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A Study on Industrial Accident Rate Forecasting and Program Development of Estimated Zero Accident Time in Korea

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Abstract: To begin a zero accident campaign for industry, the first thing is to estimate the industrial accident rate and the zero accident time systematically. This paper considers the social and technical change of the business environment after beginning the zero accident campaign through quantitative time series analysis methods. These methods include sum of squared errors (SSE), regression analysis method (RAM), exponential smoothing method (ESM), double exponential smoothing method (DESM), auto-regressive integrated moving average (ARIMA) model, and the proposed analytic function method (AFM). The program is developed to estimate the accident rate, zero accident time and achievement probability of an efficient industrial environment. In this paper, MFC (Microsoft Foundation Class) software of Visual Studio 2008 was used to develop a zero accident program. The results of this paper will provide major information for industrial accident prevention and be an important part of stimulating the zero accident campaign within all industrial environments.

Key words: Zero accident campaign, SSE, Proposed analytic function method, Accident rate, Zero accident time, Achievement probability, Industrial accident prevention

Introduction

Zero accident campaign is the progressive promotion of voluntary industrial accident prevention by both business proprietor and laborer based on a spirit of respect for human life. Also, the campaign is to form a human centered safe and healthy workplace inspiring consciousness of safety and annihilating industrial accidents. In the Ministry of Labor in Korea, from September 1, 1979, a zero accident campaign was started and continues until now. Korea adopted the danger predicted training method developed in Japan in order to revitalize the zero accident campaign by policy of the Ministry of Labor. At the same time, a 10,000,000 people signing campaign (total 10,097,609 including president, prime minister, each head of department, representatives of religions, people of fame) took place from August 21, 1992 until August 30, 1993) in order to expand the zero accident campaign in Korea[1)].

Zero accident campaign was added to the fifth clause of Article IV of the government regulation in 1982. Moreover, Korea Occupational Safety & Health Agency (KOSHA) and the Ministry of Labor, designated a target date as shown in Table 1[1)]. When the target is achieved by a company, it receives benefits on easing of safety scrutiny and other requirements.

In the case of Japan, after the zero accident campaign begun in 1975, until now a plan of promotion has been established over 7 times and continuous improvement

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Table 1. The target date(time) by industry except construction industry for achieving zero accidents at least once

No. of workers \ Industry division	First	Second	Third	Fourth	Fifth	Sixth	Seventh
Less than 50	140 d	200 d	260 d	320 d	380 d	420 d	480 d
50 through 99	120 d	180 d	240 d	300 d	340 d	380 d	420 d
100 through 199	100 d	150 d	200 d	250 d	300 d	350 d	400 d
200 through 299	80 d	120 d	160 d	200 d	240 d	280 d	320 d
300 through 499	0.3 million h	0.45 million h	0.6 million h	0.75 million h	0.9 million h	1.05 million h	1.2 million h
500 through 699	0.45 million h	0.6 million h	0.75 million h	0.9 million h	1.05 million h	1.2 million h	1.35 million h
700 through 999	0.6 million h	0.75 million h	0.9 million h	1.05 million h	1.2 million h	1.35 million h	1.5 million h
1,000 through 1,999	0.9 million h	1.2 million h	1.5 million h	1.8 million h	2.1 million h	2.4 million h	2.7 million h
2,000 through 2,999	1.5 million h	1.8 million h	2.1 million h	2.4 million h	2.7 million h	3 million h	3.3 million h
3,000 through 3,999	1.8 million h	2.3 million h	2.8 million h	3.3 million h	3.8 million h	4.3 million h	4.8 million h
4,000 through 4,999	2.3 million h	2.8 million h	3.3 million h	3.8 million h	4.3 million h	4.8 million h	5.3 million h
5,000 through 5,999	3.3 million h	3.8 million h	4.3 million h	4.8 million h	5.3 million h	5.8 million h	6.3 million h
7,000 through 9,999	4.3 million h	4.8 million h	5.3 million h	5.8 million h	6.3 million h	6.8 million h	7.3 million h
More than 10,000	4.8 million h	5.3 million h	5.8 million h	6.3 million h	6.8 million h	7.3 million h	7.8 million h

Table 2. Industrial accident rate by country in 2006 yr[3–6)]

Country	Industrial accident rate
Japan	0.26*1)
England	0.54*2)
Germany	2.87*3)
United States	3.67*4)
Korea	0.77*5)

*1,2,3) $\dfrac{\text{Total number of occupational accident workers (deaths and injuries + illnesses) requiring an absence of 4 d or more days in one year}}{\text{Total average number of workers in one year}} \times 100$

*4) $\dfrac{\text{Total number of occupational accident workers (deaths and injuries + illnesses) requiring at least one day away from work with or without days of job transfer or restriction in one year}}{\text{Total average number of workers in one year}} \times 100$

*5) $\dfrac{\text{Total number of occupational accident workers (deaths and injuries + illnesses) requiring medical care at least 4 d or more days in one year}}{\text{Total average number of workers in one year}} \times 100$

has been promoted. However, in Korea, the effort for additional research and improvement in areas related to the purpose and development of the zero accident campaign has been very rare. Currently, the industrial structure and environment are changing such as the increase in the service industries. Recruiting, variety of employment opportunities and management has radically changed[2)]. This creates the need to revise an action plan for the zero accident campaign. Table 2[3–6)] shows the industrial accident rate for Japan, England, Germany, the United States and Korea.

Therefore, this study has developed a predicted accident rate, calculation of achievement probability and zero accident time yield program to rationally reset the zero accident targeted time for certification reflecting the changes in the social and technological industrial environment. It is also intended to revitalize the zero accident campaign based on this zero accident time.

Program Development

The measure to represent the degree of danger by type of work is the accident rate. The accident rate is defined as a percentage by dividing the total number of occupational accident workers contained deaths, injuries, and illnesses by the total average number of workers in each type of business.

Thus, as accident rate increases, the zero accident target standard estimate period should be decreased in order to recalculate the target with equity among the scale and categories of businesses.

In this program, the accident rate data from the past is treated as time-series through residual analysis to calculate the accident rate up to a maximum of 250 yr. The program predicts the accident rate, the zero accident achievement days and achievement probability based on the above data.

Zero Accident Program developed in this study is defined as the predicted accident rate, the zero accident targeted time, and the zero accident time based on the achievement probability calculated rationally and practically[7]. Prediction method for the accident rate is to use the time-series of regression analysis method (RAM), exponential smoothing method (ESM), double exponential smoothing method (DESM), and auto regression and integrated moving average (ARIMA), and proposed analytic function method (AFM).

Regression analysis method

Regression analysis is to obtain a linear equation for independent and dependent variables from successive type variables observed. When an independent variable is given the equation can predict the dependent variable. If the regression analysis method is adopted to the research, the past accident rate will be the independent variable. Thus, the predicted accident rate in the future will be a dependent variable. Therefore, the correlation between the past accident rate and the predicted accident rate can be obtained. The prediction equation using the regression analysis method is[8, 9]:

$$y_t = \beta_o + \beta_1 x_t + \varepsilon_t \qquad (1)$$

Where y_t = independent variable at time t

β_o, β_1 = unknown values of the parameters

x_t = accident rate at time t (dependent variable)

ε_t = predicted error of time t.

Exponential smoothing method

Exponential smoothing method is a method to predict the future weighted results based on recent information other than past information. This method is very useful for forecasting of middle and long term periods. Especially, it is very effective on tendency and time series which are seasonal.

The predicted equation and symbols for the exponential smoothing method can be defined as[8–10]:

$$Y_t = \alpha X_{t-1} + (1-\alpha)Y_{t-1} \qquad (2)$$

Where Y_t = expected accident rate

α = constant to be optimized

X_{t-1} = accident rate at time t–1

Y_{t-1} = expected accident rate at time t–1.

The double exponential smoothing method (DESM) is a method to predict the accident rate applying the exponential smoothing twice on the material with an inclining or declining trend within the characteristic period[8, 9].

ARIMA model

ARIMA means auto-regression integrated moving average. The model uses the lag and shift of historical information to predict the future finding from the pattern of the past. The ARIMA model is decided by two factors. The first is how much time will be spent from the past (length of the weight). The second is to decide the value of the weight. The ARIMA model is represented as a regression model and moving average in more detail and precision. The regression model, simple average, simple moving average and weighted moving average models are not needed.

The prediction equation of the ARIMA model is analyzed in the autoregressive model (AR(p)) and the moving average model (MA(q)). The AR(p) is a time-series that is composed of past value and linear combination, and the equation is[8, 9]:

$$X_t = \delta + \phi_1 X_{t-1} + \phi_2 X_{t-2} + \cdots\cdots + \phi_p X_{t-p} + A_t \qquad (3)$$

Where X_t = the time series

$$\delta = (1 - \sum_{i=1}^{p} \phi_i)\mu \qquad (4)$$

ϕ_i = parameters of the model (i=1,2,……,p)

μ = the mean of accident rate

p = the order of the AR model

X_{t-i} = the time serious at t–i (i=1,2,…,p)

A_t = white noise.

The MA(q) model is a time series that is composed of a predicted error and linear combination, and the prediction equation can be represented as[8, 9]:

$$X_t = \mu + A_t - \theta_1 A_{t-1} - \theta_2 A_{t-2} - \cdots\cdots - \theta_q A_{t-q} \qquad (5)$$

Where X_t = the time series

μ = the mean of accident rate

θ_i = parameters of the model (i=1,2,……,q)

q = the order of the MA model

A_{t-i} = white noise (i=1,2,…,q).

Therefore, the symbols and equation of the ARIMA model are described by[8, 9]

$$X_t = \delta + \phi_1 X_{t-1} + \phi_2 X_{t-2} + \cdots\cdots + \phi_p X_{t-p} + A_t - \theta_1 A_{t-1} - \theta_2 A_{t-2} - \cdots\cdots - \theta_q A_{t-q} \qquad (6)$$

Proposed analytic function model

The generation process of coincidental industrial accidents with irregularity is related to the Poisson process among the continuous time of discrete status. Thus, the probability of achieving a zero accident time and targeted time is obtained by a Poisson distribution. The proposed analytical method is calculated from the optimization of the coefficient value using Sum of Squared Errors (SSE) when the time series is regarded as decreasing and vibration of the sum of phenomena about the mean of the data. SSE is the error between the accident rate and the predicted accident rate. Therefore, the optimal model for predicting the accident rate is the model that minimizes the SSE through the use of regression analysis, exponential smoothing, ARIMA, and proposed analytic function model.

Therefore, obtaining the accident rate measurements using proposed analytical function and prediction equation is done as follows:

$$y_n = \mu + \alpha e^{-\beta(t_n - t_0)} + \gamma \sin(\omega(t_n - t_0) + \phi) + \delta_n \tag{7}$$

$$E_n = \mu + \alpha e^{-\beta(t_n - t_0)} + \gamma \sin(\omega(t_n - t_0) + \phi) \tag{8}$$

Where
y_n = accident rate at n^{th} year
μ = the mean of accident rate
α, β = amplitude and decaying constant
t_0 = some initial time, usually zero
t_n = characteristic time of n^{th} year
γ = amplitude for seasonal oscillation
$\omega = 2\pi f$, seasonal oscillation angular frequency
ϕ = phase for seasonal oscillation
δ_n = difference of observed and predicted value
E_n = theoretical accident rate for n^{th} year.

In the process to predict the accident rate, the predicted value might be negative based on the existing data. In this case, the predicted value is "0". However, in the case of "0" as the predicted value, the inverse of accident rate is used instead of the accident rate. Then, this problem is easily solved. Actually, from the calculated accident rate, equation 8 will be used to obtain the zero accident rate target time[7)].

$$R_o = e^{-m(\tau)} \tag{9}$$

$$-\ln R_0 = m(\tau) = \int_0^\tau \lambda y(t) dt \tag{10}$$

Where
R_o = probability of no accident occurrence
$m(\tau)$ = accident frequency for accidents occurring during the characteristic period τ
$\lambda y(t)$ = probability function of actual accident at time t.

Also, when equation 10 is used to calculate the achievement probability R_0 where the zero accident targeted time is τ from the accident rate data.

Scope

Data for the accident rate is the time series data for 16 yr from 1991 to 2006. The accident rate is converted into a percentage by dividing total number of worker injured accidents by the total average number of workers in each type of business.

It is analyzed for 55~90 people who have been engaged in the 7th classification group of electric, gas, and water service division and the 6th classification group of food manufacturing division in order to reset the targeted standard for the zero accident rate. The accident rate can be calculated for a maximum of 250 yr.

Methodology

Currently, zero accident work group classifications do not reflect a standard such as accident rate, for the degree of danger in each work group in Korea. Thus, a rational and realistic way for improvement in setting a realistic standard for zero accident targeted period is needed. Therefore, the most useful method to predict the zero accident rates is to find the least value of the SSE obtained.

The flow of the program sets up a realistic zero accident targeted time and the achievement probability with reality through the predicted accident rate as follows:

1st step, select the job to be predicted.

2nd step, store past accident rate for the selected job modified as *.rat file in text format.

3rd step, after zero accident program is running, open the saved file of the selected job, and then click the prediction button for accident rate at the top.

4th step, modify the prediction method for the accident rate, and then, select the prediction method for the accident rate to yield the minimum SSE value.

5th step, enter the zero accident targeted time and the achievement probability. Then, click the button to calculate the achievement probability and the zero accident time. Then, the zero accident targeted time for the zero accident achievement probability is changed based on working 8 h per day.

6th step, saved the rational and realistic achievement probability and the zero accident time of the selected job using the save function.

The flow chart to calculate the achievement probability, the zero accident time from the sensible predicted accident rate, and the zero accident targeted time is as shown in Figs. 1–4.

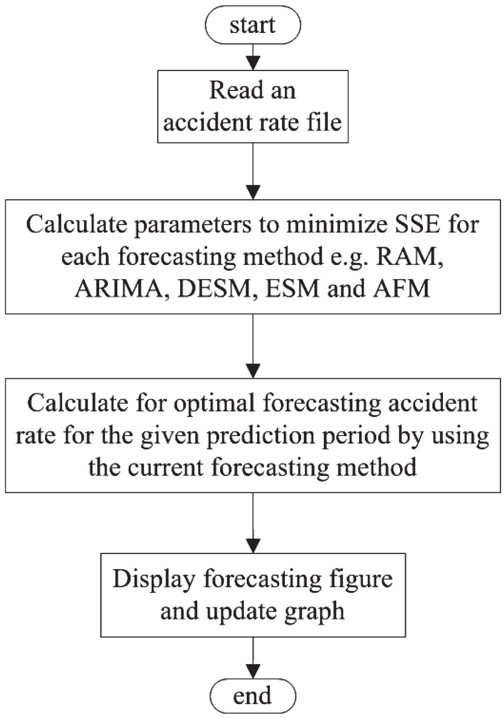

Fig. 1. Flow chart for open menu.

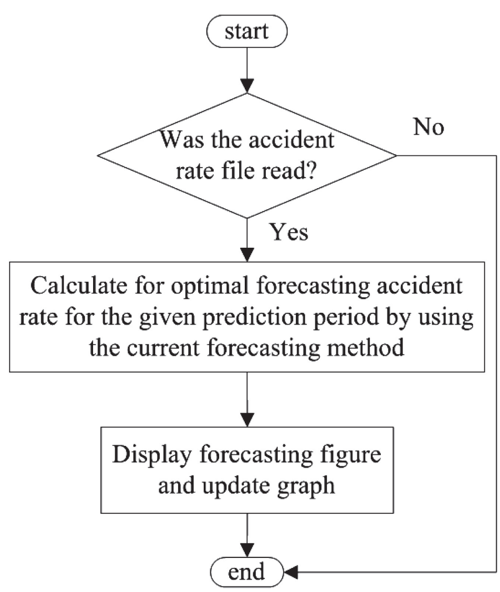

Fig. 2. Flow chart for predicted accident rate.

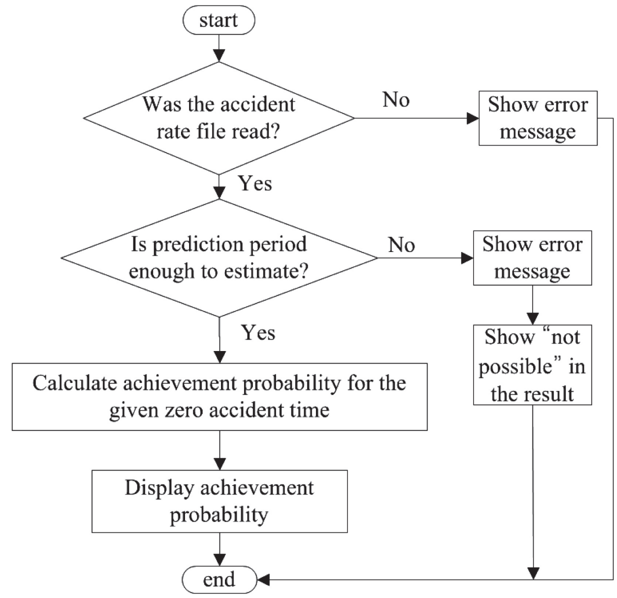

Fig. 3. Flow chart for calculation of achievement probability.

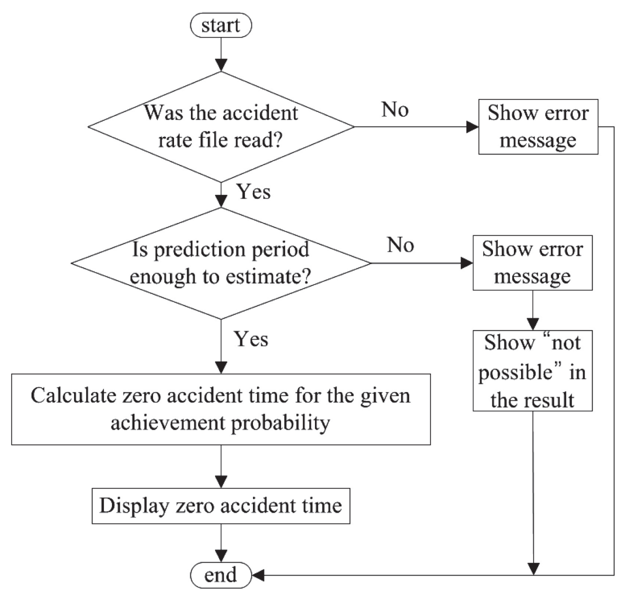

Fig. 4. Flow chart for calculation of zero accident time.

Results

In order to reset the zero accident targeted standard, an analysis is done for 55~90 people who have been engaged in the 7th classification group for electric gas, and water service and the 6th classification group for food manufacturing division. The accident rate for these types of jobs over 16 yr from 1991 to 2006 is shown in Table 3[11].

Figures 5 and 6 represent the zero accident targeted time by zero accident achievement probability and achievement probability by zero accident targeted time as well as the predicted accident rate based on Table 3.

The SSE is shown on the right of the time series with the predicted method of the accident rate shown at the top right. After predicting an accident rate, if zero accident time is entered at the bottom right, a zero achievement probability will be obtained. The plot of forecasting from past values of accident rate and the minimized SSE is shown at the very bottom.

Table 3. Accident rates of electric, gas, water utilities, and food manufacturing divisions for 16 yr

Electric gas and water division		Food manufacturing division	
Year	Accident rate	Year	Accident rate
2006	0.22	2006	0.90
2005	0.39	2005	0.91
2004	0.22	2004	0.79
2003	0.28	2003	1.01
2002	0.20	2002	0.95
2001	0.41	2001	1.06
2000	0.16	2000	1.12
1999	0.19	1999	1.01
1998	0.24	1998	0.90
1997	0.26	1997	0.90
1996	0.41	1996	1.22
1995	0.52	1995	1.05
1994	0.48	1994	1.20
1993	0.69	1993	1.27
1992	1.22	1992	1.44
1991	0.60	1991	2.11

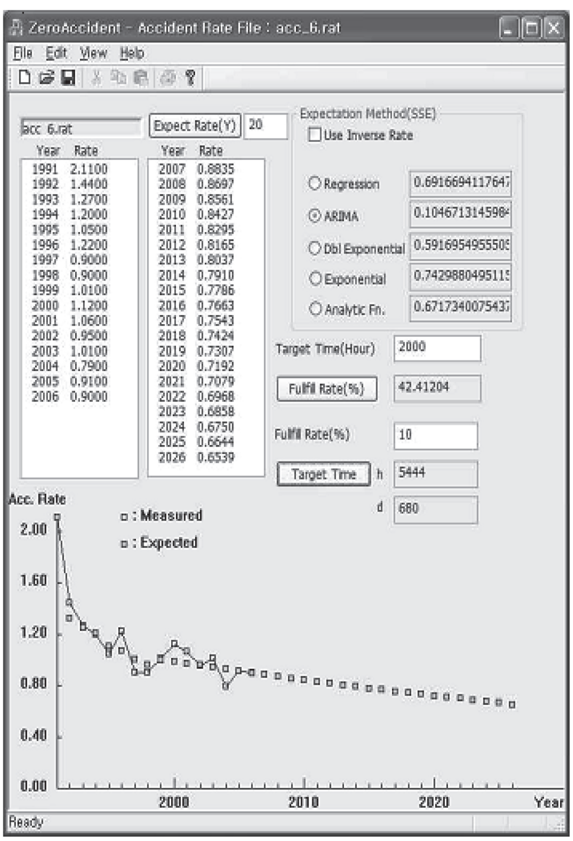

Fig. 5. The computation results of predicted accident rate, achievement probability, and zero accident time for food manufacturing division.

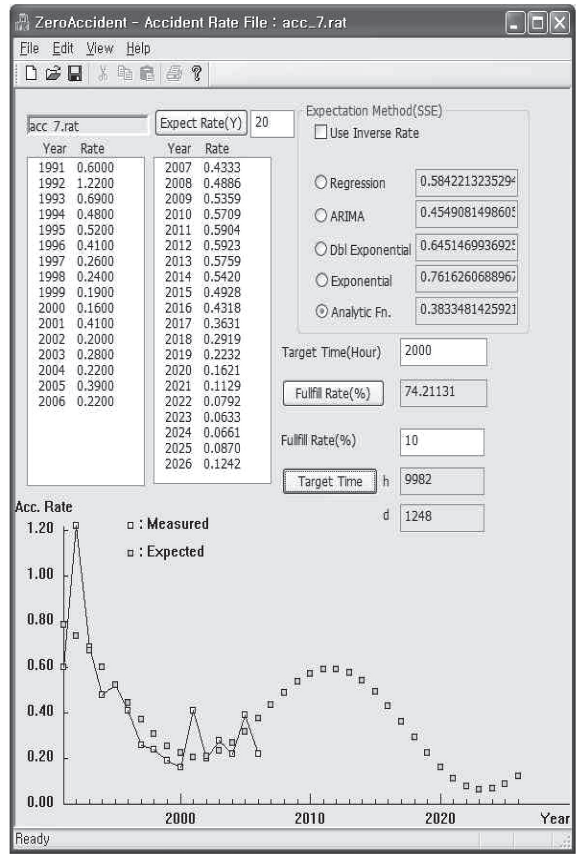

Fig. 6. The computation results of predicted accident rate, achievement probability, and zero accident time for electric gas, and water service division.

The final analysis result for the 4 methods is: The value to minimize SSE is 0.1047 and 0.3833 in the 6th and 7th job classifications, respectively. Thus, for the 6th and 7th job classifications, the ARIMA model and proposed analytical function are ideally applied. Therefore, the ARIMA model should be applied in the case of setting up the zero accident time by the zero accident achievement probability and the zero accident achievement probability by the zero accident time in the 6th job classification. Also, the proposed analytical function should be applied in the case of setting up the zero accident time by the zero accident achieving probability and zero accident achievement probability by the zero accident time in the 7th job classification.

The zero accident program can calculate the accident rate for a maximum of 250 yr with the past accident rate data using a time series analysis method. Also, the program confirms from the past data achievement probability and the zero accident time as calculated for each zero accident targeted time and zero accident targeted probability.

Conclusions

The uses of information predicted from the zero accident program developed in this study are:

The predicted accident rate and the zero accident targeted time are reset reflecting the past degree of danger standards by type of job. Therefore, it is predicted that more effective results can be obtained for each type of job.

It can contribute to detailed industrial accident prevention by applying the accident rate from each work place to set up the targeted time for each work place.

Finally, not only the accident rate but also the failure rate for a facility and the components can be predicted. Thus, it can be very effective in predicting over the lifetime of the facility.

Further study is required of the dynamic time series model minimizing the predicted error in the course of forecasting the accident rate.

Acknowledgements

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