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Production Planning Using Forecasting and Linear Goal Programming

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Abstract:
An appropriate constructive planning is the most important key to a success of production system. This paper is to describe problems in production planning using the combination of forecasting methods and linear goal programming for decision making. Both methods are used to predict sales of bakery products and to determine the best and most efficient product combinations to achieve multi goals. Forecasting methods implemented are the single exponential smoothing, double exponential smoothing, and triple exponential smoothing. Then the three methods are compared in order to choose the best forecasting method by selecting the method having the smallest MSE value. Furthermore, the best forecast result is used as constraint functions on linear goal programming. On this case of the linear goal programming, the main priority is to achieve maximum profit. Second priority is to minimize overtime and the last priority is to minimize the commodity consumption. The combination of forecasting and the linear goal programming give the optimal results by providing a guarantee that the amount of productions to be carried out meet all customer demands.

***Keywords**: Forecasting, Exponential Smoothing, Linear Goal Programming.*

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I. Introduction

A forecast is a prediction of some future event or events. Forecasting is an important problem that spans many fields including business and industry, government, economics, environmental sciences, medicine, social science, politics, and finance. The reason that forecasting is so important is that prediction of future events is a critical input into many types of planning and decision-making processes. Most forecasting problems involve the use of time series data. A time series is a time-oriented or chronological sequence of observations on a variable of interest [8].

Forecasting model has been widely examined by several previous researchers, as done by Barbosa et al. [2]. They examine a forecasting method for demand of products food industry to medium term production planning. The food industry is located in Volta Redonda, Rio de Janeiro and focuses its production in pasta and sausage, composed of 6 different production lines that produces 49 different types of products and supply two restaurants chains and a pizzeria chain located all over Brazil. Monthly sales data of all products from January 2012 to January 2014 is used to forecast demand for the next 3 months, namely February to April 2014. They used multiplicative Holt-Winters method for product 1 and the additive Holt-Winters method for product 2, with a confidence level of 95%. Considering the forecasts obtained for the months of February, March and April 2014 and the real sales in this period, a Mean Absolute Percent Error (MAPE) of 1.38% was obtained for product 1 and of 3.14% for the product 2.

Linear programming is one of the methods in determining optimal solution of a linear problems. In linear programming there is an objective function and obstacle in linear inequality form. Linear programming is usually used to solve the optimization problem in various fields, for example in business field, banking, education and many other fields that can be stated in linear forms.

Balogun et al. [1] have applied linear programming model in Bottling Company in Nigeria. The purpose is to notice how the company can earn maximum profit with limited raw materials availability. Using the simplex method, the results were obtained to make a maximum profit, the company should produce 462,547 bottles 50cl Coke and 415,593 bottles 50cl Orange Fanta with the resulting profit of 263,497,283 Nigerian Naira.

The linear programming model is growing and expanding, previously had only one goal, it develops into how to solve problems with more than one goal, that is what so called the linear goal programming. In a linear programming, the objective function is only to maximize or minimize the results, so that all objectives are formulated into one objective function only. This result in the system can be an optimal condition for one goal but it might ignore its other goals. Different with linear programming, in linear goal programming method, the result is optimal for some of the objectives to be achieved.

Hassan and Ayop [3] have conducted a research on the frozen food industry in Malaysia. The problem that occurs is that the demand for frozen food products is quite high, but not all requests can be fulfilled due to certain limiting factors. By applying the goal programming, net profit can increase and production costs can be saved. Likewise, Kumar and Sridhar [5] conduct a study at Jayaka Bakery located in the city of Durg Chhattisgarh India. From the results of the research using goal programming give suggestions on product combinations that must be produced so as to provide a maximum profit of 58.645 Rs.

Kumar [6] conducts a research on Iyyangar Bakery in India using the goal programming method by making five decision variables and considers four goal constraints, with the priority order of maximizing sales profits, minimizing overtimes, maximizing the use of machinery and minimizing raw materials consumptions. The weighted preemptive goal programming method gives the results that priority 1, 2, and 3 are achieved and priority 4 is not achieved. The researcher suggest that if the bakery wants to achieve optimal results it must produce 62 units of cupcakes per day and 215 units of egg toast per day but by adding the egg ingredients as much as 170.09 grams.

From several examples of researches that have been done before, in general they only discuss the problem of goal programming to achieve some objectives with constraints that already available at a certain time. Research on forecasting only discusses forecasting future events. In this paper, the authors discuss the combination between the forecasting methods and linear goal programming method for decision making with case studies at Rotte Bakery shop.

Rotte Bakery is a bakery company in City of Pekanbaru that has been established since 2016. Rotte produces various types of breads and cakes such as plain bread, pillow bread, sweet bread, donuts and cake decorations. Rotte Bakery has season constraints on its sales, which is usually run into fluctuating demand when entering certain times like Ramadhan and national long holidays. Meanwhile, Rotte bakery applies a profit-sharing system to the shop team, managers and investors so it is important to have a good management system. The factors of constraints on the number of human resources and the availability of raw materials very influential on the achievement of production results. Maximum profit is the priority goal in this case, then minimizing overtime and efficiency in production costs is the next priority. The authors use the preemptive method for optimization problems. In this case the authors use statistical software R version 1.3 to evaluate the forecasting methods, and LINGO version 18.0 to calculate the linear goal programming problem.

II. Forecasting method

There are two broad types of forecasting techniques, qualitative methods and quantitative methods. Qualitative forecasting techniques are often subjective in nature and require judgment on the part of experts. Qualitative forecasts are often used in situations where there is little or no historical data on which to base the forecast. Quantitative forecasting techniques make formal use of historical data and a forecasting model. The model formally summarizes patterns in the data and expresses a statistical relationship between previous and current values of the variable. Then the model is used to project the patterns in the data into the future. In other words, the forecasting model is used to extrapolate past and current behavior into the future [8]. In this research the authors used the exponential smooting method for forecasting.

A. Moving Average Method

A simple Moving Average [7] is a method that takes the average of all observed data collected to predict future data. A moving average forecast of order k, or $MA(k)$, is given by

$$F_{t+1} = \frac{1}{k} \sum_{i=t-k+1}^{t} Y_i,$$

where

Y_{t+1} ≔ Forecast for period $(t+1)$,
Y_t ≔ Actual observation for time period t,
Y_{t+1} ≔ Forecast value for the next period,
t ≔ Time period.

B. Exponential Smoothing Method

The exponential smoothing method is a development of the moving average forecasting technique. There are 3 types of exponential smoothing methods, namely:

1. *Single exponential smoothing method*

   The single exponential smoothing method is also known as simple exponential smoothing [7]. Suppose we wish to forecast the next value of our time series Y_t which is yet to be observed. Our forecast is denoted by F_t. When the observation Y_t becomes available, the forecast error is found to be $Y_t - F_t$. The method of single exponential forecasting takes the forecast for the previous period and adjusts it using the forecast error. That is, the forecast for the next period is

$$F_{t+1} = F_t + \alpha(Y_t - F_t),$$

where α is a constant between 0 and 1.

2. *Double exponential smoothing method*
The forecast for double exponential smoothing method (Holt's linear exponential smoothing) is found using two smoothing constants α and β (with values between 0 and 1), and three equations [7]:

$$L_t = \alpha Y_t + (1 - a)(L_{t-1} + b_{t-1}),$$

$$b_t = \beta(L_t - L_{t-1}) + (1 - \beta)b_{t-1},$$

$$F_{t+m} = L_t + b_t m,$$

Here L_t denotes an estimate of the level of the series at time t and b_t denotes an estimate of the slope of the series at time t.

3. *Triple exponential smoothing method*
The triple exponential smoothing method is often called the Holt-Winters exponential smoothing method. The seasonal component in Holt-Winters' method may also be treated additively. The basic equations for Holt-Winters' additive method are as follows [7]:

$$L_t = \alpha(Y_t - S_{t-s}) + (1 - a)(L_{t-1} + b_{t-1}),$$

$$b_t = \beta(L_t - L_{t-1}) + (1 - \beta)b_{t-1},$$

$$S_t = \gamma(Y_t - L_t) + (1 - \gamma)S_{t-s},$$

$$F_{t+m} = L_t + b_t m + S_{t-s+m},$$

where s is the length of seasonality (*e.g.*, number of months or quarters in a year), L_t represents the level of the series, b_t denotes the trend, S_t is the seasonal component, and F_{t+m} is the forecast for m periods ahead.

C. Mean Square Error

The error rate (error) of forecasting is the difference between the observed data values and the forecast data. The smaller the error rate in a forecast, the better the forecasting results. In this study, the mean square error (MSE) value is used as a measurement of the error rate to select the best model.

Let e_t be the error value at time t, Y_t the real value, and F_t the forecast value. Thus, $e_t = Y_t - F_t$. The MSE value is obtained by the formula

$$MSE = \frac{\sum {e_t}^2}{N},$$

where N is the number of observational data.

III. Linear Goal Programming

The goal programming method is an extension of the linear programming method which is used as a basis for decision making to analyze problem solutions, which involves many objectives in order to obtain optimal problem-solving alternatives. The goal programming method was introduced in 1955 and developed for several applications by Ignizio [4].

A. Linear goal programming model

The general form of the goal programming model is [9]

$$\min z = \sum_{i=1}^{m} (d_i^+ + d_i^-), \qquad (1)$$

subject to

$$\sum_{j=1}^{n} a_{ij}x_j - d_i^+ + d_i^-, \text{ for } i = 1,2,\dots,m, \tag{2}$$

$$x_j, d_i^-, d_i^+ \geq 0, i = 1, 2, \dots, m, \qquad j = 1, 2, \dots, n, \tag{3}$$

where

a_{ij} ≔ The coefficient of decision making variables j in constraint i, $i = 1,2,\dots,m; j = 1, 2, \dots, n.$
x_j ≔ Decision variables, $i = 1,2,\dots,m.$
d_i^+ ≔ Positive deviation variable, $i = 1,2,\dots,m.$
d_i^- ≔ Negative deviation variable. $i = 1,2,\dots,m.$

The deviation variable serves to express the objective function in the form of a goal constraint, after which it seeks a solution by minimizing the number of deviations from the objective function. The positive deviation variable $d_i^+$is the achievement above the target b_i while the negative deviation variable d_i^- is the achievement below the target b_i. If $f_i(x) \geq b_i$ then d_i^- will be minimized, likewise if $f_i(x) \leq b_i$ then d_i^+ will be minimized.

B. Preemptive goal programming method

The method of preemptive goal programming or often known as lexicographic is a method by prioritizing objectives in the goal programming method [10]. In some cases, one goal will be more important than the other so that decision makers must determine the priority order of these objectives. The notation used to mark the priority of the goal is p for $i = 1,2,\dots,m$, where m is the number of goals arranged in a sequence. These priority factors have the following relationship:

$$p_1 >>> p_2 >>>> \cdots >>> p_{m.} \tag{4}$$

In equation (4) the notation $>>>$ means much more important than. This is to state the priority order of objectives to be achieved where p_1 has a higher priority that must be achieved first before moving on to the next priority. The deviations that are contained in the higher priority must be minimized before going to the lowest priority deviation.

The general form of the preemptive goal programming method is [9]

$$\min z = \sum_{i=1}^{m} p_i(d_i^+ + d_i^-),$$

subject to (2) and (3), p_i priority factor in goal $i, i = 1, 2, \dots, m.$

C. Combination of forecasting method and linear goal program

The general preemptive goal programming with forecasting is

$$\min z = \sum_{i=1}^{m} p_i(d_i^+ + d_i^-),$$

subject to:

$$\sum_{j=1}^{n} a_{ij}x_j - d_i^+ + d_i^-, \text{ for } i = 1,2,\dots,m,$$

$$x_j \geq F_j, \qquad j = 1,2,\dots,n,$$

$$x_j, d_i^-, d_i^+ \geq 0, \qquad i = 1, 2, \dots, m, \qquad j = 1, 2, \dots, n,$$

where F_j is the value of forecasting demand x_j.

IV. Numerical Examples

A. Forecasting problem

In this study, data on the monthly sales of bread products at Rotte Bakery are given, from February 2017 to September 2020. Seven types of bread are selected to represent several product categories. The 7 types of bread are plain bread (x_1), coconut pillow bread (x_2), sausage bread (x_3), cheese floss bread (x_4), mexicana banana bread (x_5), donuts (x_6) and fit-O mini bread (x_7). Sales complete data coming from the results of research at Rotte Bakery are presented in Table 1.

Table 1. Data on sales of bakery products at Rotte Bakery (Pcs)

Month	Plain Bread	Coconut Pillow Bread	Sausage Bread	Cheese Floss Bread	Mexicana Banana Bread	Donuts	Fit-O Mini Bread
Feb-17	630	368	562	295	384	5489	14827
Mar-17	782	469	692	357	458	6846	18667
Apr-17	828	493	742	387	512	7357	19914
May-17	749	440	658	344	443	6528	17415
Jun-17	347	208	315	165	217	3053	8322
Jul-17	527	331	497	256	356	4933	13962
Aug-17	831	512	803	396	546	7821	21586
Sep-17	840	513	813	394	544	7783	21543
Oct-17	625	401	618	298	409	5967	16541
Nov-17	681	456	722	340	481	6801	18495
Dec-17	728	492	735	349	508	7224	19546
Jan-18	645	433	665	310	448	6283	17262
Feb-18	608	390	629	277	418	5794	15592
Mar-18	759	497	786	357	526	7334	19357
Apr-18	717	465	726	327	488	6830	18002
May-18	529	343	524	235	359	4833	12974
Jun-18	248	167	250	116	172	2334	6184
Jul-18	646	415	734	324	507	6095	16627
Aug-18	628	424	756	328	525	6121	17102
Sep-18	720	480	835	379	598	6896	19658
Oct-18	791	509	888	412	654	7225	20319
Nov-18	739	558	764	405	678	6177	16991
Dec-18	860	677	1072	413	853	6533	21233
Jan-19	749	571	932	339	717	5215	17393
Feb-19	730	556	875	344	697	5809	17652
Mar-19	754	587	948	329	712	6269	20767
Apr-19	776	579	896	354	719	5415	20124
May-19	527	351	634	209	530	3040	10616
Jun-19	370	238	456	114	281	2634	9668
Jul-19	861	576	915	284	755	5574	17849
Aug-19	864	481	796	311	637	5486	18792
Sep-19	1036	505	651	362	668	5379	16892
Oct-19	933	491	781	314	509	5417	18324
Nov-19	812	473	761	293	600	6230	19508
Dec-19	902	549	887	350	729	6682	20240
Jan-20	982	597	806	325	590	6583	17279
Feb-20	903	590	740	287	758	6178	16722
Mar-20	1049	644	812	264	586	6638	17802
Apr-20	1054	498	576	254	377	5586	10716
May-20	589	250	445	179	302	2728	5735
Jun-20	992	476	640	284	470	6035	12010
Jul-20	1035	517	722	279	494	6947	13305
Aug-20	903	532	686	317	578	7481	13538
Sep-20	1050	509	590	311	552	6453	11514

Single exponential smoothing (SES), double exponential smoothing (DES) and triple exponential smoothing (TES) methods are applied to the bread demand forecasting. Forecasting calculations are performed using R Studio statistical software version 1.3. This forecasting is carried out to determine the bread demand forecast for the next 8 months (May 2021). The results of the MSE calculation are shown in Table 2.

Table 2. MSE Values

Forecasting Methods	MSE						
	Plain Bread	Coconut Pillow Bread	Sausage Bread	Cheese Floss Bread	Mexicana Banana Bread	Donuts	Mini Fit-O Bread
SES	28,360	12,622	26,966	5,186	19,015	1,962,878	16,853,043
DES	41,524	17,390	36,402	7,052	23,054	2,883,599	22,259,673
TES	16,727	7,059	15,783	2,908	13,466	955,078	7,256,639

Figure 1 represents the forecasting results of the sale of fit-O mini bread. For this particular product, it can be seen that the graph of the triple exponential smoothing (TES) method is the closest to the actual data graph compared to the graphs of simple exponential smoothing (SES) and double exponential smoothing (DES). This shows that the error forecasting using TES is the smallest. This statement is in line with the MSE value in Table 2. The triple exponential smoothing method is obtained as the best method in predicting the demand data for fit-O mini bread at Rotte Bakery.

Figure 1. Sales of fit-O mini bread at Rotte Bakery and the forecasting results

Based on the obtained MSE values in Table 2, it can be concluded that the method that gives the smallest forecast error measure is the triple exponential smoothing method. Thus, the triple exponential smoothing method is chosen to forecast the demand for bread in the 8th month, namely May 2021. The results of this forecast are used as constraints on the problem of the linear goal programming. Forecasting values using the triple exponential smoothing method are shown in Table 3.

Table 3. Triple Exponential Smoothing Method Forecasting Value (Pcs)

No.	Product	Forecasting (May 2021)
1	Plain Bread	829
2	Coconut Pillow Bread	331
3	Sausage Bread	549
4	Cheese Floss Bread	200
5	Mexicana Banana Bread	437
6	Donuts	6,789
7	Fit-O Mini Bread	4,627

B. Goal programming problem

On the matter of this program's goals, there are three goals that Rotte Bakery wants to achieve, namely

1. The company has a sales target for May 2021 of IDR32,000,000, then the first goal is to maximize profits (goal 1). (IDR is the Indonesian currency)
2. The company does not want any overtime costs, the available working hours are 24,000 minutes, so the second goal is to minimize the production time (goal 2).
3. To minimize production costs, the company wants to use the minimum raw material possible (goal 3).

The constraint functions for bread production problems at Rotte Bakery are presented in Tables 3, 4 and 5.

Table 4. Selling Prices, Profits and Time Production for each Type of Bread

No	Product	Price (IDR)	Profit (IDR)	Time Production (Minutes)
1	Plain Bread	11,500	5,967	4.3
2	Coconut Pillow Bread	10,500	4,789	2.4
3	Sausage Bread	7,000	3,205	0.8
4	Cheese Floss Bread	5,000	2,969	0.8
5	Mexicana Banana Bread	6,000	3,260	0.8
6	Donuts	3,500	1,155	0.9
7	Fit-O Mini Bread	2,500	1,336	0.6

Table 5. Ingredients for each type of bread (gram)

No	Product	Plain Bread	Coconut Pillow Bread	Sausage Bread	Cheese Floss Bread	Mexicana Banana Bread	Donuts	Fit-O Mini Bread	Stock
1	Flour	250	100	30	30	33	25	15	600,000
2	Yeast	4	1.5	0.4	0.4	0.4	0.3	0.2	8,000
3	Softener	1	0.5	0.1	0.1	0.1	0.1	0.1	5,000
4	Egg	0	10	4	4	5	2	2	45,500
5	Sugar	15	30	6	16	8	4	3	110,000
6	Butter	15	15	5	20	8	3	3	90,000
7	Powdered milk	5	5	1	1	1	1	0.5	25,000
8	Water	125	40	12	12	12	9	7	270,000
9	Coffee	0	0	0	0	0	0	0.5	6,000
10	Chocolate	0	0	0	0	7	5	0	40,000
11	Cheese	0	0	7	10	5	0	0	12,000
12	Banana	0	0	0	0	25	0	0	20,000
13	Sauce	0	0	15	0	0	0	0	10,000
14	Mayonnaise	0	0	10	0	0	0	0	10,000
15	*Meses*/Chocolate sprinkles	0	0	0	0	7	0	0	10,000
16	Grated coconut	0	25	0	0	0	0	0	15,000
17	Sausage	0	0	30	0	0	0	0	20,000

The formulation of the preemptive goal programming for this problem can be stated as follows:

$$\min z = p_1(d_1^-) + p_2(d_2^+) + p_3(d_3^+ + d_4^+ + d_5^+ + d_6^+ + d_7^+ + d_8^+ + d_9^+ + d_{10}^+ + d_{11}^+ + d_{12}^+ + d_{13}^+ + d_{14}^+ + d_{15}^+ + d_{16}^+ + d_{17}^+ + d_{18}^+ + d_{19}^+)$$

subject to

$$5967x_1 + 4789x_2 + 3205x_3 + 2969x_4 + 3260x_5 + 1155x_6 + 1336x_7 - d_1^+ + d_1^- = 32000000$$
$$4.3x_1 + 2.4x_2 + 0.8x_3 + 0.8x_4 + 0,8x_5 + 0.9x_6 + 0.6x_7 - d_2^+ + d_2^- = 24000$$
$$250x_1 + 100x_2 + 30x_3 + 30x_4 + 33x_5 + 25x_6 + 15x_7 - d_3^+ + d_3^- = 600000$$
$$x_1 + 1.5x_2 + 0.4x_3 + 0.4x_4 + 0.4x_5 + 0.3x_6 + 0.2x_7 - d_4^+ + d_4^- = 8000$$
$$x_1 + 0.5x_2 + 0.1x_3 + 0.1x_4 + 0.1x_5 + 0.1x_6 + 0.1x_7 - d_5^+ + d_5^- = 5000$$
$$10x_2 + 4x_3 + 4x_4 + 4x_5 + 2x_6 + 2x_7 - d_6^+ + d_6^- = 45500$$
$$15x_1 + 30x_2 + 6x_3 + 16x_4 + 8x_5 + 8x_6 + 0.1x_7 - d_7^+ + d_7^- = 1100000$$
$$15x_1 + 15x_2 + 5x_3 + 20x_4 + 8x_5 + 3x_6 + 3x_7 - d_8^+ + d_8^- = 90000$$
$$5x_1 + 5x_2 + x_3 + x_4 + x_5 + x_6 + 0.5x_7 - d_9^+ + d_9^- = 25000$$
$$125x_1 + 40x_2 + 12x_3 + 12x_4 + 12x_5 + 9x_6 + 7x_7 - d_{10}^+ + d_{10}^- = 270000$$
$$0.5x_7 - d_{11}^+ + d_{11}^- = 6000$$
$$7x_5 + 5x_6 - d_{12}^+ + d_{12}^- = 40000$$
$$7x_3 + 10x_4 + 5x_5 - d_{13}^+ + d_{13}^- = 12000$$
$$25x_5 - d_{14}^+ + d_{14}^- = 20000$$
$$15x_3 - d_{15}^+ + d_{15}^- = 10000$$
$$10x_3 - d_{16}^+ + d_{16}^- = 10000$$
$$7x_5 - d_{18}^+ + d_{18}^- = 10000$$
$$25x_2 - d_{18}^+ + d_{18}^- = 15000$$
$$30x_3 - d_{19}^+ + d_{19}^- = 10000$$
$$x_1 \geq 829, x_2 \geq 331, x_2 \geq 549$$
$$x_4 \geq 200, x_5 \geq 437, x_6 \geq 6789, x_6 \geq 4627$$

The linear goal programming model is solved by using the LINGO 18.0. Two settlement processes are carried out, namely the completion with an additional model of forecasting constraints and a model without adding the forecasting result constraint which is the forecasting of demand in May 2021. The optimal results obtained for this problem are presented in Table 6.

Table 6. Optimal Results of Linear Goal Programming (Pcs)

Decision Variables	Value without Minimum Demand Constraints	Value with Minimum Demand Constraints
x_1	690	829
x_2	600	331
x_3	666	666
x_4	333	333
x_5	800	800
x_6	6,880	6,789
x_7	9,270	8,910

Based on Table 7 the optimal results for without demand constraints, it is obtained that the number of types of bread that must be produced by Rotte Bakery in May 2021 is 690 pcs for plain bread, 600 pcs for coconut pillow bread, 666 pcs for sausage bread, 333 pcs for floss cheese bread, 800 pcs for mexicana banana bread, 6880 pcs for chocolate donuts and 9270 pcs for fit-O mini bread. With the profit obtained is IDR33,057,277. While with a model with demand constraints, the results obtained from the number of types of bread that must be produced are 829 pcs for plain bread, 331 pcs for pillow coconut bread, 666 pcs for sausage bread, 333 pcs for cheese floss bread, 800 pcs for mexicana banana bread, 6789 pcs for chocolate donuts and 8901 pcs for fit-O mini bread. With a combination like this the profit is IDR32,000,000 according to the first goal to be achieved.

Fulfillment of the demand for certain types of bread is important to provide a customer satisfaction. A satisfied customer is one of the factors that determine the success and growth of a business in the future. So the company must be wise in making decisions in a production plan, not only prioritizing achieving profit without considering customer happiness.

V. Conclusion

The combination of forecasting method (triple exponential smoothing) and the linear goal programming give the optimal results by providing a guarantee that the amount of production to be carried out can meet all customer demands. This is because the demand value has been predicted and is being constraint functions in the goal programming model. This is beneficial for the company in the long term production plan because it will minimize the risk of customer disappointment due to not being able to meet customer demands.

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