (BL)
  $$BL = \sum_{i=1}^n BL_i = \sum_i^x l(T_{PC} - T_i) = l(xT_{PC} - \sum_i^x T_i) \quad (24)$$
- PC Operational Cost (BO)
  $$BO = \sum_{i=1}^n BO_i = \sum_{i=n}^n \frac{c}{n} = c \quad (25)$$

The total purchasing cost for member I when applying the 2nd strategy can be written as

$$(TC_i) = \mathrm{BB} + \mathrm{BO} + \mathrm{BP} + \mathrm{D} + \mathrm{BS} + \mathrm{BK} + \mathrm{BL} \quad (26)$$

4. RESULT AND DISCUSSION

A PC agent will consolidate the demand amount of several companies or working units that have become its member and represent its members in doing purchasing activity to supplier to reach the economic scale due to discount mechanism decided by supplier. To minimize the total purchasing system cost, the voting of correct in purchasing activity management in PC is needed. There will be 2 kinds of cooperation

strategies, those are *Pooled Pricing* (1st strategy) and *Pooled Purchasing* (2nd strategy).

Here are the total costs incurred in SMEs' existing condition before applying the improvement strategy:

Table 1 Total Costs Incurred in SMEs' Existing Condition

SME	Total Operational Cost (Rp/Year)	Material Purchasing Cost (Rp/Year)	Total SME's Cost (Rp/Year)
SME 1	2,425,650	993,810,000	996,235,650
SME 2	2,403,125	913,225,500	915,628,625
SME 3	2,058,875	775,230,000	777,288,875
SME 4	3,712,125	1,747,460,000	1,751,172,125
SME 5	770,475	126,340,500	127,110,975
SME 6	1,495,850	373,410,000	374,905,850
SME 7	1,173,375	238,500,000	239,673,375
SME 8	988,5	172,608,000	173,596,500
SME 9	1,561,625	520,720,000	522,281,625
SME 10	2,561,650	1,004,899,200	1,007,460,850
Total	19,151,250	6,866,203,200	6,885,354,450

Based on table 1, it's known that SMEs' total operational cost is Rp 19.151.250 while SMEs' total material purchasing cost is Rp 6.866.203.20. So, the overall total cost is Rp 6.883.846.113 per year.

The improvement design with scheme 1 to decide each SME's order policy is based on each SME's *Economic Order Quantity* (EOQ). In the existing condition, each SME do purchasing only based on the stock level where ordering is done when the stock has almost run out.

Table 2. Total Costs of System in Improvement 1 Scheme

SME	Total SME's Cost (Rp/Year)	Total Agent Cost (Rp/Year)
SME 1	2,243,012	3,360,000
SME 2	2,226,108	3,280,000
SME 3	1,986,838	2,960,000
SME 4	3,057,548	4,400,000
SME 5	784,953	1,280,000
SME 6	1,442,509	2,080,000
SME 7	1,057,790	1,680,000
SME 8	919,207	1,440,000
SME 9	1,592,186	2,400,000
SME 10	2,332,761	3,440,000
Total	17,642,913	26,320,000
System Cost	43,962,913	

Based on table 2, the total costs in improvement 1 scheme is Rp 43.962.913. The SMEs' total operational costs in improvement 1 scheme is lower than the total operational costs in existing condition. Even the total costs in scheme 1 is lower, there's still an opportunity to get lower cost by applying CRE (improvement 2 scheme). The agent will set the basic *interval replenishment for* all SMEs. Then, each SME will have the right to determine its *interval replenishment* which is the multiple of basic *interval replenishment* that has been assigned by agent.

Besides that, determining basic *interval replenishment* will enable agent to decrease the major order processing cost charged to each SME, especially for transaction cost. The agent will also determine the discount method that is used as improvement scenario in this research. The inclusive and selective method is used for discount method. The scenarios that will be used in this research are as follows.

- Scenario 1: To = 1 day with inclusive discount method
- Scenario 2: To = 1 week with inclusive discount method
- Scenario 3: To = 2 weeks with inclusive discount method
- Scenario 4: To = 4 weeks with inclusive discount method
- Scenario 5: To = 1 day with selective discount method
- Scenario 6: To = 1 week with selective discount method
- Scenario 7: To = 2 weeks with selective discount method
- Scenario 8: To = 4 weeks with selective discount method

Here is the saving calculation for SME, agent, or system using the chosen S for each scenario.

Table 3. Recapitulation of Saving for Agent, SME, and System in Each Scenario

Skenario	Metode Dikson	To	Nilai S Terpilih	Penghematan UMKM (%)	Penghematan Agen (%)	Penghematan Sistem (%)
Skenario 1	Inclusive	1 Hari	0.092	9.19%	10.08%	9.72%
Skenario 2		1 Minggu	0.23	22.95%	23.68%	23.39%
Skenario 3		2 Minggu	0.516	51.57%	21.22%	33.40%
Skenario 4		4 Minggu	0.142	14.24%	28.72%	22.91%
Skenario 5	Selective	1 Hari	0.092	4.94%	15.00%	10.96%
Skenario 6		1 Minggu	0.23	22.95%	23.68%	23.39%
Skenario 7		2 Minggu	0.516	49.27%	22.41%	33.19%
Skenario 8		4 Minggu	0.142	14.24%	28.72%	22.91%

Based on table 4, the recapitulation of saving after CRE, the most minimum system cost is gathered by applying scenario 3 with To = 2 weeks (0.03835 year). The total SME cost using scenario 3 is Rp 8,544,702.00 with the detail as follow.

Table 5. Total Operational Cost after Improvement

SMEs	Existing Operational Cost (Rupiah/Year)	After Improvement Operational Cost (Rupiah/Year)	Operational Saving (%)
SME 1	2,425,650	1,086,321	55.20%
SME 2	2,403,125	1,078,134	55.10%
SME 3	2,058,875	962,253	53.30%
SME 4	3,712,125	1,480,812	60.10%
SME 5	770,475	380,163	50.70%
SME 6	1,495,850	698,627	53.30%
SME 7	1,173,375	512,302	56.30%
SME 8	988,5	445,184	55.00%
SME 9	1,561,625	771,117	50.60%
SME 10	2.561,650	1,129,788	55.90%

Based on table 4, the saving obtained by SME after improvement compared to the existing condition can reach 50.6% - 60.1% with the average saving 55.4%.

After that, the material order scheduling for each SME is based on CRE scenario that give minimum system cost, which is the scenario 3 with To = 2 weeks/0.03835 year. Therefore, the delivery scheduling time based on each SME's *interval replenishment* when applying scenario 3.

Table 6 Total Material Costs after Improvement

SME	Existing Material Cost (Rp/Kg)	Material Cost after Improvement (Rp/Kg)	Material Cost Saving (%)
SME 1	10000	8883	11.20%
SME 2	9500		6.50%
SME 3	10000		11.20%
SME 4	10000		11.20%
SME 5	9500		6.50%
SME 6	10000		11.20%
SME 7	10000		11.20%
SME 8	9600		7.50%
SME 9	10000		11.20%
SME 10	9600		7.50%

Based on the table above, the saving percentage in each SME is different. There's approximately 6.5% - 11.2% saving after improvement, with the average saving 9.8%.

After that, the information system is designed to produce mobile information system in Android Operationg System. The SMEs and consortium agent will be the user for this information system. The establishment for this information system will simplify coordination between SME and consortium agent in ordering materials. This information system will be integrated by internet.

The usage of this mobile information system will help SME and agent in recording, where SME previously doesn't have proper recording system either in recording materials quantity purchased or the costs needed to purchase. These information will be recorded easily in the information system. The SMEs will no longer need to pay the transportation costs to do material purchasing. SME will be able to do material ordering without going out of office. The order information will also be sent real-time. Therefore, the agent will process the order faster.

The procedure from login process up to materials arrival confirmation is drawn in figure 5.1. Here are the explanations of figure 5.1.

1.a1. SME input the username and password
1.a2 SME logged in to information system
1.b1 Choosing Purchasing Menu
1.b2 Creating transaction note for materials ordering
1.b3 SME will choose materials preference that will be
2.a1 The agent input username and password
2.a2 The agent logged in to information system

2.c1 The agent receive order by the entry of notification
2.c2 The agent will process order
2.c3 After collecting order and processing it, the agent will order to vendor
3.c1 Vendor receive order from consortium agent
3.c2 Vendor will release delivery order to deliver the order
3.d1 Vendor will deliver the order directly to SME's address
1.d1 SME will receive its order
1.d2 The SME will do confirmation through the information system due to the order arrival
1.d3 The SME will do payment by transfer. SME won't be able to order again if the payment can't be done as the deadline If this happens, SME will have to confirm the payment first.
1.d4 Agent will receive confirmation about order arrival and payment from SME.

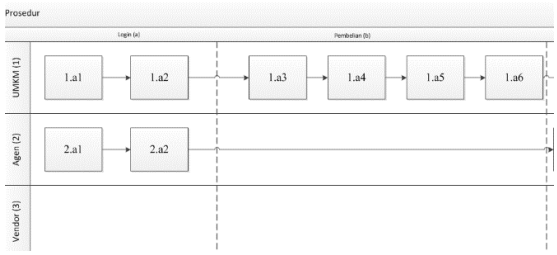

Figure 2 Flow Diagram of Information System Usage

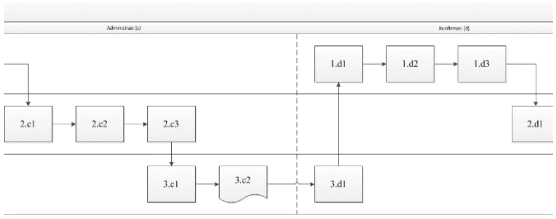

Figure 3 Flow Diagram of Information System Usage (Cont')

5. CONCLUSION

- The basic optimum replenishment time in purchasing consortium in SME is 2 weeks due to the most minimum total consortium agent and SME coordination cost compared to other basic replenishment time.
- The saving allocation due to coordination cost saving is 51.57% for SME and 21.22% for agent. The saving is obtained by comparing the scenario 2 that use CRE and scenario 1 that use EOQ.
- The saving obtained by SME is divided into two, those are operational saving due to the CRE application and saving due to material purchasing using coordinated purchasing. Total operational saving obtained is Rp.10.606.458 or 55.4%, while the material purchasing saving is Rp 685.376.514 or 9.8% compared to the existing condition before applying purchasing consortium.
- This research has produced mobile information system that help in coordination and consortium and SME's database saving, giving information about the best replenishment for SME due to the CRE, and able to give information about the discpunt granted to SME.

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