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The Application of Fuzzy Logic in Optimization Pulp in Pt.Toba Pulp Lestari, Tbk With the Mamdani Method

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ABSTRACT
Fuzzy logic is used to show data or information that is certain. This survey examines the used of *fuzzy* logic in optimizing production pulp at PT. Toba Pulp Lestari, Tbk using the *Fuzzy*-Mamdani approach. Constraints faced include the uncertain amount of pulp production from time to time . The steps in solving these problems, namely: (1) is to form a *fuzzy* set and determine the conversation. Next, (2) is to find out the *fuzzyfication* that changes the input into *fuzzy*. Next, (3) is the formation of *fuzzy* rules with the max method. (4) is *defuzzification* with MOM method. The problem solving is assisted with the assistance of the Matlab software application. The data in this study are the quantity of production, the quantity of stock and the number of requests from January 2021-December 2021. Based on the data obtained using the Mamdani method, it is known that the optimal production based on the amount of demand and supply is January 13,300 ton, February 18,200 ton, March 8,110 ton, April 10,700 ton, May 10,600 ton, June 13,400 ton, July 12,000 ton, August 10,700 ton, September 18,800 ton, October 18,300 ton, November 10,100 ton, December 10,400 ton.

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INTRODUCTION

Logic*Fuzzy i*ntroduced in 1965 by Lotfi A. Zadeh. Logic*fuzzy* used to show data or information that is uncertain. Logic*fuzzy* based on the membership function. The membership function is expressed in the form of membership degrees. The degree of membership has an important position in a set and is the main characteristic of logical reasoning*fuzzy*.

Logic*Fuzzy* has 3 methods in its inference system, namely: Method*Fuzzy*-Mamdani, Method*Fuzzy*-Tsukamoto and Method*Fuzzy*-Sugeno.*Fuzzy*-Mamdani was introduced by Ebrahim Mamdani (1975). Method*Fuzzy*-Mamdani uses linguistic rules and has an algorithm*fuzzy* which can be analyzed mathematically, making it easier to understand. The Mamdani method also pays more attention to the specific conditions that will occur in each region*fuzzy*, in order to produce more accurate decision results.

Factory activity contains a very close relationship with the production process. Factories shape the production process to complement market demand. The factory's goal is to make a profit. This goal is

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influenced by several factors, one of which is the smooth production. To form production activities, it is obligatory to have production facilities such as raw materials, labor, machines and so on. All production facilities have a limited capacity and require spending. The use of production facilities that are not suitable will make the factory unable to achieve its production goals and a waste of production budget will occur, for this reason the factory is expected to control production facilities properly (Djunaidi, 2005).

Collection*Fuzzy*

Collection*fuzzy* is the range of values whose degree of membership is between 0 and 1. Set*fuzzy* based on an idea to increase the scale of the function as a result the function will involve real numbers in the interval [0,1] (Kusumadewi, 2004).

There are several rules for notating sets*fuzzy* :

1. The *fuzzy* set is written systematically where the first element shows the identity of the element and the second element shows its membership value
2. If the universe$X$ is discrete then it is formulated by:
   $$(\tilde{A}) = \frac{\mu_{\tilde{A}}(x_1)}{x_1} + \frac{\mu_{\tilde{A}}(x_2)}{x_2} + \ldots + \frac{\mu_{\tilde{A}}(x_n)}{x_n} \quad (1)$$
3. If the universe X is continuous then it is defined by:
   $$(\tilde{A}) = \int_x \mu_{\tilde{A}}(x)/\mathrm{x} \quad (2)$$

Membership Function

The membership function is a representation that shows the mapping of data input points into membership values that have an interval between 0 and 1 (Kusumadewi, 2003).

Commonly used membership functions:

1. Linear representation
2. Triangular curve representation
3. Trapezoidal curve representation
4. Shoulder shape curve representation

The Mamdani Method

The Mamdani method was introduced by Ebrahim Mamdani. The Mamdani method is an approach used in problem solving which is commonly referred to as the Max-Min Method (Kusumadewi, 2004). There are 4 steps taken to obtain the output variable, including (Frans Susilo, 2006) :

1. Formation of *fuzzy* sets
   Formation of *fuzzy* sets is done by forming input and output variables into one or more *fuzzy* sets.
2. Application function implication
   The implication function in the Mamdani Method is*min*
3. Rule composition
   The method used to obtain an assessment of the *fuzzy* inference system is the Max method.
   Formulated as follows:
   $$\mu_{sf}(x_i) = max(\mu_{sf}(x_i), \mu_{kf}(x_i)) \quad (3)$$
4. Affirmation (defuzzification)
   Confirmation on the composition of mamdani rules using the MOM method. Where in this method, it is obtained from finding the average value of the domain that has the maximum membership value.

RESEARCH METHOD

The first is a Reference search. Second is a Data collection.The third isIdentify data to select data variables and universe of conversation.Then, we can processing data using 2 ways : (1) Using the mamdani

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method with the stages (a) Determination of *fuzzy* sets (b) Application function implication (c) Rule composition(d) Affirmation(*Defuzzyfication*).(2) Using the help of matlab software. And then Result and Discussionand The last is Conclusions and Recommendations

RESULTS AND DISCUSSION

Research data

The research data is secondary data obtained from PT Toba Pulp Lestari, Tbk. Which includes data on total production, total demand and total supply from January 2021-December 2021

Table 1. Data on Total Production, Total Inventory and Total Demand

Moon (2021)	Number of Requests	Amount of stockpile	Production Amount
January	14.211,521	13.423,441	17.202,343
February	14.141,455	12.778,391	16.309,616
March	8.321,132	7.782,391	9.218,616
April	13.851,415	13.639,905	17.535,687
May	11.815,415	14.514,457	17.584,225
June	14.149,981	13.495,197	17.564,454
July	14.156,887	15.285,441	18.245,931
August	11.987,243	12.500,771	17.724,503
September	15.124,872	11.642,875	17.040,481
October	13.857,998	11.321,728	17.862,848
November	10.832,571	12.191,211	17.176,021
December	15.915,779	14.148,191	16.107,179

Source: PT. Toba Pulp Lestari, Tbk

Data processing

Data processing is obtained by selecting variables and the universe of discussion and then creating sets*fuzzy.*

1. The stage of determining the *fuzzy* set variables

Before forming a Fuzzy set, variables and the universe of discussion are determined first. In data processing, there are 3 variables, namely, 1 output variable (production variable) and 2 input variables (demand and supply variables). The production variable has 3 linguistic values, namely increasing, moderate and decreasing. The demand variable has 3 linguistic values, namely increasing, constant and decreasing. The inventory variable has 3 linguistic values, namely a lot, medium and a little.

Table 2. Variables and the Talking Universe

Function	Variable	Speaker Universe	Information
Input	Request	[8.321,132 - 15.915,779]	Number of Requests (ton)
	Preparation	[7.782,391 - 15.285,441]	Amount of stockpile (ton)
Output	Production	[9.218,616 - 18.245,931]	Production Amount (ton)

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2. Fuzzyfics

Fuzzification is useful for converting strict input data into *fuzzy*. The entire discussion is obtained by paying attention to the smallest and largest factory data. The talking universe of the demand variable is [8,321,132 ; 15,915.78], the inventory variable is [7,782.391 ; 15,285.44] and the production variable is [9,218.616 ; 15,915.78]. Each *fuzzy* set has a domain whose values are in the universe of speech. The *fuzzy* set domain is obtained based on the smallest data, lower quartile (Q1), median (Q2), upper quartile (Q3), and the largest factory data. The following shows demand, supply and production data after sorting from the smallest data to the largest data

Table 3. Data after sorting

No	Number of Requests	Amount of stockpile	Production Amount
1	8.321,132	7.782,391	9.218,616
2	10.832,571	11.321,728	16.107,179
3	11.815,211	11.642,875	16.309,616
4	11.987,243	12.191,211	17.040,481
5	13.851,415	12.500,771	17.176,021
6	13.857,998	12.778,391	17.202,343
7	14.141,455	13.423,441	17.535,687
8	14.149,981	13.495,197	17.564,454
9	14.156,887	13.639,905	17.584,225
10	14.211,521	14.148,191	17.724,503
11	15.124,872	14.514,457	17.862,848
12	15.915,779	15.285,441	18.245,931

The data above is a single data, the number of data is 12. So looking for variable Q1 setup is$\frac{1(12)}{4} = 3$so that Q1 is obtained in the 3rd data of11.642,875. Find variable Q2 inventory$\frac{2(12)}{4} = 6$,so that Q2 is obtained on the 6th data of12.778,391. Find variable Q3$\frac{3(12)}{4} = 9$ Until obtained Q3 on the 9th data as large13.639,905. With a similar model, Q1, Q2, and Q3 will be searched for the demand and production variables.

Table 4. Formation of fuzzy sets

Function	Variable	Collection*Fuzzy*	Speaker Universe	Domain
Input	Request	A little	[8.321,132 – 15.915,78]	[8.321,132 -13.857,998]
		Currently		[11.815,211-14.156,887]
		Lots		[13.857,998-15.915,779]
	Preparation	A little	[7.782,391 – 15.285,441]	[7.782,391 -12.778,391]
		Currently		[11.642,875-13.639,905]
		Lots		[12.778,391-15.285,441]
Output	Production	Reduce	[9.218,62 – 18.245,93]	[9.218,616 -17.202,343]
		Permanent		[16.309,616-17.484,225]
		Increase		[17.202,343-18.245,931]

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There are 3 *fuzzy* variables represented in the membership function, including:

1. Request variable representation

The demand variable consists of 3 *fuzzy* sets, namely, few, medium and many *fuzzy* sets. Each *fuzzy* set has a membership function that is, the membership function of the *fuzzy* set is few, medium and many.Set membership function*fuzzy* slightly wears the left shoulder shape curve membership function. Then we get the membership function of the set*fuzzy* few include:

$$\mu_{\textbf{Sedikit}} = \begin{cases} \mathbf{1} & ,x \leq \mathbf{8.321,132} \\ \dfrac{\mathbf{13.857,998} - x}{\mathbf{13.857,998} - \mathbf{8321,132}} & ,\mathbf{8.321,132} \leq x \leq \mathbf{13.857,998} \\ \mathbf{0} & ,x \geq \mathbf{13.858} \end{cases}$$

$$\mu_{\textbf{Sedang}} = \begin{cases} \mathbf{0} & ,x \leq \mathbf{11.815,211}\ \textbf{atau}\ x \geq \mathbf{14.156,887} \\ \dfrac{x - \mathbf{11.815,211}}{\mathbf{13.857,998} - \mathbf{11.815,211}} & ,\mathbf{11.815,211} \leq x \leq \mathbf{13.857,998} \\ \dfrac{\mathbf{14.156,887} - x}{\mathbf{14.156,887} - \mathbf{13.857,998}} & ,\mathbf{13.857,998} \leq x \leq \mathbf{14.156,887} \end{cases}$$

$$\mu_{\text{Banyak}} = \begin{cases} 0 & ,x \leq 13.857,998 \\ \dfrac{x - 13.857,998}{15.915,779 - 13.857,998} & ,13.857,998 \leq x \leq 15.915,779 \\ 1 & ,x \geq 15.915,779 \end{cases}$$

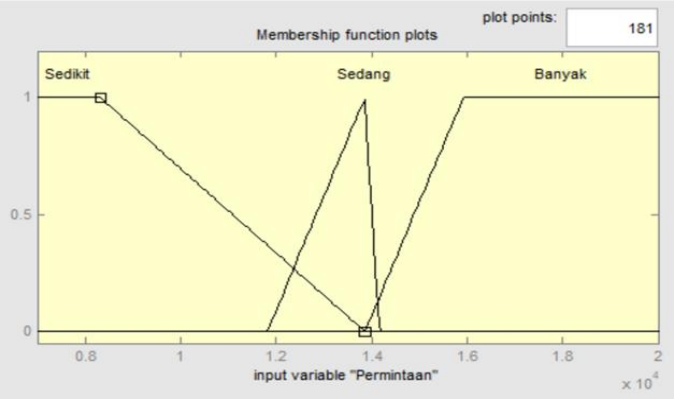

Image 1. *Fuzzy* set of query variables

2. Inventory variable representation

The set-up variable consists of 3 *fuzzy* sets, namely, few, medium and many *fuzzy* sets. Each *fuzzy* set has a membership function that is, the membership function of the *fuzzy* set is few, medium and many.Set membership function*fuzzy* slightly wears the left shoulder shape curve membership function. Then we get the membership function of the set*fuzzy* few include:

$$\mu_{\textbf{Sedikit}} = \begin{cases} \mathbf{1} & ,x \leq \mathbf{7.782,391} \\ \dfrac{\mathbf{12.778,391} - x}{\mathbf{12.778,391} - \mathbf{7.782,391}} & ,\mathbf{7.782,391} \leq x \leq \mathbf{12.778,391} \\ \mathbf{0} & ,x \geq \mathbf{12.778,391} \end{cases}$$

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$$\mu_{\text{Sedang}} = \begin{cases} 0 & ,x \leq 11.642,875 \; atau \; x \geq 13.639,905 \\ \dfrac{x - 11.642,875}{12.778,391 - 11.642,875} & ,11.642,875 \leq x \leq 12.778,391 \\ \dfrac{13.639,905 - x}{13.639,905 - 12.778,391} & ,12.778,391 \leq x \leq 13.639,905 \end{cases}$$

$$\mu_{\text{Banyak}} = \begin{cases} 0 & ,x \leq 12.778,391 \\ \dfrac{x - 12.778,391}{15.285,441 - 12.778,391} & ,12.778,391 \leq x \leq 15.285,441 \\ 1 & ,x \geq 15.285,441 \end{cases}$$

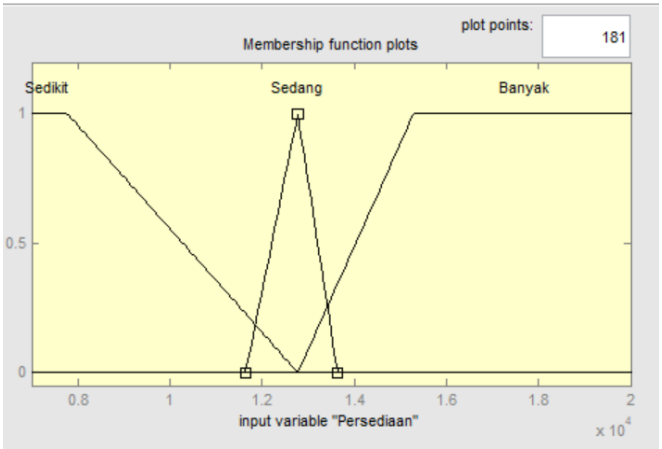

Image 2. Inventory variable *fuzzy* set

3. Production variable representation

The production variable consists of 3 sets*fuzzy* is, a collection*fuzzy* little, medium anda lot. Each collection*fuzzy* the membership function is formed, the membership function of the set*fuzzy* little, medium and a lot.Set membership function*fuzzy* slightly wears the left shoulder shape curve membership function. Then we get the membership function of the set*fuzzy* bit as follows:

$$\mu_{\text{Berkurang}} = \begin{cases} 1 & ,x \leq 9.218,616 \\ \dfrac{17.202,343 - x}{17.202,343 - 9.218,616} & ,9.218,616 \leq x \leq 17.202,343 \\ 0 & ,x \geq 17.202,343 \end{cases}$$

$$\mu_{\text{Tetap}} = \begin{cases} 0 & ,x \leq 16.309,616 \; atau \; x \geq 17.584,225 \\ \dfrac{x - 16.309,616}{17.202,343 - 16.309,616} & ,16.309,616 \leq x \leq 17.202,343 \\ \dfrac{17.584,225 - x}{17.584,225 - 17.202,343} & ,17.202,343 \leq x \leq 17.584,225 \end{cases}$$

$$\mu_{\text{Bertambah}} = \begin{cases} 0 & ,x \leq 17.202,343 \\ \dfrac{x - 17.202,343}{18.245,931 - 17.202,343} & ,17.202,343 \leq x \leq 18.245,931 \\ 1 & ,x \geq 18.245,931 \end{cases}$$

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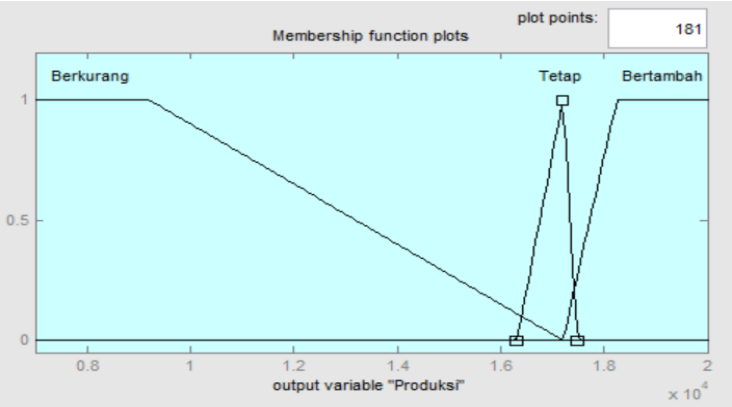

Image 3. *Fuzzy* set of production variables

3. Formation of *fuzzy* rules

Formation of rules adapted to factory production conditions and logic rules*fuzzy* in this study was formed by combining existing sets. The number of rules created according to 3 sets*fuzzy* is as many as 27 rules.

Table 5. *Fuzzy* rules

Rule	Request	Preparation	Implication function	Production
R1	A little	A little	For	Reduce
R2	A little	A little	For	Permanent
R3	A little	A little	For	Increase
R4	A little	Currently	For	Reduce
R5	A little	Currently	For	Permanent
R6	A little	Currently	For	Increase
R7	A little	Lots	For	Reduce
R8	A little	Lots	For	Permanent
R9	A little	Lots	For	Increase
R1	Currently	A little	For	Reduce
R11	Currently	A little	For	Permanent
R12	Currently	A little	For	Increase
R13	Currently	Currently	For	Reduce

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Rule	Request	Preparation	Implication function	Production
R14	Currently	Currently	For	Permanent
R15	Currently	Currently	For	Increase
R16	Currently	Lots	For	Reduce
R17	Currently	Lots	For	Permanent
R18	Currently	Lots	For	Increase
R19	Lots	A little	For	Reduce
R20	Lots	A little	For	Permanent
R21	Lots	A little	For	Increase
R22	Lots	Currently	For	Reduce
R23	Lots	Currently	For	Permanent
R24	Lots	Currently	For	Increase
R25	Lots	Lots	For	Reduce
R26	Lots	Lots	For	Permanent
R27	Lots	Lots	For	Increase

4. Affirmation (*Defuzzification*)

PT Toba Pulp Lestari, Tbk has a minimum factory production standard of 7,000 tons and a maximum production of 20,000 tons per month. where according to the lower limit (minimum production) of the reduced fuzzy set trapezoidal membership function which is worth 7,000 Tons and the upper limit (maximum production) of the increased fuzzy trapezoidal membership function which is worth 20,000 Tons. Based on the demand and supply obtained from PT Toba Pulp Lestari, Tbk in January 2021 - December 2021, the optimal production amount will be determined using the Mamdani method. In January 2021 with a demand of 14,211,521 and a supply of 13,423,441 we get:

$\mu_{PMD}(14.211{,}521) = 0$

$\mu_{PMS}(14.211{,}521) = 0$

$\mu_{PMB}(14.211{,}521) = 0{,}17179816511$

$\mu_{PSD}(13.423{,}441) = 0$

$\mu_{PSS}(13.423{,}441) = 0{,}251259991$

$\mu_{PSB}(13.423{,}441) = 0.257294429$

After being reflected into the set image*fuzzy*, rule form*fuzzy* it is:

[R22] If there is a lot of demand and moderate supply, production will decrease.

$\alpha_2 = min(\mu_{PMB}, \mu_{PSS}) = min(0{,}17179816511; 0{,}251259991) = 0{,}17179816511$

then the production set:

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Because of the Set*Fuzzy* The production variable increases in the form of a trapezoid and has a lower production limit of 7000 tons. So obtained

$$x_1 = 7.000$$

$$\mu_{PRK} = \frac{17.202{,}343 - x_2}{17.202{,}343 - 9.218{,}616} = 0{,}17179816511$$

$$17.202{,}343 - x_2 = 1.371{,}5896$$

$$x_2 = 15.830{,}753$$

$$x = [7.000;\ 15.830{,}753]$$

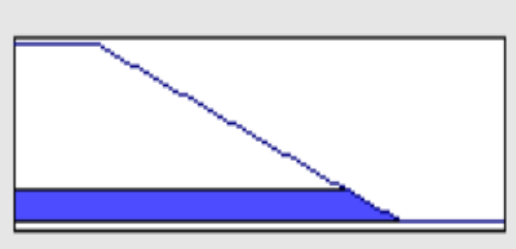

Image 4. *Defuzzification* results [R22]

Table 6. Total Demand, Total Inventory and Optimal Production Amount (tons)

Moon (2021)	Number of Requests	Amount Preparation	Optimal Production Amount
January	14.211,521	13.423,441	13.400
February	14.141,455	12.778,391	13.400
March	8.321,132	7.782,391	12.900
April	13.851,415	13.639,905	13.100
May	11.815,211	14.514,457	13.000
June	14.149,981	13.495,197	13.400
July	14.156,887	15.285,441	13.400
August	11.987,243	12.500,771	13.100
September	15.124,872	11.642,875	13.300
October	13.857,998	11.321,728	13.200
November	10.832,571	12.191,211	12.800
December	15.915,779	14.148,191	12.700

Based on these results it can be seen that there is a difference in the optimal production of the Mamdani method with the amount of factory production. Production Optimization Results with*Fuzzy*-Mamdani compared to the production carried out by the factory can be seen in the following table:

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Table 7.Optimal Production Amount and Production Difference

Production Amount	Optimal Production Amount	Production Difference	Information
17.202,3	13.400	3.802	Surplus
16.309,6	13.400	2.910	Surplus
9.218,62	12.900	-3.681	Less
17.535,7	13.100	4.436	Surplus
17.584,2	13.000	4.584	Surplus
17.564,5	13.400	4.164	Surplus
18.245,9	13.400	4.846	Surplus
17.724,5	13.100	4.625	Surplus
17.040,5	13.300	3.740	Surplus
17.862,8	13.200	4.663	Surplus
17.176	12.800	4.376	Surplus
16.107,2	12.700	3.407	Surplus

Based on the explanation above, it can be seen that production has not met the target in March. In order to meet the production objectives, the addition of demand and supply variables is carried out so that production becomes more optimal. While production that has met the target occurred in January, February, April, May, June, July, August, September, October, November and December. From the above results it can also be seen that overproduction often occurs in large enough quantities

CONCLUSION

Based on the discussion obtained conclusions on the method*fuzzy*-Mamdani to acquire*output* using several levels, among others: Formation of collections*fuzzy*, Implication function*min,* Composition of rules with methods*max.* as well as, Affirmation by method*MOM.*

Based on data obtained using the Mamdani method, it is known that optimal production is based on total demand and supply, namely January 2021 of 13,400 Tons, February 2021 of 13,400 Tons, March 2021 of 12,900 Tons, April 2021 of 13,100 Tons, May 2021 of 13,400 Tons, June 2021 13,400 tons, July 2021 13,400 tons, August 2021 13,100 tons, September 2021 13,300 tons, October 2021 13,200 tons, November 2021 12,800 tons, and December 2021 12,700 tons.

Based on the results of research using the method*fuzzy*-Mamdani with help*software matlab* R2016a shows that there is production that has not reached its target in March. Meanwhile, production that has reached its target occurred in January, February, April, May, June, July, August, September, October, November and December. From the above results it can also be seen that there is often an overproduction with quite a large amount due to the amount of production not being adjusted to the amount of demand and supply.

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