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An improvement of supplier-manufacture inventory system integrated with stochastic periodic review modeling for SMEs in Indonesia

Abstract. SME LCR is one of the handicrafts SME in Yogyakarta, Indonesia. This SME produces several handicraft products such as storage baskets with various variants, and furniture. The process of ordering raw materials for SMEs is carried out when there is a demand for incoming products with the order quantity based on the raw material needs in meeting product demand. This study intends to provide recommendations for improving raw material governance to overcome demand fluctuations during the lead time and reduce the total cost of supply chain inventory by implementing an integrated inventory system. To meet the study aim, the EOQ Probabilistic P system (Period Review Method) is utilized. The P inventory model is distinguished into two models namely model P with backorder and model P with lost sales. Next, the Purchase Cost (Ob) and Procurement Costs are applied to the P model. The research method comprises through 3 stages: the pre-field stage, field stage, and the advanced stage (laboratory analysis, data analysis, and reporting). Given the results regarding banana and mendong raw materials supply, it can be observed that for banana raw materials, the reorder time interval that can generate the minimum total inventory cost for banana raw materials is 0.1470 years or 53 days with a total cost of IDR 263,721,081.72. Moreover, it is seen that the suggested model generates the minimum total cost of supply chain inventory compared to the SME policy and the individual model, which justifies the economic feasibility of this model.

Keywords: Inventory System; Supplier; Manufacture; Sales; Supply Chain; Craft Business; Handicraft; Banana Raw Materials; Mendong Raw Materials
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1. Introduction

Currently, the craft business has increased in various variations and various forms of handicrafts both from household industrial equipment to women's and men's fashion accessories.

The increase in the variety of crafts goes hand in hand with the development of creativity of the craftsmen (Harwiki & Malet, 2020). Also, it is based on the impact of competition in competing to create superior products and favored by the public in the market segment (Juergensen et al., 2020).

One of the craft SMEs that is still operating and still active in distributing goods to various places is SME LCR. This SME is engaged in handicrafts (de Sousa Jabbour et al., 2020). Based on the results of interviews conducted with SME owners, it is said that most recent booking raw materials are done when there is a demand for products with the number of orders based on the needs of raw materials to meet the demand for products. Also, the quantity of the order takes into account the remaining stock of raw materials previously in the warehouse (Mittal et al., 2020). This may result in the production process being hampered if the inventory in the previous warehouse has run out or the demand exceeds the amount of inventory stock in the warehouse (Chowdhury & Shumon, 2020)it is believed that small- and medium-sized enterprises (SMEs. While new orders are made when there is a demand to cause a waiting time before the production process runs. The raw materials needed by SME LCR to produce this product consists of two materials, namely the main material and supporting materials (Tsilika et al., 2020). The main ingredients are banana stems or commonly referred to as Banana SME, Mendong, and Water Hyacinth.

Currently, the products that are in great demand by customers in the last one-year period are products made from Banana and Mendong. Hence, the need for raw materials is higher than other raw materials. Therefore, in this study, the authors will focus on two raw materials namely Banana and Mendong. Based on the results of interviews with SMEs, it is known that both SME supplier's banana and mendong not only serve one customer only. Both suppliers have customers from various SMEs who produce similar goods in the field of handicrafts (Mura et al., 2019). This results in increased competitiveness between customers so that a strategy is needed in the management of the supply chain of SMEs and suppliers. One strategy that can be used is the implementation of an integrated system that connects the two and coordinates. The problem that will be solved is how to implement an integrated system in managing raw materials in the SME supply chain so that the total cost managed by the supply chain becomes minimum (Shashi et al., further research is required to analyse the simultaneous effect that these two approaches have on both environmental and financial performance. Therefore, this paper investigates the relationships existing between leanness, process innovation, product innovation, environmental performance, and financial performance. To achieve this aim, we test the hypothesised model empirically using data from 374 Indian manufacturing SMEs. This paper builds upon structural equation modelling (SEM2019).

The integrated system results in cooperation between suppliers-manufacturing can be established in the long term to obtain a stable source of supply and demand (Sarkar et al., 2020). So, it can increase each other's profits. The integrated model of the single supplier-single customer, first developed by. The research obtained the results that the optimal booking time with the implementation of an integrated system can reduce the total cost of the supply chain (Sumadi et al., 2020). The main purpose of applying this method is to prosper both parties bet ween suppliers and manufacturers by minimizing inventory costs. Therefore, SMEs LCR needs to conduct integrated supply chain management to establish good cooperation with suppliers.

2. Research Methods

This study uses the EOQ Probabilistic P system (Period Review Method). The P inventory model is distinguished into two models, namely, model P with backorder and model P with lost sales. The difference between the two models lies in the cost of saving. In the case of backorders, inventory shortages can be met later to allow for negative inventory while in the case of lost sales inventory shortages are left alone so it is not possible to have negative inventory.

The method that will be used in this study is the P method which is the determination of the optimal order period with a backorder model.

The following cost components apply to the P model.

2.1. Purchase Cost (Ob)

This fee is obtained from the multiplication between the number of goods to be purchased according to the level of demand (D) with the purchase price per unit of material (c):

$$O_b = Dc \ . \quad (1)$$

2.2. Procurement Costs

The procurement fee is the cost of booking multiplied by the frequency of bookings made for one year. Here is a model of procurement costs systematically:

$$O_p = Af \ . \quad (2)$$

If each order is made during the period T, the model of ordering frequency per year is:

$$f = \frac{1}{T} \ . \quad (3)$$

In such a way, the procurement costs per year can be formulated as follows:

$$O_p = \frac{A}{T} \ . \quad (4)$$

2.3. Cost of saving

The storage cost is the cost of storing raw materials in units for one year multiplied by the inventory level in the warehouse for one year. Based on the elaboration of the formula about Nur Bahagia (2006), saving costs are made based on two cases of backorders and lost sales. Here is the cost of saving in the case of backorders:

$$O_s = \left(R - D_L + \frac{TD}{2}\right) r_b \ . \quad (5)$$

And the formulation for the lost sales case is as follows:

$$O_s = \left(R - D_L + \frac{TD}{2} + N\right) r_b \ . \quad (6)$$

With the value of N, namely the possibility of the number of ingredients that are not enough (Inventory Deficiency):

$$N = St.dv\sqrt{T+L}[f(Z_\alpha) - Z_\alpha \Psi(Z_\alpha)] \ , \quad (7)$$

where:

- The value of Z_α is the fixed value of sale;
- The values of $f(Z_\alpha)$ and $\Psi(Z_\alpha)$ are the saving and lost functions;
- L is the lead time.

2.4. Inventory Shortage Costs

In the P model, the possibility of inventory shortages can occur at any time. Therefore, safety stock is needed to control the shortage within the period $(T + L)$, namely during the reorder interval period plus the lead time. If the cost of each raw material that is less valuable C_u and the expected number of inventory shortages for one year is N_T, then the inventory shortage costs are as follows:

$$O_k = N_T C_u \ . \quad (8)$$

The N_T value is the amount of inventory deficiency during one cycle in one year as follows:

$$N_T = N\frac{1}{T} \ . \quad (9)$$

In such a way, the cost of the inventory shortage (O_k) is equal to:

$$O_k = \frac{C_u N}{T} \ . \quad (10)$$

The model formulation for the total cost of inventory in the P model is as follows:

$$TCP = O_b + O_p + O_s + O_k, \quad (11)$$

$$TCP = Dc + \frac{A}{T} + r_b \left[R - D_L + \frac{DT}{2}\right] + \frac{c_u}{T} N \ . \quad (12)$$

The P model inventory control mechanism with the Hadley-Whitin method is as follows. Calculating the T_0 value, the inventory model used is the Wilson model (or EOQ - Economic Order Quantity - system) as follows:

$$T_0 = \sqrt{\frac{2A}{Dr_b}} \ . \quad (13)$$

We find the values of α and R with the equation below:

$$\alpha = \frac{Tr_b}{c_u} \ , \quad (14)$$

$$R = D(T + L) + Z_\alpha \sqrt{T + L} \ . \quad (15)$$

Calculating the total cost of inventory Model P using the equation (12). Repeat step 2 by changing T_0 with $T_0 = T_0 + \Delta T_0$.

If the result is $(TCP)_0$ new is greater than $(TCP)_0$ initial iteration, Iteration of additions T_0 Stopped.

Then try with iteration reduction $T_0 = T_0 - \Delta T_0$ until found $T^* = T_0$ which provides the total cost value of the $(TCP)^*$ Minimum.

If the result is $(TCP)_0$ new is smaller than $(TCP)_0$ Early, Iteration additions $T_0 = T_0 + \Delta T_0$ continued and only stopped when $(TCP)_0$ new is greater than $(TCP)_0$ previously calculated. The price T_0 which provides the smallest total cost value $(TCP)^*$ is the optimal time lapse T^*.

3. Results And Discussion

3.1. Integrated Inventory Model

Properly managing the flow of materials/products is one of the main objectives of the supply chain. The right flow means not too late and not too early and the amount is following the needs which means minimizing the presence of overstock or out of stock. Product shortages or oversupply both negatively impact the supply chain (Keerthana et al., 2020). Therefore, supply chain management is required (Kouki et al., 2016). The inventory policy that offers this is an inventory policy with an integrated system (Xu et al., 2019).

The initial Inventory Model that will be used in this study is a model that has been developed based on an integrated concept. Based on research conducted by (Pazhani et al., 2016) inventory policy was developed by taking into account the cooperative relationship between suppliers and buyers so that there are decision variables involving supplier parameters. The purpose of the study was to create an integrated inventory policy that considers something thoroughly and brings together certain elements. In this condition, the elements that will be put together are inventory costs between the two parties, namely buyers and suppliers to improve good relations in the long term (Pooya & Pakdaman, 2018). In this study, there will be two models that will be discussed, namely individual inventory models and integrated inventory models, and will be used as a comparison of the total cost results of both parties, namely buyers (SMEs) and suppliers.

The cooperation relationship between vendor and buyer can be formulated as follows. First, the total annual cost for suppliers will be presented and will be part of the total overall inventory cost for suppliers and buyers.

3.2. Total Supplier Fees

The total annual cost of the supplier consists of setup cost per production run, processing cost per order, save cost, and opportunity interest loss (Li et al., 2020). The average inventory of suppliers per year is as follows:

$$\frac{DT_i}{2}\left[(n-1)\left(1-\frac{D}{P}\right)+\frac{D}{P}\right]. \quad (16)$$

And the cost of storing suppliers per year is:

$$r_s c = \frac{r_s DT_i}{2}\left[(n-1)\left(1-\frac{D}{P}\right)+\frac{D}{P}\right]. \quad (17)$$

Thus, the total inventory cost of suppliers for one year is:

$$TS = \frac{S+n_i F}{n_i T_i} + \frac{r_s DT_i}{2}\left[(n-1)\left(1-\frac{D}{P}\right)+\frac{D}{P}\right], \quad (18)$$

where:
i = 1 and 2 according to the case on the calculated inventory model.

3.3. Individual Inventory Models

This model treats buyers and suppliers as individual units i.e., determining the charging time interval does not take into account inventory costs from suppliers. The individual models to be used are Wilson's formula as follows:

$$TB_0 = \frac{D}{Q}A + \frac{Q}{2}r_b . \quad (19)$$

Based on the purpose of this study, the optimal value that will be determined is the integrated booking time interval, then substitution of Equation (20) to Equation (19) to obtain a value that will be partially lowered from TB_0 presented in a common form in the following way:

$$TB_0 = \frac{A}{T_{01}} + \frac{DT_{01}}{2}r_b . \quad (20)$$

Hence, we obtain:

$$T_{01}{}^* = \sqrt{\frac{2A}{Dr_b}} . \quad (21)$$

3.4. Integrated Inventory Model

An integrated model is an inventory model that considers inventory costs between buyers and suppliers. The optimal order time interval is derived from the total cost of buyer inventory plus supplier inventory costs. In the integrated inventory model developed, the main principle is to determine inventory policy by partially lowering the equation of the combined cost of buyers and suppliers (Atan et al., 2017). Modeling inventory costs that are different from the concept of the model resulted in researchers having to perform mathematically decreasing formulas that will be discussed in the discussion section.

The integrated model that will be derived consists of two models, namely the initial model (the initial model is a model that uses the Wilson method while the final model is a model that uses the periodic Review Method. In general, the total annual cost in the integrated model is as follows:

$$TAC = TB_1 + TV . \quad (22)$$

In this study, before entering the integrated model, it is known that the individual model is an inventory model without involving a supplier policy consisting of two models, namely the Wilson model and the P model. The comparison of the final result of the total inventory cost will define the individual and integrated model form and the impact of the integrated model on the inventory costs of both parties if applied (Barrett & Boyaval, 2018). Therefore, there are certain fundamental differences between the two models that make the total cost of inventory both different. The differences between the two models can be reviewed from the information system (Rosasco et al., 2020).

In the application of individual inventory models, the parties who play a role and set policies are sourced from one informant, namely SMEs. The data collected in setting inventory policy is in the form of cost data such as message costs, storage, shortages, and raw material costs.

Also, other data in the form of average raw material capacity in SME warehouses and historical data on the annual demand level is used.

The difference in the flow of information previously found in the role of informants is solved in the way presented below. In the integrated model, inventory policy involves not only information from SMEs but also from suppliers such as cost data (cost of storage, setup, and fixed cost), annual production rate, and frequency of shipments per order. The source of the information of the two models is what triggered the total difference in inventory between the two models.

3.5. Modification of Integrated Inventory Model

An integrated inventory model is a model that produces optimal inventory policies taking into account both buyer and provider costs. In this case, the buyer is an SME and the provider is a supplier of Banana and Mendong. This model is assumed for one buyer and one provider, therefore, the policy analysis that will be made in this study takes into account the values of parameters intended for one buyer and one provider. In this discussion, 2 integrated models are derived, namely, the initial model that produces and the final model that produces.

3.6. Model

This model is a model that is derived by the combined cost of inventory buyer-supplier with the total cost of buyer inventory (SME) using the Wilson model which is a model with a deterministic inventory system which is the opposite of the probabilistic inventory model and total inventory cost of supplier using Equations (2-7). Here is the total inventory cost of 1 SME and 1 supplier for one year:

$$TC_0 = Dc + \frac{A}{T_{02}} + \frac{DT_{02}r_b}{2} + \frac{S+nF}{nT_{02}} + \frac{r_s DT_{02}}{2}\left[(n-1)\left(1-\frac{D}{P}\right)+\frac{D}{P}\right]. \quad (23)$$

Simplification is performed $L_{(n)}$ and $V_{(n)}$ corresponds to Equations (24) and (25). The total cost (above will be minimum if eligible as follows) TC_0 is total cost of initial conditions:

$$\frac{dTC_0}{dT_{02}} = 0 \text{ and } \frac{d^2TC_0}{d^2T_{02}} > 0\ , \quad (24)$$

therefore, derivatives are carried out against T_{02} the $T_{02} = T_{02}{}^*$,

$$L_{(n)} = \frac{Dr_s}{2}\left[(n-1)\left(1-\frac{D}{P}\right)+\frac{D}{P}\right], \quad (25)$$

$$V_{(n)} = A + \frac{S+n_1F}{n_1}\ , \quad (26)$$

$$T_{02}{}^* = \sqrt{\frac{2V_{(n)}}{Dr_b+2L_{(n)}}}\ . \quad (27)$$

The model equation above will be used on model P to look for the value of the R and N parameters that will be used to calculate the value T_{A}.

3.7. Model $T_{A2}{}^*$

This model is the final model after the Hadley-Whitin method is applied. From the results of calculations with the Hadley-Whitin method, R and N values are obtained from the iteration model with the lowest or optimal total cost. The difference between this model and the previous model is found in the total cost of SME inventory (Total Cost Annual) will consider the inventory system that is probabilistic with the use of the model P backorder. Things considered on the P model are the cost of deficiency (C_u), reorder point (R), and safety stock (ss). Here is the total inventory cost of SMEs and 1 supplier for one year:

$$TC_A = Dc + \frac{A}{T_2} + r_b\left(\frac{DT_2}{2} + R - D_L\right) + \frac{c_u N}{T_2} + \frac{S+nF}{nT_2} + \frac{r_s DT_2}{2}\left[(n-1)\left(1-\frac{D}{P}\right)+\frac{D}{P}\right]. \quad (28)$$

Simplification is performed $L_{(n)}$ and $V_{(n)}$ corresponds to Equations (25) and (26). Similar to the previous model, the total cost (above will be minimum if it meets the following requirements:

$$\frac{dTC_A}{dT_{A2}} = 0 \tag{29.1}$$

and

$$\frac{d^2TC_A}{d^2T_{0A}} > 0 \ , \tag{29.2}$$

therefore, derivatives are carried out against T_{A2} the $T_{A2} = T_{A2}{}^*$,

$$T_{A2}{}^* = \sqrt{\frac{2V_{(n)}+2c_uN}{Dr_b+2L_{(n)}}} \ . \tag{30}$$

3.8. Comparison Analysis Results with SME Policy Results

Based on the results of the inventory analysis of model P with the results of SME policy analysis, it can be done a comparison of results to find out if there is a change in the total cost for the proposed integrated inventory model. The comparison of total cost results will determine the results of inventory analysis can be said to be successful or reach the most optimal rebooking time from the previous inventory policy (Chiu et al., 2016). The comparison results for Banana and Mendong raw materials will be shown and discussed below as the result of our studies. In Table 1, the comparison for banana raw material is given.

Table 1:
Comparison for banana raw materials

Information	SME Policy	Model P with payment delay	
		Model 1	Model 2
T	0.0278	0.0566	0.1470
Day	10	21	53
n	48	48	48
TB	Rp. 263,737,375.19	Rp. 263,393,811.44	Rp. 263,311,629.54
TS	Rp. 1,372,652.41	Rp. 719,242.05	Rp. 409,452.18
TC	Rp. 265,110,027.60	Rp. 264,113,053.50	Rp. 263,721,081.72
PTCR (%)		0.38	0.52

Source: Compiled by the authors

From the analysis of banana raw material comparison obtained in Table 1 known total inventory costs are the minimum resulting from model 2 with a total cost of Rp. 263,721,081.72 and a decrease in total inventory costs to SME policies is 0.52%. SME costs and supplier costs in model 2 decreased from the other two models, namely in SME policy and model 1. In the integrated model 2, the optimal rebooking time interval is 0.1470 years or 53 days.

Here is the difference in cost between model 1 and model 2 against SME policy in Table 2.

Table 2:
Comparison of cost difference of banana raw materials

Information	Model 1 Against SME needs	Model 2 Against SME needs
TB	Rp. 343,563.75	Rp. 425,745.65
TS	Rp. 653,410.35	Rp. 963,200.23
TC	Rp. 996,974.10	Rp. 1,388,945.88
PTCR (%)	0.38	0.52

Source: Compiled by the authors

From the table of cost differences (Table 2), it is known that the cost changes that occur in each model show a reduction or decrease in total inventory costs in mode 1 of Rp 996,974.10 and on model 2 of Rp 1,388,945.88. Based on the comparison of the two models can be seen the model that produces the minimum cost is model 2, and it is an integrated model (Table 3).

Results of comparative analysis of raw materials the medong in Table 3, known total inventory costs are the minimum resulting from model 2 with a total cost of Rp. 147,902,654.98 and a decrease in total inventory costs to SME policies is 0.86%. Just like the banana raw material comparison table that SME cost and supplier cost in model 2 decreased from the other two models

Table 3:
Comparison for mendong raw materials

Information	SME Policy	Model P with payment delay	
		Model 1	Model 2
T	0.0278	0.0615	0.1527
Day	10	23	55
n	36	36	36
TB	Rp. 147,996,604.56	Rp. 147,630,479.56	Rp. 147,555,059.74
TS	Rp. 1,193,442.50	Rp. 582,635.77	Rp. 347,595.24
TC	Rp. 149,190,047.06	Rp. 148,213,115.33	Rp. 147,902,654.98
PTCR (%)		0.65	0.86

Source: Compiled by the authors

namely in SME policy and model 1. From model 2 it is known that the optimal rebooking time interval is for 0. 1527 years or 55 days.

Here is the difference in costs that we can see between each model against SME policy on mendong raw materials in Table 4.

Just like Banana, the cost difference in Table 4 shows the cost changes that occur in each model. Reduction or decrease in total inventory costs on model 1 was Rp 976,931.74 and on model 2 amounted to Rp 1,287,392.08. Based on the comparison of the two models can be seen the model that produces the minimum cost is model 2 is an integrated model.

Table 4:
Comparison of cost difference of mendong raw materials

Information	Model 1 Against SME needs	Model 2 Against SME needs
TB	Rp. 366,125.00	Rp. 441,544.82
TS	Rp. 610,806.73	Rp. 845,847.26
TC	Rp. 976,931.74	Rp. 1,287,392.08
PTCR (%)	0.65	0.86

Source: Compiled by the authors

In both comparison tables, the two raw materials have been explained that the minimum total inventory cost is obtained from model P with model 2 so that the following discussion will focus on comparing model 2 with the other two models.

The decrease in total inventory costs changes in line with the decrease in the inventory costs of SMEs and suppliers so that the lower the cost of SME inventory and suppliers, the lower the total inventory cost. The decision variable that affects the cost of SMEs so that it can be interrelated with supplier costs is the optimal T value that is the interval of reordering time by paying attention to the condition of SME and supplier inventory. Therefore, in the integrated model, implementing inventory policies that can result in the cost of SMEs and suppliers can reach the minimum value together by paying attention to the components of inventory costs both.

The cost components that affect the comparison between the two models are given in Table 5.

Table 5:
Cost Components

Party	Cost component	SME Policy	Model 2	Difference	Information
SME	Message cost	Rp. 481,142.86	Rp. 90,944.91	Rp. 390,197.95	Decreased
	Save Costs	Rp. 233,773.33	Rp. 431,349.56	Rp. 197,576.22	Increased
	Shortage Fee	Rp. 287,459.00	Rp. 54,335.07	Rp. 233,123.93	Decreased
Supplier	Fixed Cost	Rp. 1,343,250.00	Rp. 253,899.13	Rp. 1,089,350.87	Decreased
	Save Costs	Rp. 29,402.41	Rp. 155,553.05	Rp. 126,150.64	Increased

Source: Compiled by the authors

If observed in more detail, the cost of proposed improvements for both SMEs and suppliers to the inventory costs of the previous SME policies has increased and decreased. The cost of proposed improvements that have decreased in SMEs is the cost of messages and the cost of shortages (shortage cost). The message costs for the proposed improvements decreased as the frequency of orders was lower than the costs in the previous SME policy. The cost of shortages has decreased due to the results of the proposed decision resulting in less N value (possibly insufficient raw material) compared to the SME inventory policy. Meanwhile, the cost that has increased is the cost of saving caused by the number of goods in the warehouse more than the previous

SME policy. This is because the average order quantity on the proposed improvements has increased compared to the previous inventory policy. So that the raw materials that must be stored in the warehouse have also increased.

Fixed costs resulting from the proposed improvements have decreased from the previous policy. The decline occurred due to the reduced frequency of orders for SMEs. The frequency of these orders affects the frequency of suppliers handling each order so that the associated cost factors also decrease. Meanwhile, the cost of storing suppliers has increased due to the larger order time interval compared to the previous SME policy. Hence, the number of goods that have not been sent pile up in the warehouse and experience an increase in costs due to the large quantity of the previous policy.

4. Conclusion

Based on the results, it can be concluded that for banana raw materials, the reorder time interval that can produce the minimum total inventory cost for Banana raw materials is 0.1470 years or 53 days with a total cost of IDR 263,721,081.72. The inventory policy resulted in a total inventory cost of SMEs of IDR 263,311,629.54 and supplier inventory costs of IDR 409,452.18. The maximum desired inventory in the above inventory policy is 2094 kg. To find out the average quantity of shipments per order as a measure of the ability of the warehouse to meet the number of raw materials per shipment, the average order quantity is calculated. Based on the results of the analysis, the average quantity of Banana raw materials per shipment is 644 kg and the average capacity of raw materials in the warehouse for Banana raw materials is 900 kg. Therefore, it can be concluded that the quantity of Banana raw materials per shipment can meet the average capacity of Banana raw materials in the warehouse. This policy applies to the limit on demand for Banana raw material, which ranges from 30910 kg in one year with no significant changes.

The probabilistic method with the P model in the backorder case with an integrated inventory system application produces a better inventory policy decision than the previous SME policy in controlling raw materials. This can be seen in the conclusion of the raw material inventory policy. From the results of data processing obtained from the two raw materials, it can be concluded that the proposed model, namely the integrated model, produces the minimum total cost of supply chain inventory compared to the SME policy and the individual model.

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