COMPILER
Vol. 10, No. 2, November 2021, pp. 117-125
ISSN: 2252-2403 (Print), ISSN: 2549-2403 (On Line)
Aaccredited Fourth Grade by Kemenristekdikti, Decree No: 200/M/KPT/2020
DOI: 10.28989/compiler.v10i2.1119

Production planning optimization using linear goal programming method (a case study in UD. Koing)

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Article Info

Article history:

Received November 14, 2021
Accepted November 28, 2021
Published November 30, 2021

Keywords:

Optimization
Planning Production
Goal Programming

ABSTRACT

Small Medium Enterprise (SME) industry hold significant role in economic development. In order to be competitive in competition, industry is demanded to be able to make optimum production plan for fulfilling the customer needs. UD KOING as one of product made based skin manufacture companies from time to time is demanded to maximize profit production-target volume, formulating model problems and optimization of raw material. The purpose of this research is that the company gets output according to consumer demand which minimizes production costs and maximizes profits. To answer all those challenges, this research applied goal programming method, where this method can achieve more than one goal only. Based on the data processing, the company target can be achieved through the company profit IDR 7,089,620 compared to the realization of IDR 7,052,410. The total production cost is IDR 16,635,380 compared to realized production cost of IDR 16,554,590 by producing wallet with the number 51 pieces, purse 9 pieces, nametag 13 pieces, pouch 15 pieces and necklace 14 pieces.

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1. INTRODUCTION

Small industries play an important role in the economy. Currently, many small industries are growing and competing. In order to survive, entrepreneurs are required to be able to make optimal production planning so that they are able to meet the number of requests from their consumers. Fluctuating consumer demand urges small industries to have the right ability to predict demand, so that there is no accumulation of raw materials, work in process and products.[1]

UD Koing is a manufacturing company which is engaged in the leather manufacture products including wallets, nametags, bags, pouches, bag hangers and animal necklaces. UD Koing implements a "make to stock" and "make to order" system so that the company must continue to control the use of its resources. Thus, the company will get output according to consumer demand while minimizing production costs and can increase company profits both in terms of production and costs.[2]

One of the ways to optimize profits is to determine production planning appropriately. One of the plans is the use of minimal raw materials (inputs), minimal costs, minimum working hours and maximum profit [3]. In order to be able to use production inputs efficiently, it is necessary to use the benefits of the goal programming method in applying the production process [4]. Thus, the company can prepare production estimation accurately and optimally with minimum costs [5]. In preparing a production plan, many things are considered. One of them is the optimization of the production planning process which allows more than one goal to be achieved. On the other hand, companies in producing a product will always be faced a problem of optimizing goals in each of its production processes. The condition is that these goals are interrelated and contradict each other and the conflict when one goal is optimized will affect other goals which will result in losses [6]. Therefore, the purpose of this research is to optimize production planning to satisfy the targets to be achieved, formulate the constraint function and optimize the availability of UD Koing raw materials.

One of the ways to solve this problem is using Goal Programming (GP) decision-making method. In addition, the Goal Programming method has the potential to resolve conflicting aspects between elements in production planning, namely consumers, products, and manufacturing processes. This method is also effective when it is used to determine the optimal combination of products while achieving the desired goals by the company [7], such as optimal production at low costs and to obtain maximum profit.

2. RESEARCH METHOD

The research design used is qualitative with a literature study approach, with stages 1) data collection includes: demand data, raw material and availability data, additional materials and availability, production cost data and selling prices; 2) data processing, by predicting product demand using POM software for windows 3) linear goal programming formulation that shows the objective function, target constraint and non-negative constraint 4) and linear goal programming processing using winQSB software. The problem under study is the optimal production at UD Koing based on the Goal Programming method by determining 3 factors, namely, decision variables, objective functions, and boundary functions.

3. RESULTS AND ANALYSIS

The types of products produced by UD Koing are leather wallets, leather bags, name tags, pouches, and animal necklaces. In addition, UD Koing also applies "make-to-order" in accordance with customer orders, the number of which is uncertain and adjusted to the existing production capacity.

3.1. Production Process Time Data

The production process for making leather products begins with pattern making, sewing, finishing and packing. The processing time for each product is as follows:

Table 1. The data of production process time

No	Type of Products	Symbol	Time (minutes)
1	Leather wallet	X_1	150
2	Leather bag	X_2	135
3	Nametag	X_3	65
4	Pouch	X_4	90
5	Animal necklaces	X_5	40

The company's working hours are 7 hours each day for 6 working days a week. So, the total working hours each month is 7 hours x 24 days x 60 = 10,080 minutes.

3.2. Sales Data

Production planning is done by taking into past account of the sales data. And it will be got product sales data in the previous period in table 1.

3.3. Sales Prediction

Based on the sales data in table 2, plotting the data pattern on the graph shown in Figure 1 is needed to determine the appropriate prediction method. Figure 1 shows a random data pattern where this data pattern fluctuates (up/down), it does not contain trend and seasonal elements, so it is necessary to approach several prediction methods. Prediction is carried out referring to past data (time series), this assumption is used with the possibility that the number of past requests will be repeated in the future [8]. The data pattern is random and fluctuating, so time series prediction methods can be used, namely the moving average and exponential smoothing methods. Both of these methods are expected to minimize errors in prediction. [9].

Table 2. Sales data each month

No	Period	Product Sold (Unit)					
		Bag	Wallet	Pouch	Necklace	Nametag	Total
1	August 2019	22	61	31	24	17	155
2	September 2019	23	63	26	22	23	157
3	October 2019	22	63	25	21	23	154
4	November 2019	28	70	24	24	25	171
5	December 2019	31	72	24	21	26	174

6	January 2020	26	71	22	23	23	165
7	February 2020	27	65	24	18	18	152
8	March 2020	20	60	15	12	14	121
9	April 2020	18	54	14	8	14	108
10	May 2020	14	49	10	9	12	94
11	June 2020	15	51	11	11	10	98
12	July 2020	8	51	16	14	13	102
	Total	**254**	**730**	**242**	**207**	**218**	**1651**

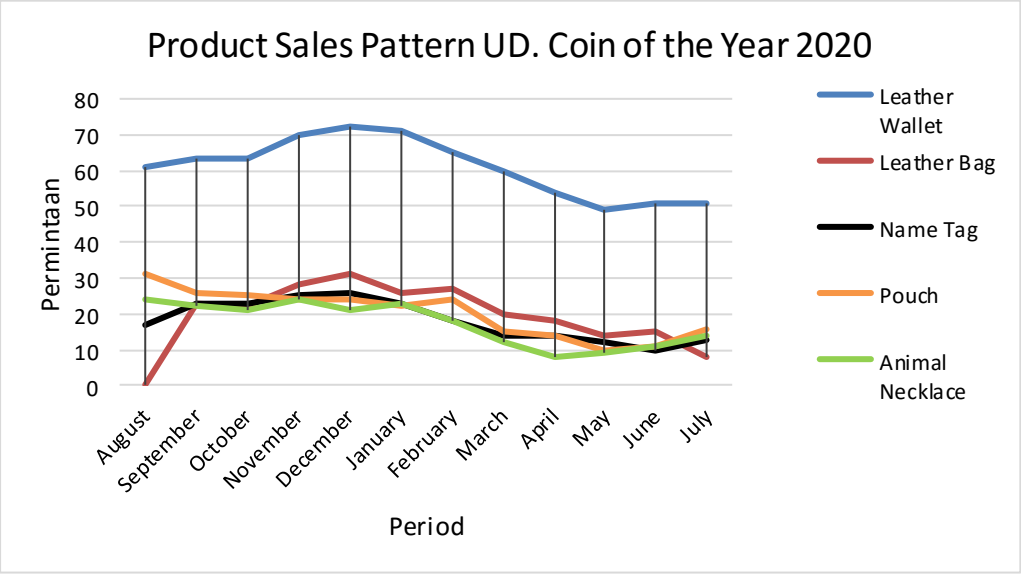

Figure 1. Plotting of product sales in UD. Koing

The moving average and exponential smoothing methods are explained as follows:

1. Moving average, a prediction method that is carried out by taking a group of observed values, looking for the average value as a prediction for the future period. [10]
2. Exponential smoothing, this method is used for short-term prediction. The model assumes that the data fluctuates around a fixed mean, with no consistent growth trend or pattern. Unlike Moving Averages, Exponential Smoothing places greater emphasis on the current time series through the use of a smoothing constant. The smoothing constant may range from 0 to 1. A value close to 1 place the greatest emphasis on the current value, whereas a value close to 0 place emphasis on the previous data point [11].

At this stage, the calculation is done computerized using POM for Windows software using the two methods described above. The following is a recapitulation of the results of data processing using these methods:

Table 3. Product selected prediction method in UD. Koing

No	Prediction Method	Leather Wallet		Leather Bag		Name Tag		Pouch		Animal Necklace	
		MAD	MSE	MAD	MSE	MAD	MSE	MAD	MSE	MAD	MSE
1	*Moving Average n=2*	4.6	32.4	4.15	22.18	3.15	12.88	3.3	16.55	3.35	17.33
2	*Moving Average n=3*	6.44	54.1	5.19	34.05	3.89	20.01	4	23.23	4.07	25.88
3	*Moving Average n=4*	7.53	71.98	5.72	44.54	4.63	28.09	4.78	31.26	4.75	34.78

4	*Exponential Smoothing a=0,1*	7.1	66.44	5.51	44.29	5.49	32.94	8.39	84.84	5.61	51.19
5	*Exponential Smoothing a=0,5*	4.98	34.91	4.1	24.63	3.79	17.35	3.89	20.24	3.33	17.4
6	*Exponential Smoothing a=0,9*	3.47	18.78	3.45	17.61	2.73	10.53	2.92	14.61	2.93	11.44

The selection of the best prediction method is based on the level of prediction error with the assumption that the smaller the error rate generated, the more precise a method is in predicting. The calculation of the error rate used is mean absolute deviation (MAD) and mean squared error (MSE) [12]. Based on the table above, the method that has the smallest MAD and MSE values is the Exponential Smoothing method with a = 0.9. The purpose of selecting a value for the smoothing constant is to obtain an accurate prediction. The results of product prediction using the Exponential Smoothing method can be seen in table 4.

Table 4. Product prediction result

No	Product Name	Prediction Result
1	Leather Wallet	51
2	Leather Bag	9
3	Nametag	13
4	Pouch	15
5	Animal Necklace	14

3.4. Data on Production Costs, Usage and Capacity of Raw Materials

Production costs are the cost of raw materials, direct labor costs and overhead costs (costs for transportation or unexpected). Table 5 shows the use of raw materials and auxiliary materials for every 1 unit of product.

The production cost each unit of product is calculated by multiplying the use of raw and auxiliary materials by the cost of raw materials and auxiliary materials per unit of use. Production costs for all products can be seen in table 6:

Table 5. Data on raw materials and auxiliary materials

No	Product Name	Raw Material	Auxiliary Materials							
		Leather	Filler	Cardboard	Dorwil Cloth	Mica	Zipper	GTO	Rivet	Nylon Thread
		(ft)	(pcs)	(pcs)	(yard)	(pcs)	(m)	(pcs)	(pcs)	(m)
1	Leather Wallet	5	1	2	1	0,5	-	-	-	1,3
2	Leather Bag	9	3	-	3	-	2	2	3	3,6
3	Nametag	1	-	1	-	0,5	-	1	1	0,4
4	Pouch	7	2	-	2	-	1	2	3	1,6
5	Animal Necklace	0,5	-	-	-	-	-	1	1	-
	Total	22,5	6	3	5	1	3	6	8	5,6
Availability		540 ft	112 pcs	72 pcs	124 pcs	344 pcs	48 pcs	93 pcs	132 pcs	1025 pcs

Table 6. Production cost

No	Product Type	Raw Materials Cost	Direct Labor Costs	Overhead Cost	Total Production Cost
1	X_1	Rp.166.780	Rp. 2.500	Rp. 600	Rp. 169.880
2	X_2	Rp. 353.500	Rp. 3.500	Rp. 900	Rp. 357.900
3	X_3	Rp. 34.520	Rp. 1.500	Rp. 450	Rp. 36.470
4	X_4	Rp. 263.260	Rp. 3.000	Rp. 850	Rp. 267.110
5	X_5	Rp. 17.860	Rp. 1.000	Rp. 400	Rp. 19.260

Among the five products that will be planned for production, leather bag products use the largest production costs. It is because the use of raw materials for leather bags is more than other leather products.

3.5. Business Targets

In this study, the company has two business targets, namely maximizing company profits and minimizing production costs. From the two targets, it can be obtained the value of the following calculations:

1. Maximizing Company Profit

The company's profit data can be obtained from the selling price of the product each piece minus the production cost each piece, as follows:

a. Leather Wallet : Rp. 258.000 - Rp. 169.880 = Rp.88.120
b. Leather Bag : Rp. 448.000 - Rp. 357.900 = Rp. 90.100
c. Nametag : Rp. 85.000 - Rp. 36.470 = Rp. 48.530
d. Pouch : Rp. 320.000 - Rp. 267.110 = Rp. 52.890
e. Animal Necklace: Rp. 45.000 - Rp. 19.260 = Rp. 25.740

Furthermore, the results of the profit calculation each product above will be multiplied by the number of requests for each product resulting from prediction each 1 period as follows:

Table 7. Calculation of profit target value

No	Type of Products	Total Demand/pcs	Profit/pcs	Total
1	Wallet	51	Rp. 88.120	Rp. 4.494.120
2	Bag	9	Rp. 90.100	Rp. 810.900
3	Nametag	13	Rp. 48.530	Rp. 630.890
4	Pouch	15	Rp. 52.890	Rp. 793.350
5	Necklace	14	Rp. 25.740	Rp. 360.360

Then the multiplication results will be added up, and the total target value to be achieved to maximize the company's profit is Rp. 7,089,620.

1. Minimize Production Costs

For production cost, the data was obtained from existing cost data in the company which consists of raw material costs, additional material costs, and labor costs which have been calculated by the company itself with the total value of production costs each piece for wallet products is Rp. 169,880, bags are Rp. 357,900, nametag is Rp. 36,470, pouches are Rp. 267,110, necklace is Rp. 19,260. Then the cost is multiplied by the number of requests for each product resulting from prediction each one period as shown in the table below:

Table 8. Calculation of production cost target value

No	Type of Products	Total Demand/PCS	Production Cost/PCS	Total
1	Wallet	51	Rp. 169.880	Rp. 8.663.880
2	Bag	9	Rp. 357.900	Rp. 3.221.100
3	Nametag	13	Rp. 36.470	Rp. 474.110
4	Pouch	15	Rp. 267.110	Rp. 4.006.650
5	Necklace	14	Rp. 19.260	Rp. 269.640

Furthermore, the results of the multiplication will be added up, so that the total target value to be achieved to minimize production costs is Rp. 16,635,380.

3.6. Data of Selling Price, Production Costs and Profits

The following is data on selling prices, production costs and product profits in UD Koing:

Table 9. Data on selling prices, production costs and product profits/PCS

No	Type of Products	Selling Price (/pcs)	Production Cost (/pcs)	Profit (/pcs)
1	Wallet	Rp. 258.000	Rp. 169.880	Rp. 88.120
2	Bag	Rp. 448.000	Rp. 357.900	Rp. 90.100
3	Nametag	Rp. 85.000	Rp. 36.470	Rp. 48.530
4	Pouch	Rp. 320.000	Rp. 267.110	Rp. 52.890
5	Necklace	Rp. 45.000	Rp. 19.260	Rp. 25.740

3.7. Data processing

3.7.1. Making a Goal Programming Linear Model

From the data above, it can be used as a parameter to include in the goal programming model, these parameters include:

1.) Decision Variables

The decision variable used is the product produced by the company. In this case, the decision variables are as follows:

X1 = Leather Wallet
X2 = Leather Bag
X3 = Nametag
X4 = Pouch
X5 = Animal Necklace

2.) Purpose Function

The formulation of the objective function is as follows:

Min= $P_1 + P_2 + P_3 + P_4 + P_5 + P_6 + P_7 + P_8 + P_9 + P_{10} + N_{11} + P_{11} + N_{12} + P_{12} + N_1 + P_{13} + N_{14} + P_{14} + N_{15} + P_{15} + N_{16} + P_{17}$

Information:

N_i and P_i are deviations at the goal where N_i is the possible negative deviation from a right-hand side of the goal and P_i is the positive deviation from a right-hand value or aspiration level with N_i and P_i 0.

Priority 1: Using leather raw materials no more than 540ft from available stock. (Goal 1)
Priority 2: Using no more than 112pcs of filler raw materials from available stock. (Goal 2)
Priority 3: Using cardboard raw materials no more than 72pcs from available stock. (Goal 3)
Priority 4: Using dorwil cloth raw materials no more than 124yards from available stock. (Goal 4)
Priority 5: Using mica raw materials no more than 344pcs from available stock. (Goal 5)
Priority 6: Using zipper raw materials no more than 48m from available stock. (Goal 6)
Priority 7 : Using gto raw materials no more than 93pcs from available stock. (Goal 7)
Priority 8 : Using rivet raw materials no more than 132pcs from available stock. (Goal 8)
Priority 9 : Using nylon thread as raw material no more than 1025m from available stock. (Goal 9)
Priority 10 : Using no more than 10,080 minutes of work. (Goal 10)
Priority 11: Meet the demand for 51 wallets production. (Goal 11)
Priority 12 : Fulfill the demand for bag production as many as 9. (Goal 11)
Priority 13 : Fulfill the demand for nametag production as many as 13. (Goal 13)
Priority 14 : Fulfill the demand for 15 pouch production departments. (Goal 14)
Priority 15 : Fulfill the demand of 14 necklaces production department. (Goal 14)
Priority 16 : Make a profit of at least IDR 7,089,620. (Goal 16)
Priority 17 : The production cost used should not exceed Rp. 16,635,380. (Goal 17)

3.) Limitation Function

The constraint functions that limit the objective function above are:

a. Raw Materials
   Coefficient values and target values are obtained from Table 5.
   Leather
   1. $5x_1 + 9x_2 + 1x_3 + 7x_4 + 0{,}5x_5 + N_1 - P_1 \leq 540.$
b. Auxilary Materials
   Filler
   2. $1x_1 + 3x_2 + 2x_4 + N_2 - P_2 \leq 112.$
   Cardboard
   3. $2x_1 + 1x_3 + N_3 - P_3 \leq 72.$
   Dorwil Cloth
   4. $1x_1 + 3x_2 + 2x_4 + N_4 - P_4 \leq 124.$
   Mica
   5. $0{,}5x_1 + 0{,}5x_3 + N_5 - P_5 \leq 344.$
   Zipper

6. $2x_2 + 1x_4 + N_6 - P_6 \leq 48.$

GTO

7. $2x_2 + 1x_3 + 2x_4 + 1x_5 + N_7 - P_7 \leq 93.$

Rivet

8. $3x_2 + 1x_3 + 3x_4 + 1x_5 + 1x_5 + N_8 - P_8 \leq 132.$

Nylon Thread

9. $1{,}3x_1 + 3{,}6x_2 + 0{,}4x_3 + 1{,}6x_4 + N_9 - P_9 \leq 1.025.$

c. Working Hours

Coefficient values and target values are obtained from table 4.11

10. $150x_1 + 135x_2 + 65x_3 + 90x_4 + 40x_5 + N_{10} - P_{10} \leq 10.080.$

d. Demand

The coefficient values and target values are obtained from table 4. In fulfilling the market demand, the negative and positive deviation values from the demand target limiter must be minimized because a shortage of production will result in inability to meet customer demand and excess production will lead to high inventory costs. It is getting bigger and the production costs incurred cannot be overcome. So, the objective function must be minimized. Here are the constraint functions for each product:

11. $X_1 + N_{11} - P_{11} \geq 51.$
12. $X_2 + N_{12} - P_{12} \geq 9.$
13. $X_3 + N_{13} - P_{13} \geq 13.$
14. $X_4 + N_{14} - P_{14} \geq 15.$
15. $X_5 + N_{15} - P_{15} \geq 14.$

e. Target

Maximizing Company Profit

Coefficient values and target values are obtained from table 4. UD Koing aims to obtain maximum profit so that the profit target that is below the target or negative deviation value will be minimized which can be formulated as follows:

16. $88.120x_1 + 90.100x_2 + 48.530x_3 + 52.890x_4 + 25.740x_5 + N_{16} - P_{16} \geq 7.089.620.$

Minimize Production Cost

Coefficient values and target values are obtained from table 5. The goal is to minimize the costs used during production, so that the minimum value is positive or excess deviation. The model constraint function is formulated as follows:

17. $169.880x_1 + 357.900x_2 + 36.470x_3 + 267.110x_4 + 19.260x_5 + N_{17} - P_{17} \leq 16.635.380.$

$X_i \geq 0$, untuk $i = 1, 2, 3, 4, 5.$

$N_i - P_i \geq 0$, untuk $i = 1, 2, 3, \ldots 17.$

3.7.2. Processing Using Software

From the goal programming model that has been compiled above, then the model is then processed using WinQSB in order to find out whether the targets can be achieved optimally or not. The results of processing using software are as follows:

1. Optimization Goal

The following are the objectives that can be achieved from the results of data processing using winQSB software.

Table 10. Achievement of targets and goals

Goal	Target	Solution	Status
Company Profit Maximization	7.089.620	7.089.620	fulfilled
Minimize Production Cost	16.635.380	16.635.380	fulfilled

2. Production Combination

The following is a production combination solution from the results of data processing using winQSB software.

Table 11. Analysis of production combination

Type of Products	Target	Solution	Status
Wallet	51	51	Fulfilled

Bag	9	9	Fulfilled
Nametag	13	13	Fulfilled
Pouch	15	15	Fulfilled
Necklace	14	14	Fulfilled

3. Resource Usage

The solution for using resources consisting of raw materials, additional materials, and working hours is as follows:

Table 12. Resource utilization analysis

Resources	Unit	Solution	Availability
Material Raw			
Leather	Ft	524	540
Additional Raw			
Filler	Pcs	108	112
Cardboard	Pcs	72	72
Dorwil Cloth	Pcs	108	124
Mica	Pcs	320	344
Zipper	Pcs	33	48
GTO	Pcs	75	93
Rivet	Pcs	99	132
Nylon Thread	Meter	1025	1025
Working Hours	Minute	10.080	10.080

3.8. Optimization Result Analysis

1. Analysis of Optimization Purpose

Solutions that can be achieved from the results of data processing using software are according to the targets that have been set for a total profit value of Rp. 7,089,620. Furthermore, for the total cost of production, it can be achieved as much as Rp. 16,635,380. It is considered that the model can achieve the main goal in accordance with the nominal target set previously from maximizing the company's profit with minimum production costs, where the company's profit is to produce 51 pcs of wallets, 9 pcs of bags, 13 pcs of nametags, 15 pcs of pouches and 14 pcs of necklaces for Rp. 7,089,620 can not be added anymore and for cost minimization it can not be reduced anymore with a cost Rp.16,635,380.

2. Production Combination Analysis

Production combination solutions for consumer demand for each product can be met by the company in accordance with the targets to be achieved through predicting the demand for the next 1 period with the number of production for 51 pcs leather wallets, 9 pcs leather bags, 13 pcs nametags, 15 pcs pouches, and 14 pcs animal necklaces.

3. Resource Usage Analysis

From the solution optimization results, it can be seen that the company must reduce the availability of resources because the results of the product combination show that the total product that must be produced for the next 1 period is 102 pcs for the five products, so the availability of resources must be adjusted to the production capacity in order to fit and avoid the wasteful.

4. Comparative Analysis

In this comparative analysis, we will compare the optimization results using the winQSB software with the realization data in the previous production period. Thus, it can be known whether the model that has been made is optimal or not.

Table 13. Comparative analysis

Goal	Optimization Result	Realization	Difference
Company Profit Maximization	7.089.620	7.052.410	37.210
Minimize Production Cost	16.635.380	16.554.590	80.990

5. CONCLUSION

The main target of the company is to maximize the profit of the company and minimize the production costs of making existing products in the company that can be achieved according to the target. The total value of the company's profit is Rp. 7,089,620 can be fulfilled by using the goal programming model, which is Rp. 7,089,620 compared to the realization of Rp 7,052,410. The total value of production costs is Rp. 16,635,380 can be fulfilled by using the goal programming model, which is Rp. 16,635,380 compared to the realization of Rp 16,554,590. The combination of products resulted in 51 pcs leather wallets, 9 pcs leather bags, 13 pcs nametags, 15 pcs pouches and 14 pcs animal necklaces.

ACKNOWLEDGEMENTS

This research is a case study in UD. Koing. We thank to the director of UD. Koing for the support.

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