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A COMPARATIVE STUDY ON THE FORECAST OF FRESH FOOD SALES USING LOGISTIC REGRESSION, MOVING AVERAGE AND BPNN METHODS

Wan-I Lee
Department of Marketing and Distribution Management, National Kaohsiung First University of Science and Technology, Kaohsiung, Taiwan

Cheng-Wu Chen
nstitue of Maritime Information and Technology, National Kaohsiung Marine University, Kaohsiung, Taiwan. Global Earth Observation and Data Analysis Center, National Cheng Kung University, Tainan 701, Taiwan, R.O.C,
chengwu@mail.nkmu.edu.tw

Kung-Hsing Chen
HI-LIFE International Co., Ltd., 3F, 502, Rueiguang Rd., Neihu District, Taipei City, Taiwan

Tsung-Hao Chen
Department of Business Management, Shu-Te University, Kaohsiung, Taiwan.

Chia-Chi Liu
College of Management, National Kaohsiung First University of Science and Technology

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A COMPARATIVE STUDY ON THE FORECAST OF FRESH FOOD SALES USING LOGISTIC REGRESSION, MOVING AVERAGE AND BPNN METHODS

Wan-I Lee[1], Cheng-Wu Chen[2,3], Kung-Hsing Chen[4], Tsung-Hao Chen[5], and Chia-Chi Liu[6]

Key words: Moving average, BPNN, logistic regression, fresh food in POS database.

ABSTRACT

Different prediction methods give different performance predictions when used for daily fresh food sales forecasting. Logistic Regression (LR) is a good choice for binary data, the Moving Average (MA) method is good for simple prediction, while the Back-Propagation Neural Network (BPNN) method is good for long term data. In this study we develop and compare the performance of three sales forecasting models, based on the above three prediction methods, for the forecasting of fresh food sales in a point of sales (POS) database for convenience stores. Fresh food is characterized by two factors: its short shelf-life and its importance as a revenue producer for convenience stores. An efficient forecasting model would be helpful to increase sales volume and reduce waste at such stores. The correctness of the prediction rate is a good way to compare the efficacy of different models which is the method used here. The research results reveal that LR performs better than the other methods although MA is better suited to the management of convenience stores.

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[1] Department of Marketing and Distribution Management, National Kaohsiung First University of Science and Technology, Kaohsiung, Taiwan.
[2] Institue of Maritime Information and Technology, National Kaohsiung Marine University, Kaohsiung, Taiwan.
[3] Global Earth Observation and Data Analysis Center, National Cheng Kung University, Tainan 701, Taiwan, R.O.C.
[4] HI-LIFE International Co., Ltd., 3F, 502, Rueiguang Rd., Neihu District, Taipei City, Taiwan.
[5] Department of Business Management, Shu-Te University, Kaohsiung, Taiwan.
[6] College of Management, National Kaohsiung First University of Science and Technology.

I. INTRODUCTION

With the changing of the structure of society and households, the way fresh food is sold in the market is rapidly changing. Freshness and rapid speed of turnover are important consideration. Sellers must maintain high standards for facilities and equipment, be serious about the quality of production and have suitable options for sources raw materials. The period that one can keep fresh food, from the day of production to when it must be discarded, is shorter than for cooked food, which means that it is important to predict how much fresh food will be required in the market. In this study we will focus on making this type of prediction with different forecasting sales models.

Reliable prediction of sales is of immense benefit to a business because it can improve the quality of the business strategy and decrease costs due to waste, thereby increasing profit. To improve an enterprise's competitiveness, the manager must make correct decisions using the available information. This "forecasting" is viewed as an important part of decision making. Forecasting of future demand is central to the planning and operation of the retail industry. Managers need sales forecasts as essential input to many decision activities in a variety of areas such as marketing, sales and production.

Before regression analysis, the training data have to satisfy four assumptions: normality and resemblance or variation, independence of raw data, linearity and zero error average. The increasing usage of statistics and probability has made forecasting techniques become more critical. As technology requirements increase, so does the demand for greater exactness and efficiency. A growing number of studies are being made which shed some light on these two independent requirements for computing with complex statistics or algorithms. These forecasting systems must deal with the following constraints:

- Substitution of most of the items collected is subjective.
- Long lead time needs to be taken into consideration when

producing and planning sources for a mid-term horizon
- Influence of explanatory variables. These factors can include: weather data, holidays, marketing actions, promotions, fashion, even economic environment.

These types of constraints are being incorporated by more and more researchers who are applying sales forecasting models to deal with forecasting problems. All of these models possess fault tolerance ability and high-speed computability. In the past, the three most commonly applied methods have been Logistic Regression (LR), the Moving Average (MA) method, and Back-Propagation Neural Networks (BPNNs) [86, 87, 89, 111, 132, 135, 149, 160, 161, 180]. These methods have been applied in many different areas including for ecological and microbial studies, in Morgan Stanley Capital International (MSCI), for finding ecosystem attributes, and so on. Some have concluded that the BPNN methods perform better than others, however these approaches are inherently different and whether one approach has better diagnostic performance than the other is not easy to determine.

The purpose of this current study is to build sales forecasting model utilizing the Logistic Regression, Moving Average and Back-Propagation Neural Network methods for the prediction of daily fresh food sales. The goal is to deal with short-term sales forecasting for convenience stores. The uncertainty and the complex relationship between the data will be considered in proposed sales forecasting models.

II. SALES FORECASTING

The importance of sales forecasting for a firm [127] is best expressed by what happens when it is absent [159]. An efficient forecasting system can help a firm improve machine utilization, reduce inventory, achieve greater flexibility to change and increase profits [85]. Sales forecasting is particularly important because its outcome affects many functions in the organization [130]. Business operations can only respond retroactively, leading to lost orders, inadequate service and poorly utilized production resources in the short term; financial and market decisions leading to misallocation of resources so that the organization's continuing existence may be brought into question in the longer term [88].

Collectively, there is some empirical evidence indicating that the subjective techniques popular for all types of forecasting situations are effective. Among the statistical forecasting approaches, exponential smoothing has recently been gaining in popularity [84]. In particular, in recent years, extensions and modifications of the BPNN have been developed. The BPNN is the most common of the neural network applications having the advantage of yielding high classification accuracy [109]. However, this method has two problems, slow training speed and the likelihood of entering into a local minimum during the process. Moreover, in logistic regression, the model complexity is relatively, especially when no or few interaction terms and variable transformations are used [86]. The use of specific forecasting techniques is a crucial aspect of the forecasting process [128].

III. RESEARCH METHOD

1. Research Subject and Data Collection

Taiwan's Hi-Life convenience store chain is selected as the research subject. We collected data on 35 days of fresh food sales from the POS database of the Hi-Life convenience stores. The sales data included number of sales and amount of fresh food discarded. Fresh foods herein are comprised of four kinds of sandwich, three kinds of hand-made rolls, two kinds of rice balls and sushi. The data are shown in Appendix 1.

In this study, a "single product" is defined as the test unit. Information includes the type of fresh food, ordering cycle, quantity ordered, arrival date and expiration date. The ordering cycle is defined as daily. Quantity ordered is defined ranging from zero to ninety-nine. Arrival date is defined as arrival on the next morning following ordering. Finally, expiration date is defined as one and a half days after arrival at the store.

2. Logistic Regression (LR)

Logistic distribution is a model transform method that utilizes logic analysis after the selection of variables. The following Cumulative Probability Function is utilized for the logistic regression analysis [133]:

$$P_i = F(Z_i) = F(\beta_0 + \beta_1 X_1) = \frac{1}{1+e^{-Z_i}} = \frac{1}{1+e^{-(\beta_0+\beta_1 X_i)}} \quad (1)$$

Eq. (1) can be rewritten as Eq. (2) and comprises the logistic regression analysis model used in this study

$$Z_i = \beta_0 + \sum_{j=1}^{n} \beta_j X_{ij} + e_i \quad (i = 1, 2, \ldots, n) \quad (2)$$

From a pool of n samples, n-1 can be fitted to an LR model defined by $(p_m) = \alpha + \sum_{i=1}^{10} \beta_i X_i$, where p_m is the probability of discarded items; α and β_i are unknown parameters that determine the shape of the logistic curve described. The unknown parameters α and β_i are estimated using a maximum-likelihood approach. Meanwhile, the estimated parameters $\hat{\alpha}$ and $\hat{\beta}$ are used to calculate the probability of discarded items.

3. Back-Propagation Neural Network

The most common learning mechanism is the "back propagation" approach [134]. The Back-Propagation Neural Network (BPNN) is a supervised learning network well suited for prediction [49, 52]. In BPNN one attempts to minimize the mean-square output error throughout the entire training set. It is similar to the statistical calculation of the best fitting line for

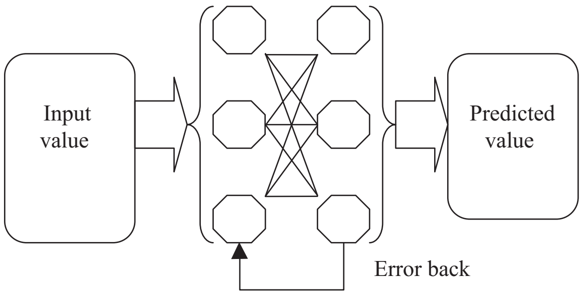

Fig. 1. Mapping of BPNN.

Table 1. LR model prediction results.

			Prediction		
			Discard number		Correct percentage
			.00	1.00	
Observed	Discard number	.00	23	0	100.0
		1.0	9	3	25.0
	Overall percentage				74.3

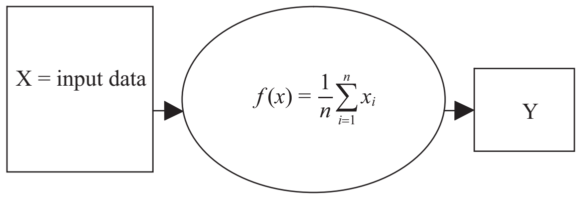

Fig. 2. Mapping of the MA method.

dispersed points. The output of the network, after introduction of the input data, is compared to the true output. The process is shown in Fig. 1.

The training data may be sometimes is over-fitted by the training network [83] which compromises the performance with new data. By halting the training from time to time and testing the performance with a new data set, one can avoid the over-fitting condition. This difficulty is less of a problem for large data sets. Once the network has been trained it must still be tested again with further cases with known outcomes. The Work Toolbox of MATLAB is used to develop and simulate the BPNN. One and two hidden layers are selected as the input for the model. The learning rate is 0.01 and the error less than 10^{-11}. Here, we choose the sample (e.g., sandwich A and sushi) for input, and run the training function. Finally, a predicted value is generated and a correct percentage is calculated.

4. Moving Average (MA)

MA is simply a time series analysis forecasting method. The advantage of MA is that it is simple and easy to use. It also gives a basic and efficient tendency index. Based on this, this method is commonly used to make forecasts from historical data. Eq. (3) can be used to find the simple moving average by first computing the sum of the observations and then dividing by the number of observations. The structure is shown in Fig. 2. In other words, we calculute the average of a circle, where the average value is an expected value X_{n+1}.

$$MA = X_{n+1} = \sum_{i=1}^{n}\left[\frac{X_i}{n}\right] \quad (3)$$

where

n: days of moving average

$\sum_{i=1}^{n} x_i$: the sum value of recall n days include calculate day.

5. Error Calculation

The correct percentage means the percentage of correct predictions while the incorrect percentage means the failure to predict all values. The correct forecast percentage is the summation of the predicted values, divided by the total sample number. For example, in Table 1, it can be seen that the correctly predicted value for sandwich A is 26 and the incorrect prediction is 9. The correct percentage for sandwich A is 74.3%. Here, we define error in the correct percentage as the incorrect percentage.

IV. EXPERIMENTS

Forecasting the correct percentage is a simple and fast method for evaluating the performance of a prediction model. In the study, three models are developed and evaluated. SPSS 13.0 is used to analysis the LR model, MATLAB 7.0 is used for the BPNN model and EXCEL 2003 is utilized to evaluate the MA model.

1. Logistic Regression

The LR prediction model is developed to predict the number of items sold and the number that have to be discarded. The number of items sold is the independent variable and the discard number is the dependent variable. If the value of the dependent variable is 0 it means that no items are discarded; 1 means that some items are discarded. The LR model is verified by SPSS 13.0. The prediction results for sandwich A are shown in Table 1 and overall results are shown in Table 3.

2. Back-Propagation Neural Network

The parameters for the BPNN prediction model used are shown in Table 2.

In addition, the expected values are predicted using different periods of data (including 7 days, 14 days, 21 days, and 28 days). The correct percentage prediction for sandwich A is 71.43% for 28 days, 61.9% for 14 days, 50% for 21 days and 32.14% for 7 days. The prediction results are shown in Table 3 and the architecture for the method is shown in Fig. 3.

Table 2. Parameters for BPNN.

Parameter	1
Input	1
Layers	2
First adaption function	tansig
Second adaption function	purelin
Training function	taming
Epoch limit	3000
Error	10-11
Neuron network choice	Network increase
Initial weight	1
Bias weights	1
Perform function	MSE

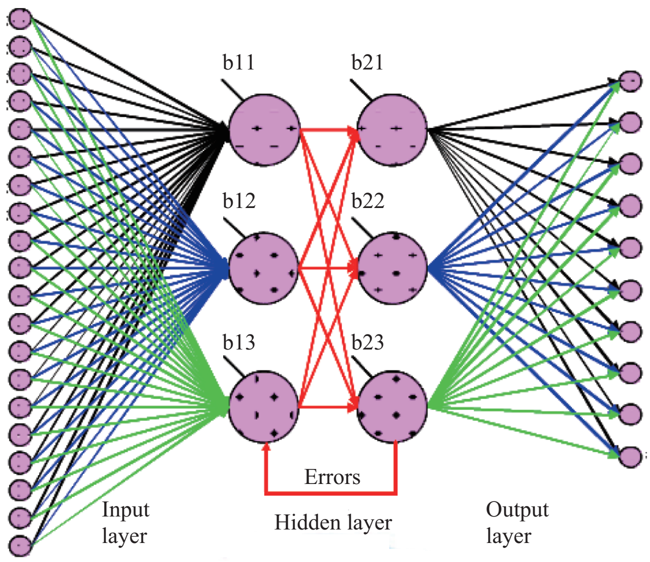

Fig. 3. BPNN network.

3. Moving Average

The differences in data are checked by T-testing, and then induced [87]. After induction, we find that there are two variables distinguished by date. One is holiday and the other is ordinary day. After distinction, data are input into the MA model and used to predict expected values. The prediction results are shown in Table 3. The correct percentage prediction of MA is 78.57% (for hand-made rolls C).

V. DISCUSSION

Recently, soft computing and artificial intelligence have been successfully applied to the systemengineering [1-82, 90-108, 110, 113-127, 131, 136-158, 162-179, 181]. The BPNN, MA and LR prediction models are used to predict the number of sales of fresh food at a convenience store. Results are shown in Table 3. It can be seen that the MA method gives the highest correct percentage for sandwich A; the BPNN method gives the highest correct percentage for sushi; the LR model gives the highest value for all others. On the whole, it is clear that the performance of LR is better than that of MA or BPNN. The standard error obtained with LR is less than with other methods, which means less variance in the LR model. The error value of LR is less than that of either MA or BPNN, as shown in Table 4. In Table 3, it can be seen that, for most samples, the LR forecast is higher than that of the other methods. The correct BPNN percentage for sushi is higher than that obtained by the other methods while the correct percentage predicted by MA is greater for sandwich A and hand roll C than that for the others. The standard error for LR is 0.108964 which is less than that of the other methods.

In this study, the correct percentage obtained by LR is higher than that obtained with the other methods. However, this result is different from that found in past related studies, where it was found that the BPNN performed better than the other methods. Why does this difference occur? We explore some inferred reasons. One reason is that the BPNN program is very subjective, so different models may produce different results. Table 2 shows parameters used in this study for the BPNN model. The second reason is the differences in the samples. For example, as noted by Song, researchers use different methods on different samples, but even the same method will perform differently with different samples. In other words, one method is not always suitable for all samples. Different samples have different features and are suitable for data with different periods. In Table 3 it can be seen that performance is better for long period data. According to these results, BPNN is more suitable for samples with long periods. Thus, we find that LR gives better correct percentage performance than others; its standard error is also better than the other methods. This means that LR will not be influenced by different types of samples. On the whole, the explanatory ability of LR is better than that of the other methods. In addition, there are software tools available to calculate LR. On the other hand, MA is a fast and easy method, which can be used on any sample. It is easy to understand the overall tendency, although its performance is not as good. The error rate of BPNN is too high. The error rate of MA is also higher than that of LR which is 20.3%. Although still high, a 20% error rate is acceptable for small samples. In conclusion, MA and BPNN are not suitable for predicting the amount of fresh food sales.

In order to reduce costs, we would suggest that Hi-Life managers utilize MA to make sales predictions. The MA model is effective at showing first time tendencies and is also an easy method to use. Although the prediction precision of LR is greater than that of MA, it needs complex statistical software to use. In addition, LR requires the data to be switched into binary data. Only if managers are familiar with statistical software, could they use the LR model. The BPNN

Table 3. Correct percentages for LR, MA and BPNN.

	LR (Enter)	MA	BPNN (7 days)	BPNN (14 days)	BPNN (21 days)	BPNN (28 days)
sandwich A	74.30%	75%	32.14%	61.90%	50%	71.43%
sandwich B	77.10%	39.29%	42.86%	42.86%	50%	14.29%
sandwich C	77.10%	57.14%	39.29%	28.57%	21.43%	42.86%
hand roll A	82.90%	42.86%	10.71%	14.29%	14.29%	14.29%
hand roll B	77.10%	53.57%	10.71%	28.57%	28.57%	42.86%
hand roll C	60%	78.57%	46.43%	57.14%	57.14%	28.58%
rice ball A	85.70%	39.29%	35.71%	33.33%	35.71%	57.15%
rice ball B	94.30%	35.71%	0.00%	28.57%	35.71%	0.00%
sushi	71.40%	71.43%	0.00%	52.38%	57.14%	100%
Average	79.70%	52%	21.79%	34.76%	35%	37.14%
S.E.	0.108964	0.18384	0.1923006	0.193154805	0.191797384	0.324367728

Table 4. Error for all samples by each method.

	LR (Enter)	MA	BPNN (7 days)	BPNN (14 days)	BPNN (21 days)	BPNN (28 days)
sandwich A	25.70%	25.00%	67.86%	38.10%	50.00%	28.57%
sandwich B	22.90%	60.71%	57.14%	57.14%	50.00%	85.71%
sandwich C	22.90%	42.86%	60.71%	71.43%	78.57%	57.14%
hand roll A	17.10%	57.14%	89.29%	85.71%	85.71%	85.71%
hand roll B	22.90%	46.43%	89.29%	71.43%	71.43%	57.14%
hand roll C	40.00%	21.43%	53.57%	42.86%	42.86%	71.42%
rice ball A	14.30%	60.71%	64.29%	66.67%	64.29%	42.85%
rice ball B	5.70%	64.29%	100.00%	71.43%	64.29%	100.00%
sushi	28.60%	28.57%	100.00%	47.62%	42.86%	0.00%
Average	20.30%	48.00%	78.21%	65.24%	65.00%	62.86%
S.E.	25.70%	25.00%	67.86%	38.10%	50.00%	28.57%

model is not suggested for short period prediction of fresh food sales.

VI. CONCLUSIONS

This study proposes using Logistic Regression, Moving Average and Back-Propagation Neural Network methods for sales models designed to predict daily fresh food sales. We found that the correct percentage obtained by LR to be better than that obtained by the BPNN and MA models. This knowledge is valuable for fostering informed decision making by the company and for the application of forecasting models by academics in the fresh food setting. Future research could be done to extend the sales forecasting model to a variety of other products and to integrate the factor of climate to find rigorous sales trends. Furthermore, further research could be done to consider the distribution timing of logistics to forecast the sales of fresh food.

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APPENDIX 1.

35 days of data from the POS database for a Hi-Life convenience store in Taipei.

Item	Sandwich A		Sandwich B		Sandwich C		Sandwich D		Hand roll A		Hand roll B		Hand roll C		Rich boll A		Rich boll B		Sushi		Total	
Date	sales	discard	sales	discard	sales	discard	sales	discard	sales	discard	sales	discard	sales	discard	sales	discard	sales	discard	sales	discard	sales	discard
10/17	2	1	2	1	5	1	1	1	5	0	3	1	0	0	5	1	10	1	1	4	34	11
10/18	2	1	3	0	6	0	0	1	4	1	2	2	0	0	6	0	12	0	2	3	37	8
10/19	3	0	3	0	5	1	1	1	6	0	3	0	0	0	6	1	8	2	4	1	39	6
10/20	2	1	2	1	4	2	0	1	4	0	4	0	1	1	5	1	6	4	1	5	29	16
10/21	3	0	3	0	4	2	1	0	3	1	3	1	2	0	5	1	10	2	2	3	36	10
10/22	0	2	0	2	2	1	0	2	2	1	1	1	1	0	2	1	3	1	0	3	11	14
10/23	1	1	1	1	3	0	0	1	2	1	0	2	0	1	4	0	3	1	1	2	15	10
10/24	3	0	3	0	4	2	1	1	5	0	2	2	1	1	6	0	10	2	2	2	37	10
10/25	3	0	3	0	5	1	1	0	5	0	3	1	1	1	6	0	9	3	3	0	39	6
10/26	3	0	3	0	4	2	1	1	4	2	3	1	1	0	7	0	9	4	3	1	38	11
10/27	4	0	2	1	3	3	1	1	5	0	2	3	2	0	4	2	8	4	3	0	34	14
10/28	3	1	3	0	3	2	0	2	3	2	4	0	1	0	5	1	12	0	3	0	37	8
10/29	1	1	1	1	2	1	0	1	3	1	1	0	1	0	3	1	3	2	1	0	16	8
10/30	2	0	0	2	1	2	1	0	2	2	0	1	1	0	3	1	2	3	0	2	12	13
10/31	4	0	4	0	4	1	1	0	4	1	3	0	3	0	6	0	9	2	3	1	41	5
11/1	4	0	4	0	4	2	0	2	3	2	2	2	2	1	5	1	10	1	3	0	37	11
11/2	5	0	3	1	3	2	2	0	1	3	4	0	2	0	7	0	8	3	4	0	39	9
11/3	4	1	3	1	2	3	0	2	4	0	2	3	2	1	5	1	9	4	1	0	32	16
11/4	4	1	3	0	4	1	1	1	4	3	3	1	3	0	6	0	7	5	3	0	38	12
11/5	2	0	1	1	1	2	1	0	2	2	1	0	1	2	2	1	3	1	1	0	15	9
11/6	2	0	1	1	2	1	0	1	3	0	0	1	2	0	3	0	1	4	0	0	14	8
11/7	5	0	3	1	4	2	0	1	3	1	2	2	0	3	6	0	9	2	3	0	35	12
11/8	5	0	3	1	3	1	1	1	4	0	3	0	1	2	6	0	9	1	3	0	38	6
11/9	4	0	4	0	3	2	1	1	3	1	3	0	2	1	6	0	10	0	2	0	38	5
11/10	5	1	2	2	3	1	0	2	4	1	2	1	2	0	6	0	8	3	3	0	35	11
11/11	5	0	3	1	2	3	1	1	3	1	3	1	2	0	5	1	10	1	3	0	37	9
11/12	2	0	2	0	2	1	0	1	1	2	0	1	2	0	3	1	4	0	1	0	17	6
11/13	3	0	0	2	1	2	0	1	3	0	1	0	0	2	3	0	2	2	0	0	13	9
11/14	5	0	3	1	2	2	1	0	3	1	0	3	1	1	5	1	10	1	3	0	33	10
11/15	5	0	2	2	2	3	1	1	3	1	0	3	1	2	6	0	10	1	3	0	33	13
11/16	5	1	4	0	2	3	0	1	4	1	3	0	2	2	5	1	9	2	2	0	36	11
11/17	6	0	2	2	1	2	1	0	3	1	2	2	2	1	7	0	10	1	3	0	37	9
11/18	6	1	3	1	1	2	1	1	4	1	2	0	2	0	5	1	7	3	3	0	34	10
11/19	3	0	1	1	1	1	1	0	4	0	1	1	2	0	4	0	4	0	1	0	22	3
11/20	3	0	1	1	1	1	0	1	2	1	1	0	2	1	3	0	4	1	1	0	18	6
total	106	7	67	23	70	51	18	24	92	30	53	29	44	21	138	13	206	56	61	6	855	260

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