

## Risk Analysis Model of Automobile Defect Based on Weibull

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### Abstract

*Currently, from the statistical analysis of accidents at home and abroad, the number of automobile defects and the resulting automobile accidents are very large. Obviously, the automobile defects have become one of the main factors affecting traffic safety, and risk assessment as an automobile key technical defect of risk management, the elimination of defects and reduce automobile accidents are of great significance. Through statistical study of automobile defect recall, this paper analyzes the automobile defects and its risk characteristics and the event tree analysis (ETA) method was introduced to determine the risk flow route of automobile defects. Based on thousands of automobile breakdown cases for risk probability forecast, this paper proposes a three-dimensional matrix risk assessment model of automobile defect. According to the dispersibility of automobile, a risk forecast method based on the Weibull distribution is established. The results indicate that on gathering actual failure data from after-sales service, the Weibull distribution model has a favorable applicability for forecasting risk possibility, and then apply it to auto defect in three-dimensional matrix model so as to get the overall risk level of defect automobile.*

**Keywords:** *Automobile, Defect, Risk assessment, Three-dimensional matrix, Weibull distribution*

### 1. Introduction

Automobile is a complex high-tech consumer product with its very complex design and manufacturing techniques, the variable using environment, and a high degree of consistency. Once there are problems, it will prone to a wide range of defects. Shorter development cycle makes the time of automobile reliability test correspondingly shorten. A lot of design and manufacturing problems cannot be exposed before the automobile sell in the market, which must lead to defects [1]. Therefore, it should be analyzed and judged the level of defect risk in automotive product safety management. At present, China automobile industry is not using risk assessment concepts and procedures directly in the defect analysis, but using mature technology and experiment to analyse the possibility of defects and severity indirectly, which could get similar results [2]. Auto defects risk assessment has many uncertainties, using Weibull distribution model to predict the trend of automobile fault can improve assessment accuracy. In this paper, event tree analysis (ETA) method is introduced to analyse the risk transmission path of the automobile defects. Weibull distribution model predicts failure or dangerous probability in the automobile life cycle. It can assess the risk of automobile defects.

### 2. Automobile Defect and Risk Characteristics

## 2.1 Automobile Defect

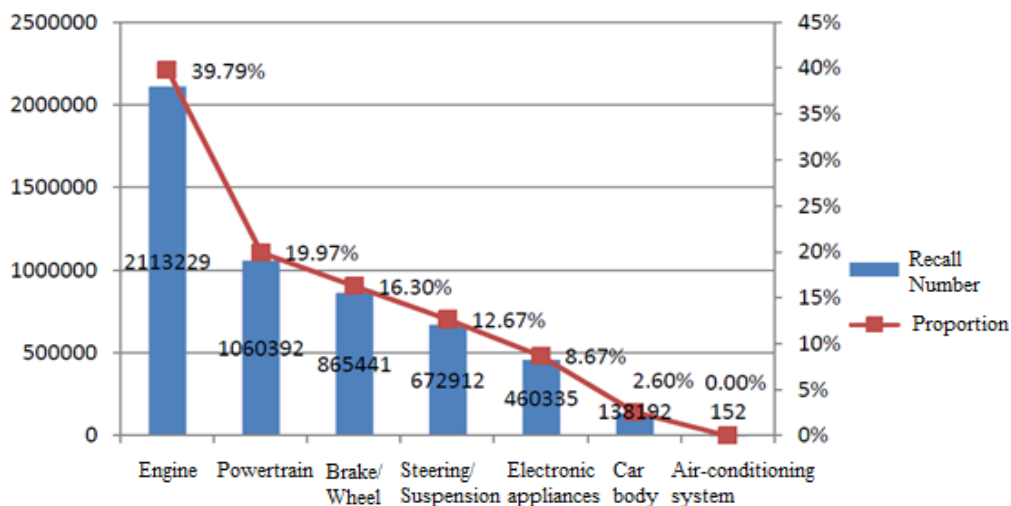
According to AQSIQ and other four ministries jointly issued the "defective auto product recall regulations," automobile defect is defined as: due to the design, manufacture, identification and other causes, the same batch, model or automotive products in the category often do not meet the national standards and industry standards that guarantee the personal and property safety or other unreasonable risks endanger the personal and property safety. In the actual recall process, in addition to the design, manufacturing and identify defects, there are some defects caused by other factors, such as defects produced in the transport, the conversion process.

According to the division of the defect types, in 2013, the 133 recalls of defective automobiles in China, 48 recalls are caused by manufacturing defect, 85 design flaw, no identify defects [3]. As shown in Table 1.

**Table 1. 2013 Annual Numbers of Defective Auto Product Recall Involve the Type of Defect Distribution Table**

Defect Type	Recall times	Proportion
Manufacturing defects	48	36.09%
Design flaws	85	63.91%
Identify defects	0	0
<b>Total</b>	<b>133</b>	<b>100%</b>

The automobile is a very complicated system, which contains ten thousands of automobile parts. According to automobile construction principles, automobile assembly system defects include: engine, transmission, brakes, steering, travel, electronics, auto mobile accessories. In 2013, the automobile recalls classified by assembly system are specifically shown in Figure 1[3].



**Figure 1. 2013 Annual Numbers of Product Recalls Involving Defective Automobile Assembly Maps**

## 2.2 Risk Characteristics

Risk characteristics are the basis of automobile defect risk assessment. Different forms of risks need to select the corresponding risk assessment. Automotive structures and conditions determine the complexity and uncertainty of the automobile defects risk

assessment and the complexity of risk. The main features of the automobile defect risks are shown as follows:

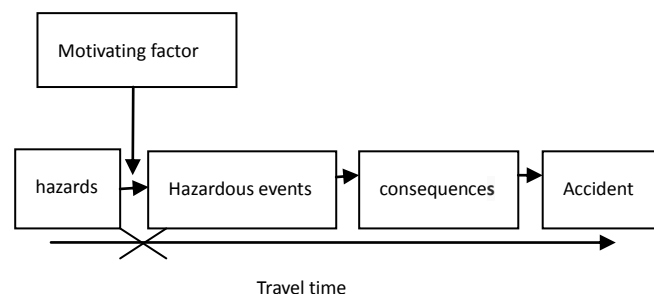
- (1) The complexity of automotive system components that leads to the risk of transmission become very complex;
- (2) The difference of using environment makes the reasons of injury by automobile become more complex, which increase the difficulty of risk analysis;
- (3) The diversity of injury pattern makes the risk of the underlying event very uncertain;
- (4) The seriousness of the accident, in case of danger, the consequences are very serious;
- (5) The driver has a wide range. Different drivers make the potential risks of automotive products vary greatly and will bring a lot of difficulties in the automobile's risk analysis and risk assessment;
- (6) Production of automotive products is relatively stable, if there is unreasonable risk of defects, it will causes a great loss to the same batch of product on all the defects, users and manufacturers [4].

### 3. Automobile Defect Risk Transfer

#### 3.1 Risk Transfer Process

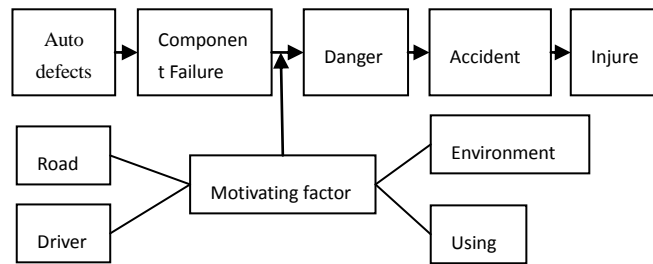
ETA analysis method is a kind of logic analysis method. At the beginning of a given event under the premise of analysis of this event may lead to the result of subsequent events [5], which can evaluate the system reliability and security.

The source of the accident is existed risks and inciting events. Accidents can be considered a failure to identify realistic and potential risks or caused by the unreasonable risk control measures. In quantitative risk analysis, probability or frequency of accident rate are used to measure the possibility of accident. Accidents are caused by risks, but from risks to be accidents, it must have certain conditions, and experience an evolution process, namely the process of system state changes. As shown in Figure 2:



**Figure 2. Dangerous evolution process**

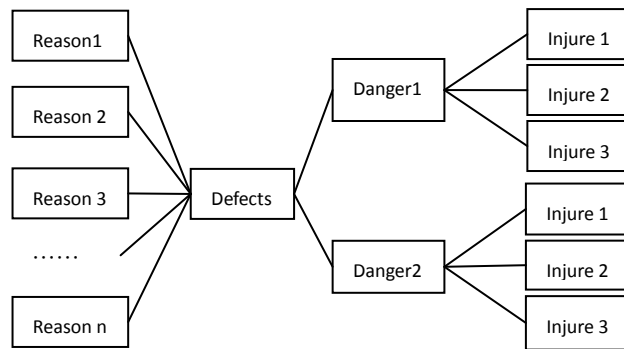
The risk of automobile from the original design and manufacture leads to the risk of product defects → faults → dangers → accidents → personal injury, passing from the causes to the results, and expressions divided from the identified product defects to the risk of a number of different forms, which lead to accidents and development of the diverse, varying degrees of damage [6], ultimately different losses (such as environmental damage, property damage). This risk transfer process from the defect to injury, like the process of risk evolution. Therefore, the risk of automobile defects pathway is shown in Figure 3.



**Figure 3. The Risk Transmission Process of Automobile**

### 3.2 Risk Transmission Path

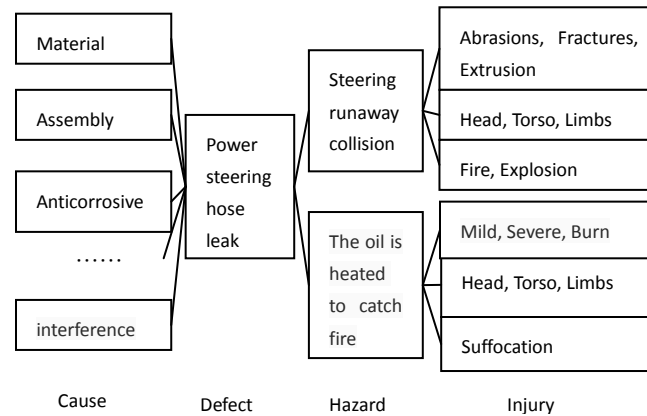
Transfer process in accordance with the risks mentioned above, we abstract and simplify the risk of transmission paths for different defects. As a result, in a single sample of a batch, although the reason of harm is certain, the probability of each node in the path of events progressively reduces the probability of a particular event and specific accidents may also have low probability. General risk pathway in Figure 4:



**Figure 4. The Defect Theory of the Risk of Transmission Path**

### 3.3 Example Analysis

Taking automobile power steering hose defect resulting in oil spills as example, we use analytical methods to build ETA risk transfer model. While the top event for the power steering hose design flaws, it unable to respond to the temperature requirements of the working environment, thus leading to cracking of power steering hose failure and steering oil leak. Specific transmission path is shown in Figure 5.



**Figure 5. Risk Transfer Path Instance of Defects**

## 4. Three-Dimensional Matrix Model of Automobile Defect Risk

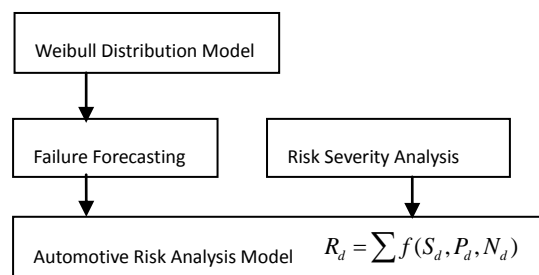
### 4.1 The Number of Defects Introduced Parameters

Risks arising from automobile defect risk are not a single object. According to the definition of defect, the defect has an identity and bulk. The recall case shows that automotive products have a few flaws, or millions or even tens of millions, so only based on the likelihood and severity of dangerous conduct occurred risk assessment of defects can not reflect the real level of overall risk. For example: In the same situation of the automobile defect severity and likelihood of occurrence, the number of defects may affect the scope of the risks and do harm to the society.

Therefore, as for the defect in the risk analysis, it is necessary to measure the risk from a two-dimensional multi-dimensional extension. Based on the research of existing risk assessment models and examples of analysis, we stipulate three-dimensional risk assessment models that consider the scope of risks and the number of defected products in order to reflect the nature of the risk more objectively and assess risk accurately.

### 4.2 Dimensional Matrix Model

The purpose of auto defects risk model is to establish a set of systematic automobile risk assessment model group, and use respectively for risk prediction and risk analysis, risk assessment and the expression of risk results, As shown in Figure 6. Weibull distribution model form failure forecasting model, which is applied to historical failure data; input predicate results-  $P_d$ , the risk of serious degrees data-  $S_d$  and the total numbers of defect-  $N_d$  to the automobile defect risk model, and a Three-dimensional matrix graph is introduced to describe overall risks [7].



**Figure 6. Automotive Risk Assessment Model Group**

Put the three-dimensional matrix model into computer software, and get the risk unit simulation diagram, shown in Figure 7. Risk unit is evolved from low risk to high risk, the closer the matrix (cube) starting point, the lower the risk level; the closer matrix (cube) peripheral, the higher the level of risk; maximum points of risks are at the diagonal of the starting point.

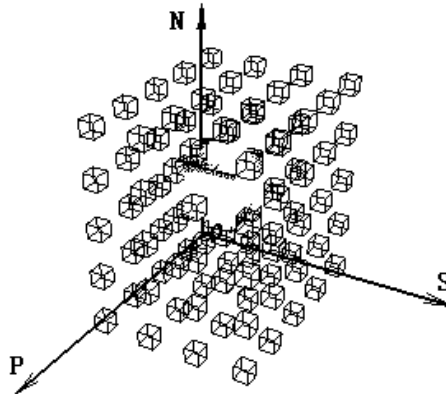


Figure 7. Three-Dimensional Risk Matrix

## 5. Weibull Distribution Model

### 5.1 Establish Weibull Distribution

Weibull distribution is one of random variables distributions, which belongs to the minimum III distribution, and is widely used in the reliability engineering, especially suitable for the distributed form which expires in the mechanical and electrical kind of product's attrition accumulation. It may infer its distributed parameter using the probability value, and is widely used in each kind of length-of-life test data processing [8, 9]. In automobile's life data analysis, we can select one "appropriately" life statistical distribution from the representative samples, and forecast all products' life situations in parent substance [10]. It is necessary to do following things step by step when using the Weibull distribution to make the automobile life data analysis and forecast: ①collecting life data; ②choosing life distribution and establishing the product life model; ③estimating parameters; ④drawing probability maps and estimating the life characteristic quantity.

Weibull probability density function expression:

$$f(t) = \begin{cases} \frac{\beta(t-\delta)^{\beta-1}}{\theta^\beta} \exp[-(\frac{t-\delta}{\theta})^\beta], & t \geq \delta \\ 0 & , t < \delta \end{cases} \quad (1)$$

In that,

F(t): the Weibull cumulative distribution function.

t: The experimental time, the testing cycle number of times or the distance in kilometer.

$\beta$ : The shape parameter, its size has decided the weibull curve shape.

$\theta$ : The scale parameter, is related with the average of measurements [11], its size has decided the range of random variable life size.

$\delta$ : Location parameter, product has 100% reliabilities before time  $\delta$ , or failure occurs after time  $\delta$ .

Taking time as example, the definition of the probability density is: at some point, the probability of failure occurred in the unit time. The Weibull cumulative distribution function refers the probability of failure which occurs with the time from 0 to t. It is a

Weibull probability density function obtained in the time period  $[0, t]$  . so the automobile defect distribution function is shown as follows,

$$F_{(t)} = \begin{cases} 1 - \exp[-(\frac{t-\delta}{\theta})^\beta], & t \geq \delta \\ 0, & t < \delta \end{cases} \quad (2)$$

Weibull reliability function refers to no failure probability from time 0 to t . From the perspective of the probability, failure and no failure are complementary, and their probabilities is 1. Therefore, the Weibull reliability function obtained by the following formula:

$$R(t) = \begin{cases} \exp[-(\frac{t-\delta}{\theta})^\beta], & t \geq \delta \\ 0 & , t < \delta \end{cases} \quad (3)$$

R (t) represents the Weibull reliability function.

Weibull damage function is the instantaneous damage rate and the ratio of the Weibull probability density function and the Weibull reliability function. The expression is:

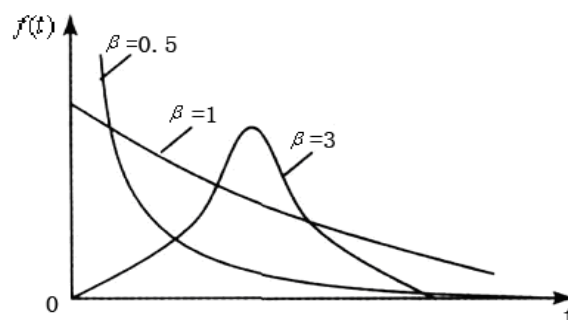
$$h_{(t)} = \frac{f_{(t)}}{R_{(t)}} = \frac{\beta(t-\delta)^{\beta-1}}{\theta^\beta} \quad (4)$$

h (t) represents the Weibull damage function. Weibull damage function has practical significance, contributing to the understanding of the failure type.

To change the parameters of the Weibull distribution function can well describe the "bathtub curve" of the three failure modes and other probability distributions, which is not only the other life unmatched distribution function, but also the reason why life test of Weibull distribution is widely one of the main applications [12]. Weibull distribution function is determined by three parameters: the shape parameter  $\beta$ , size and location parameters  $\delta$  parameter  $\theta$ . Studies on the Weibull damage function show: When  $\beta < 1$ , damage function is a decreasing function and the type of failure is premature failure; when  $\beta = 1$ , damage function is a constant function, and the type of failure is random failure; when  $\beta > 1$ , damage function is an increasing function and the type of failure is loss failure. To change parameters  $\beta$  can also allow the Weibull distribution identical or similar to other probability distributions:

- $\beta = 1$ , the Weibull distribution is equivalent to the exponential distribution;
- $\beta = 2$ , the Weibull distribution is equivalent to the Rayleigh distribution;
- $\beta = 2.5$ , the Weibull distribution approximates the lognormal distribution;
- $\beta = 3.6$ , the Weibull distribution approximates a normal distribution.

When  $\beta$  take different values, the Weibull probability density map is not the same. As shown in Figure 8.



**Figure 8. Weibull Probability Density Maps**

Usually assuming  $\delta = 0$  is reasonable. Its actual meaning is: The samples could fail in any time from the beginning of the experiment. When  $\delta = 0$ , the three-parameter Weibull distribution becomes the two-parameter Weibull distribution. However,  $\delta \neq 0$  is also possible, and usually,  $\delta > 0$ , which is based on the fact that the test sample will not fail at the beginning of the experiment. The usual way to determine  $\delta$  is to select a value, which is a little lower than minimum failure time of a set of text samples.

The three-parameter Weibull distribution has been defined and also determined the  $\delta$ ,  $\beta$  and  $\theta$  values, and it is possible to obtain the automobile life reliable distribution model to estimate the confidence interval of the reliable parameters. It is necessary to point out that, as to the failure caused by auto manufacturing defects, possibly failure may occur in any time with the parameter  $\delta$  is 0 under this situation when starting to use it (when time  $t=0$ ). Such three parameters Weibull distribution becomes two parameters Weibull distribution, after carrying on the accurate parameter estimation to the shape parameter and the size parameter, which determines the automobile Weibull cumulative distribution function. Therefore, the automobile flaw reliable life model becomes two parameters Weibull distribution:

$$F_{(t)} = 1 - \exp \left[ - \left( \frac{t}{\theta} \right)^\beta \right] \quad (5)$$

## 5.2 Determine Weibull Distribution Parameters

Weibull distribution is fit on the reliability of data. As for the general methods of parameters graphing method and numerical method, the latter one includes the probability weighted moment method, the maximum likelihood method, bilinear regression method, correlation coefficient method and Grey estimation method, *etc.* [13, 14]. Usually, graphing method is not accurate enough and often calculated by the numerical calculation.

### (1) Two parameter estimation with MLE

As the distribution parameters  $\beta$ ,  $\theta$  is often unknown; therefore, it can only use statistical methods test data to estimate the parameters. Usually, there are several methods in domestic and abroad, such as maximum likelihood estimation (MLE), the best linear unbiased estimation, best linear invariant estimation. Maximum likelihood estimation direct iterative calculation, and apply to timing and fixed number tests [15-18]. Censored time tests can stop at any time, which is very convenient. With computer technology, iterative calculation are not an obstacle to these difficulties. So it makes sense in the practical application of the maximum likelihood estimation on Weibull distribution.

To draw an item at random  $n$  sample carries on fixed time or fixed number chopped life experiment from one batch of products, if carries on fixed time chopped life experiment, its chopped time is  $\tau$ , then experimental data are  $t_1 \leq t_2 \leq \dots \leq t_r$ . In order to express the unification, set  $\tau = t_r$ . The life distribution of Automobile is  $W$  (Beta, Theta), and the logarithm likelihood function of experimental data is shown as:

$$l = r \ln \beta - \beta r \ln \theta + (\beta - 1) \sum_{i=1}^r \left( \frac{t_i}{\theta} \right)^\beta - (n - r) \left( \frac{\tau}{\theta} \right)^\beta \quad (6)$$

To the logarithm likelihood function derivation, it may obtain the likelihood equation is:



$$\left. \begin{aligned} \theta^\beta &= \frac{1}{r} \left[ \sum_{i=1}^r t_i^\beta + (n-r)\tau^\beta \right] \\ \frac{\sum_{i=1}^r t_i^\beta + (n-r)\tau^\beta \ln \tau}{\sum_{i=1}^r t_i^\beta + (n-r)\tau^\beta} &= \frac{1}{\beta} + \frac{1}{r} \sum_{i=1}^r \ln t_i \end{aligned} \right\} \quad (7)$$

The above equation set is a surmounting equation set. The structure of this equation set is complex, and it is a nonlinear simultaneous equation. It is impossible to obtain the analytic solution directly, however, we must use computer to carry on the solution. First, estimating solution equation set with the diagram or other methods can obtain the iterative starting value, then using the Newton iteration method to carry on the computer iteration to find out MLE  $\beta\lambda$ ,  $\theta\lambda$ , and then this equation can be solved.

(2) MLE parameters estimation by MATLAB

In MATLAB, fsolve function is used to solve the nonlinear simultaneous equation, and the fsolve function algorithm is the misalignment least squares method. Its advantage is that if the system does not have any root or it is impossible to obtain system's root because of insufficiently precise, there is a solution to return. If system's Jacobian matrix is strange, it is also possible to restrains to a spot, but this spot is not the solution of equation set [19]. In addition, the fsolve function may also choose other algorithms through the controlled variable options establishment, when options (5) =0, then we uses the Gauss - Newton algorithm, when option (5) =1, we uses the Levenberg-Marquardt, when options (7) =0, then we uses two and three multinomial interpolation mix algorithm, when options (7) =1, we uses three time multinomial interpolation algorithm [20].

Corresponding MATLAB program flow is:

First step: write an M-file

function F = fun (theta)

T=[t<sub>1</sub>,t<sub>2</sub> ... ,t<sub>k</sub>];% failure data

S=[s<sub>1</sub>,s<sub>2</sub> ... ,s<sub>n</sub>];% censored data

F=[sum(1/β+ln(t<sub>i</sub>-γ)-ln(η)-((t<sub>i</sub>-γ)/η)<sup>β</sup>\*ln((t<sub>i</sub>-γ)/η)+ ...

sum(-((s<sub>i</sub>-γ)/η)<sup>β</sup>\*ln((s<sub>i</sub>-γ)/η));

sum(C-β)/η+(β/η)\*((t<sub>i</sub>-γ)/η)<sup>β</sup>+sum((β/η)\*((s<sub>i</sub>-γ)/η)<sup>β</sup>);

sum((1-β)/(t<sub>i</sub>-γ)+(β/η)\*((t<sub>i</sub>-γ)/η)<sup>β-1</sup>+ ...

sum((β/η)\*(t<sub>i</sub>-γ)/η)<sup>β-1</sup>)

Step Two: Solving

theta<sub>0</sub>=-0.5\*ones(3,1);% Initial value

options = foptions;

options(1)=1;%Display the output of intermediate results

theta=fsolve('fun',theta<sub>0</sub>,options)

①When  $C = \Phi$ , the equations apply to the corresponding full data column and corresponding MATLAB program will subsequently change, i.e., deletion of S<sub>i</sub> summing portion;

②When  $\gamma = 0$ , the three-parameter Weibull model reduces to the two-parameter Weibull model, then you can directly call Weibfit function parameter  $\beta$ ,  $\eta$  estimate function Weibfit. There are three kinds of usage formats:

(i) phat = weibfit(T)

(ii) [phat ,pci]=weibfit(T)

(iii) [phat ,pci]=weibfit(T,alpha)

Where T is the given data samples, "phat" parameter  $\beta$ ,  $\eta$  estimated confidence interval, "alphat" of confidence [21].

With the parameter  $\beta$ ,  $\theta$  maximum likelihood estimate  $\beta\lambda$ , after  $\theta\lambda$ , you can get an estimated Weibull distribution reliability index. For example, the reliability of the estimate is:

$$\hat{R}(t) = \exp \left[ - \left( \frac{t}{\hat{\theta}} \right)^{\hat{\beta}} \right] \quad (8)$$

Therefore, the average life expectancy (ie automobile MTTF) and life variance are:

$$\hat{E}(T) = \hat{\theta} \Gamma \left( 1 + \frac{1}{\hat{\beta}} \right) \quad (9)$$

$$\text{var}(T) = \hat{\theta}^2 \left[ \Gamma \left( 1 + \frac{2}{\hat{\beta}} \right) - \Gamma^2 \left( 1 + \frac{1}{\hat{\beta}} \right) \right] \quad (10)$$

Reliability refers to the corresponding given life, that is reliable life t (R):

$$t(R) = \hat{\delta} + \hat{\theta} \left( \ln \frac{1}{R} \right)^{1/\hat{\beta}} \quad (11)$$

When R = 0.5 the reliable life, that is the median life expectancy t (0.5):

$$t(0.5) = \hat{\delta} + \hat{\theta} (\ln 2)^{1/\hat{\beta}} \quad (12)$$

When R = e-1 reliable life, that is characteristic life:

$$t(e^{-1}) = \hat{\delta} + \hat{\theta} \quad (13)$$

The Weibull distribution models use maximum likelihood estimation to estimate the amount of reliability characteristic parameters. So long as automobile's breakdown data are collected, we might obtain the reliable parameter, and then obtain its reliable distribution model. This method has good convergence, which can provide the reliable data for the automobile risk assessment.

## 6. An Example

### 6.1 Situation Of Defect

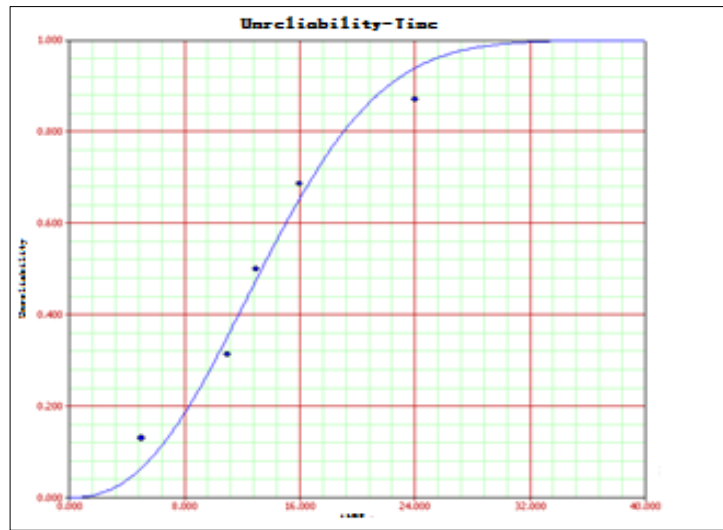
An automobile factory brake booster device malfunction data (total numbers--250,000) and its statistics are as followings: there are 1214 complaints occurred in the market, and the failure is harden brake pedal, abnormal tone, EG fault lights and other issues, including 6 minor automobile accidents without casualties, which is introduced in details in the accident tables. Failure data can obtain from the actual automobile service station. To consider the thousands of automobiles breakdown number after several months, the statistics of automobile service system is shown in Table 2.

**Table 2. After Several Months of Statistics for the Thousand Automobile Breakdown Number**

Time (months)	1	2	3	4	5	6	7	8	9	10	11	12
the thousand automobile breakdown number	5	13	16	11	24	22	39	52	53	63	83	102
Time (months)	13	14	15	16	17	18	19	20	21	22	23	24
the thousand automobile breakdown number	76	84	84	58	66	57	54	58	47	60	35	40
Time (months)	25	26	27	28	29	30						
the thousand automobile breakdown number	6	3	2	0	1	0						

### 6.2 Model Prediction

Weibull + +7 provides a Visualization environment, and also brings great convenience for parameter estimates, calculation and graphics of the Weibull distribution. So parameter estimation and simulation data calculated use the software in this paper.



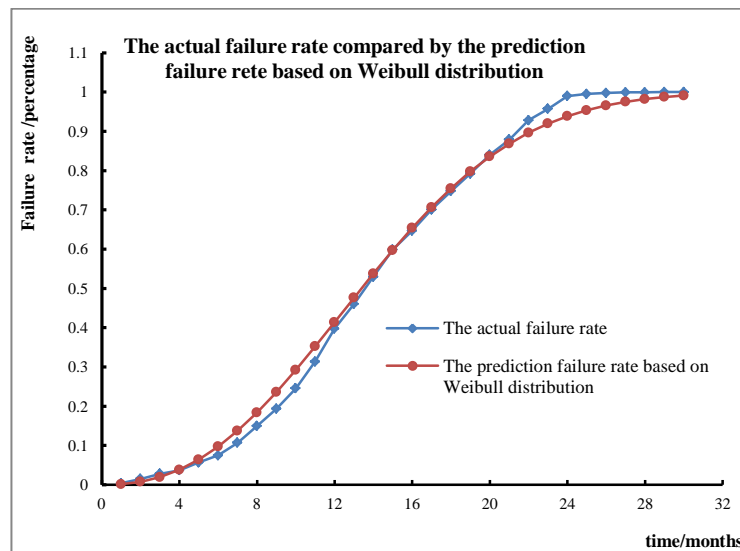
**Figure 9. The result of Weibull Distribution Possibility**

Using the parameter and estimating with MLE and fit predicted values by Weibull + +7, as is shown in Figure 9, solution are:  $\beta = 2.3841$ ,  $\theta = 15.6047$ , therefore,

$$F_{(t)} = 1 - \exp\left[-\left(\frac{t}{\theta}\right)^\beta\right] = 1 - \exp\left[-\left(\frac{t}{15.6047}\right)^{2.3841}\right] \quad (14)$$

### 6.3 Result Analysis

The result of automobile risk based on Weibull distribution model is shown as Figure 10, and compared by the actual fault data from after-sale service.



**Figure 10. The Result Compare by Weibull Distribution Possibility and Actual Date**

From Figure 10, from curve graph of failure probability data based on Weibull model and the actual fault data from after-sale service, we can know that Weibull predicted data fit to the actual data, and the overall trend line coincident, the relative residual control

within an acceptable range. Therefore, it is reasonable to use Weibull distribution model to forecast the risk of automobile defects.

#### 6.4 Calculate the Overall Risk

(1) According to the defect mode, the severity of the risk analysis  $S_d$

Through the automobile structure and function failure analysis, automobile brake booster device fails. If the automobile continued to travel, it will cause brake failure, and then the loss of active safety features. Compared with the "risk level reference Table", we can see: Automotive brake booster device defect severity  $S_d$  risk as "very serious", the rating is "4".

(2) The calculation of risk occurrence probability

Take the prediction time  $t = 30$  (month), and predicted failure rate  $F(t) = 0.99135501 \approx 1$ , i.e., at this time represents the total number of defects to achieve the ultimate failure of 1214. So the possibility of risk occurrence  $P_d = 1214/250000 = 0.004856 = 4.856\%$ . Compared with a "risk assessment probability reference Table",  $P_d$  in  $[1/2000, 1/50]$  interval, the possibility of risk is "not often, but it is possible", the rating is "3".

(3) Determine the defect automobile quantity grade

The total number of automobiles involved in this defect ( $N_d$ ) is 250,000. Compared with the "scale of the defect number of automobiles," the number of defects in the automobile belongs to the "great", the rating is "5".

(4) Calculate the overall risk

The  $S_d, P_d, N_d$  import automobile defect risk assessment model,

$$R_d = \sum f(S_d, P_d, N_d) \\ = \sum_{i=1}^n (S_{di} W_s \times P_{di} W_p \times N_{di} W_n) \quad (15)$$

In that,

$R_d$ : Dangerous defects in;

$S_{di}$ : First  $i$  severity of danger caused by defects;

$P_{di}$ : In the life cycle, the possibility of danger caused by defects in the  $i$ -th;

$N_{di}$ : The total number of the  $i$ -th dangerous automobiles exist.

Using the Delphi method and risk cases iterative method to obtain  $S_d, P_d, N_d$  three index weight,

$$W_d = [W_s \quad W_p \quad W_n] = [0.55 \quad 0.28 \quad 0.17]$$

With index weights for  $S_d, P_d, N_d$  correction, the value will be substituted into the equations (type 15), on  $R_d$  solved, and the overall risk can be calculated value  $R_d = 1.5708$ .

If  $S_d, P_d, N_d$  level values entered into the computer software, three-dimensional matrix output is: Overall Risk Rating automobile brake booster device defects as "medium risk", shown in Figure 11.

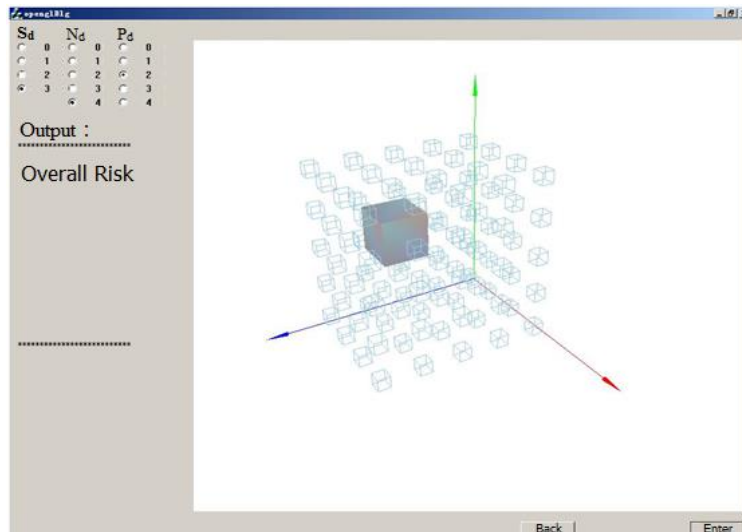


Figure 11. The Overall Risk Assessment

## 7. Conclusions

(1)According to the defects and risk characteristics of automobile, the event tree analysis (ETA) method was introduced to determine the risk flow route of automobile defects; The number of defects introduce parameters to establish a three-dimensional matrix model;

(2)The Weibull distribution model was studied, and the automobile defect risk forecast method based on the Weibull distribution was proposed;

(3)The results of actual fault data from after-sale service of automobile and probability data based on Weibull model showed that Weibull predicted data fit to the actual data and the overall trend line coincident. The analysis and calculation of actual cases prove that there is a higher degree of matching to use the Weibull model to predict and assess automobile defect.

(4)Put the severity of the risk of data  $S_d$ , the number of defects  $N_d$ , and failure probability  $P_d$  predicted in the Weibull model and into a three-dimensional matrix model of automobile defect risk assessment so as to calculate the overall risk assessment of the automobile defects.

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