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Stochastic Analysis of Accidents and of Safety Problems

Analyse stochastique d'accidents et problèmes de sécurité

Stochastische Analyse von Unfällen und Sicherheitsproblemen

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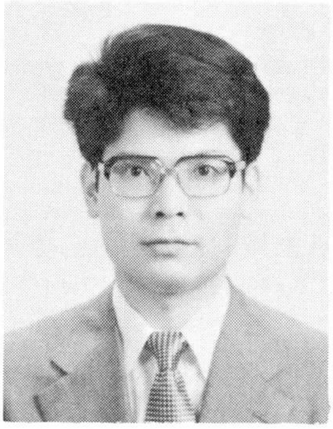

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SUMMARY
The time intervals between occupational accidents can be used as a valuable measurement for evaluating safety performance at working places. The frequency distribution of the occurence of accidents in a fixed time interval is a Poisson distribution, the time intervals between successive accidents are exponentially distributed. Statistically significant accident frequency rates can be used as an early indication of changes in the accident situation.

RESUME
L'intervalle de temps entre les accidents de travail peut être utilisé comme mesure de la sécurité sur les chantiers. La fréquence des accidents est conforme à une distribution de Poisson; les intervalles de temps entre les accidents successifs sont distribués de façon exponentielle. Des taux d'accidents fiables du point de vue statistique peuvent être un indice précurseur du changement de la sécurité sur le chantier.

ZUSAMMENFASSUNG
Die Zeitintervalle zwischen Arbeitsunfällen können zur Messung der Arbeitssicherheit auf Baustellen benützt werden. Die Häufigkeit des Auftretens von Unfällen in einem festen Zeitraum ist Poisson-verteilt, die Zeitintervalle zwischen aufeinanderfolgenden Unfällen sind exponential-verteilt. Statistisch zuverlässige Unfallraten können als frühzeitiger Hinweis auf Veränderungen der Arbeitssicherheit verwendet werden.

1. INTRODUCTION

Every year many occupational accidents take place in the construction industry in Japan. They account for about one third of all occupational accidents, and more than 40% of all fatal accidents. Also, all indices related to occupational accidents in the construction industry, such as the accident frequency rate and the accident severity rate, have higher rates than in many other industries.[1]

The basic reasons why the construction industry is such a dangerous one can be explained from the various point of view. For example, the construction industry has a wide range variety of situations in construction process management, i.e., working conditions as well as environment, and a system of employment of workers, in comparison to that of other industries. These differences might explain the disadvantages concerning occupational accident prevention.[2] Another drawback related to the occupational safety in construction work is that the actual safety management in each construction workplace has to be carried out in accordance with the individual construction site's characteristics. Therefore it is very difficult to formulate a systematic safety management program throughout the construction industry as a whole. Also, the methodology how to evaluate safety performance in working places has not been established, except for the measurement of the accident frequency rate and the accident severity rate.

In this paper, the frequency distribution of the occurrence of occupational accidents was studied from the stochastic point of view, for the purpose of providing a better understanding of the nature of the real accident situation in construction work. Then, based upon the knowledge on the accident situation obtained from observational investigation of the occupational accidents, one fundamental problem in connection with the occupational safety area, the measurement of safety performance in working places, was considered. In particular, emphasis was placed on the stochastic treatment of the time intervals between occupational accidents, regarding it as a useful measurement of safety performance in a working place having a certain accident risk.

In many industrial areas the accident frequency rate has been used as one of the measurement of safety performance over a long period of time. The accident frequency rate is defined as the number of occurrences of occupational accidents for a certain unit of man-power or employee hour exposure. The accident frequency rate, which implies the potential of accident risk in working places, is closely related to the number of occurrences of occupational accidents. This paper, on the contrary, takes the fluctuating time intervals between occupational accidents into consideration instead of the number of occurrence of accidents, in the hope of establishing its usefulness as a measurement of safety performance in working places.

To put it concretely, statistical significant tests for the accident frequency rate using time periods of accidents was considered in order to discover whether there is any significant tendency for changing accident situation in succeeding intervals of time. Also, for the purpose of estimating the unknown exact accident frequency rate, statistival estimation of confidence intervals of the accident frequency rate by means of the time intervals between occupational accidents was proposed.

2. THE BASIC OCCUPATIONAL ACCIDENT SITUATION

To throw light on the basic accident situation in many industrial areas in Japan various types of statistical accident investigation have been conducted by the government every year.[1] According to them, we can, for example, easily find the annual changes of the number of labour accidents, as well as the trends of the accident frequency rate and the accident severity rate in each industry. Also causal agents of accidents and types of accidents are reported as the basic statistics of labour accidents. Obviously, these statistics of accidents will provide a sefety committee or safety experts of a firm with much useful information. However, statistical investigation from the stochastic point of view, such as the frequency distrubution of occurrence of accidents or the time intervals between occuaptional accidents, are not included in the governmental statistical survey program.

Though there is little observatinal investigation concerning stochastic analysis as the time periods between accidents, it is possible to construct the model with the help of the statistics theory. According to the literature of statistics to date, it can be said that if some events are taking place at random and the expectation of the events per unit time is constant, then the frequency distribution of occurrence of events in a fixed interval of time have poisson distribution and the frequency of the time intervals between events are negative-exponentially distributed. It can also be shown that the frequency distribution of the sum of the successive intervals of time of occurrence of events comes to be gamma distribution, provided the time intervals between events is exponentially distributed. [3]

In order to clarify if the actual accident situations agree with the poisson process mentioned above, several observational investigations on the frequency distribution of occurrence of occupational accidents in various types of population was conducted.[4,5] Fig.-1 shows the frequency distribution of the number of occurrences of fatal accidents (deaths) in one day in the Tokyo metropolitan area in the year of 1973, classified by industry. From this figure it could be recognized that each industry has its frequency distribution in accordance with the poisson distribution. (Tests of goodness of fit were applied to verify if the observed distributions agree with the supposed poisson distribution and no significant difference was found between these distributions.) Also several frequency distributions of the number of fatal accidents in one day in various kinds construction sectors such as wooden-house construction, building construction, tunnel construction, bridge construction and road construction, in the year of 1977 are illustrated in Fig.-2 respectively. Clearly the frequency distribution in each construction sector had distributed as poisson distribution similar to Fig.-1. Hence, as far as the fatal accidents are concerned, we can conclude that they might take place at random in various work situations.

For the sake of getting further information on accident situations, especially individual construction site, another investigation on the frequency distribution

$$P(x)=\frac{m^x e^{-m}}{x!}$$

	Construction	Others	All Ind.
m	0.493	0.447	0.940

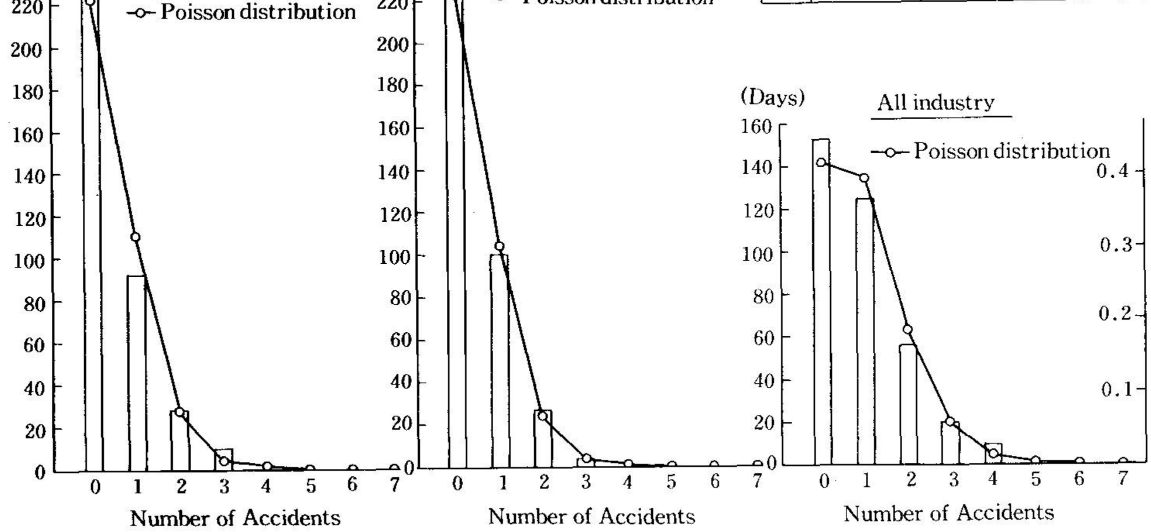
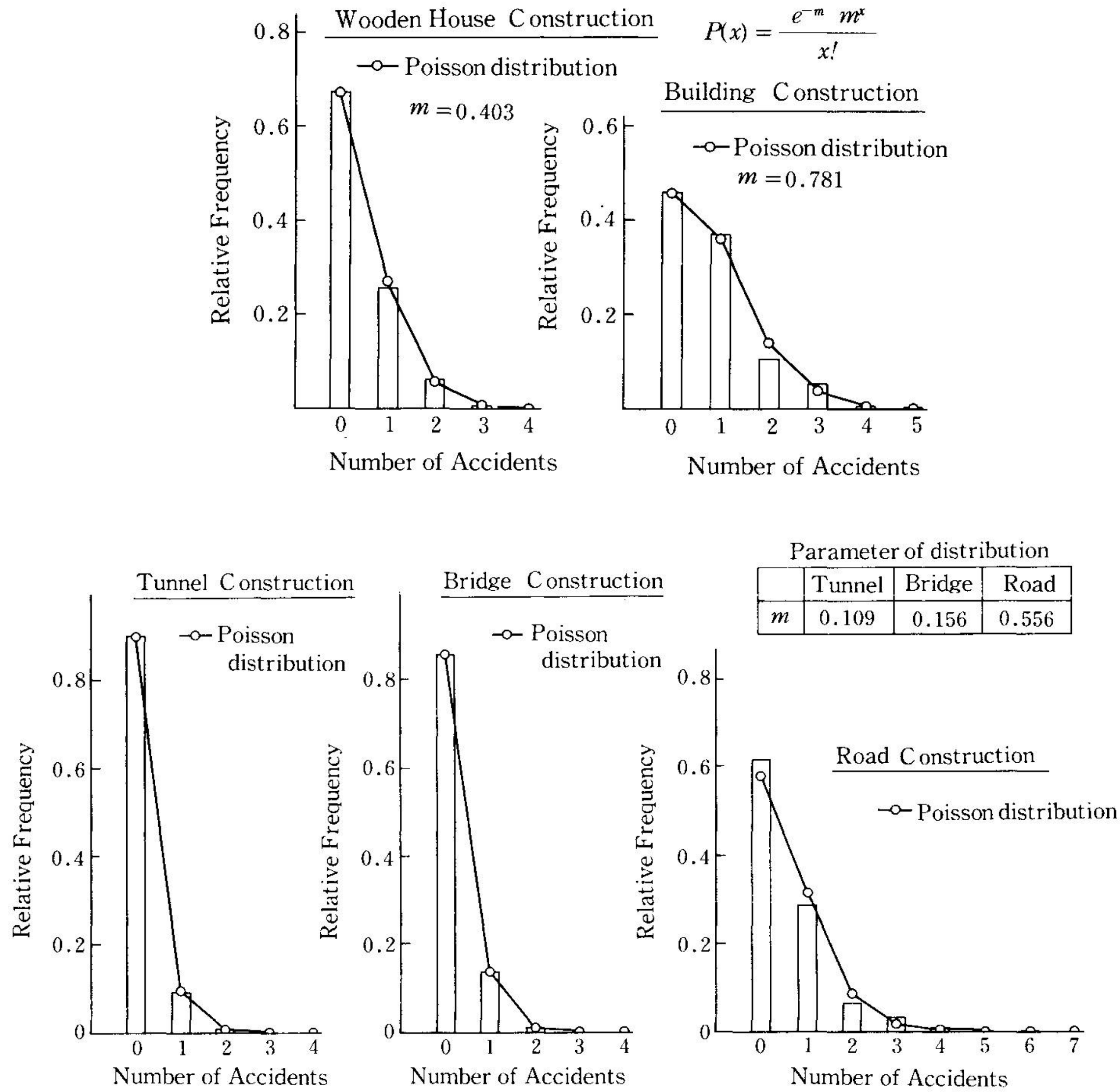


Fig.-1 Frequency Distributions of Fatal Accidents in Tokyo in the Year of 1973, classified by Industry



	Tunnel	Bridge	Road
m	0.109	0.156	0.556

Fig.-2 Frequency Distributions of Fatal Accidents in various Construction Sectors in the Year of 1977

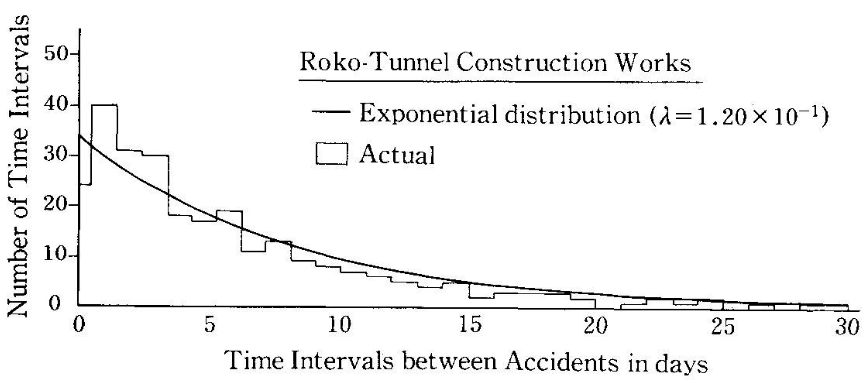


Fig.-3 Time Intervals between successive Accidents in days in a Tunnel Construction Site of the time intervals (in days) between all injury accidents in a tunnel construction site (Rokko tunnel in the New Sanyo rapid trunk line), was performed as shown in Fig.-3. Besides fatal accidents as in Fig.-1 and 2, all injury occupational accidents in this construction site showed up approximately at random, that is the time intervals between successive accidents becomes a rough exponential distribution as exhibited in Fig.-3. In this connection, another example can be seen in the work by B. A. Maguire, et al., in which the time intervals between successive compensable accidents in one district of a British mine was approximately distributed as the exponential distribution.[6] Therefore, depending upon these statistical evidences concerning accident situations obtained through several accident investigations, it may be possible to assume that occupational accidents take place at random, so that the number of occurrences of accidents have the poisson distribution and the time intervals between successive accidents becomes the exponential distribution, to at least a rough approximation. In short, exponential/gamma distribution can be used as the frequency distribution of the time intervals between occupational accidents in the following discussion. The probability density functions of the exponential and gamma distribution are expressed as in the following equations.

$$f_1(t) = \lambda e^{-\lambda t} \qquad \text{-----------------(1)}$$

$$E_1(t) = 1/\lambda \quad , \quad V_1(t) = 1/\lambda^2$$

$$f_K(T) = \frac{(\lambda T)^{k-1}}{(k-1)!} \lambda e^{-\lambda T} \qquad \text{-----------------(2)}$$

$$E_K(T) = k/\lambda \quad , \quad V_K(T) = k/\lambda^2$$

where : k is the number of occurrence of accidents
T is the sum of k intervals of time between successive accidents
E(·) is the expectation, V(·) is the variance of the distribution

3. EVALUATION OF SAFETY PERFORMANCE IN WORKING PLACES USING TIME INTERVALS [7]

Since the probability density functions of the time intervals between occupatioal accidents are expressed as exponential or gamma distribution shown above, statistical evaluation for safety performance in workplaces using time intervals between occupational accidents can be conducted by executing integration of these density functions.

In order to calculate a probability of the exponential/gamma distribution, it is necessary to estimate a value of λ, a parameter of these distribution functions , prior to the calculation. As a statistical property of exponential distribution, the parameter λ agrees with the reciprocal number (inverse) of the expectation of the distribution. Meanwhile, the accident frequency rate is defined (in Japan) as the number of occurrence of accidents per 1,000,000 man-hour exposure, so that the mean time between accidents could be calculated as 100/A. (unit is 10,000 hour) Therefore, the parameter λ of the exponential as well as gamma distribution can be connected to the accident frequency rate as in the following manner;

$$\lambda = A/100 \qquad \text{---------------------(3)}$$

where : A is an accident frequency rate in work places

Then the probability whether an accident will occur or not within a given time t for a certain accident frequency rate can be calculated by equation(4) and (5) respectively.

$$F_1(t) = 1 - \exp\{-At/100\} \qquad \text{---------------(4)}$$

$$R_1(t) = \exp\{-At/100\} \qquad \text{------------------(5)}$$

Also the probability whether k occupational accidents will take place or not within a particular time T for a certain accident frequency rate can be analyzed by the gamma distribution similar to exponential distribution.

$$F_K(t) = 1-\sum \frac{(AT/100)^i}{i!} \exp\{-AT/100\} \quad \text{-------}(6)$$

$$R_K(T) = \sum \frac{(AT/100)^i}{i!} \exp\{-AT/100\} \quad \text{----------}(7)$$

Fig.-4 shows an illustrated example of the probability density function of the gamma distribution given by equation(2), assuming that the accident frequency rate equals to 20.0. Also, an example of the upper probability distribution function given by equation(7) is illustrated in Fig.-5, in the case of the number of

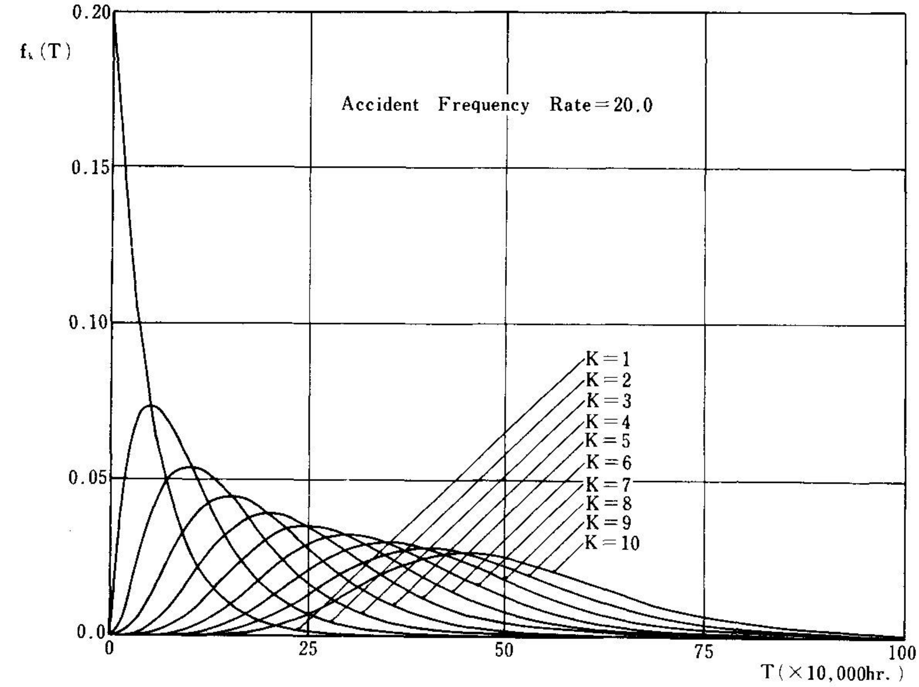


Fig.-4 Probability Density Function of Gamma Distribution

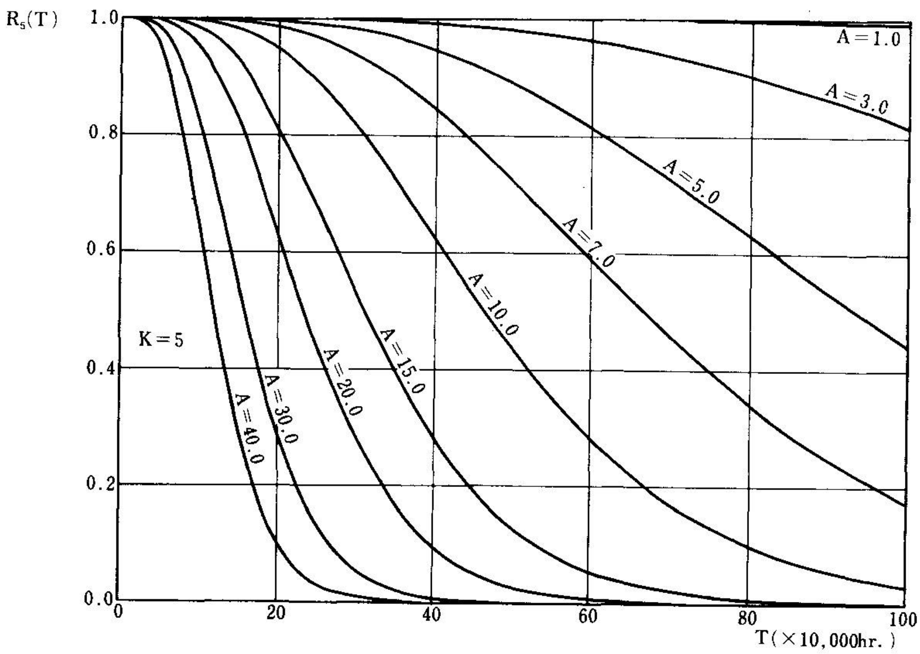


Fig.-5 Probability Distribution Function of Gamma Distribution

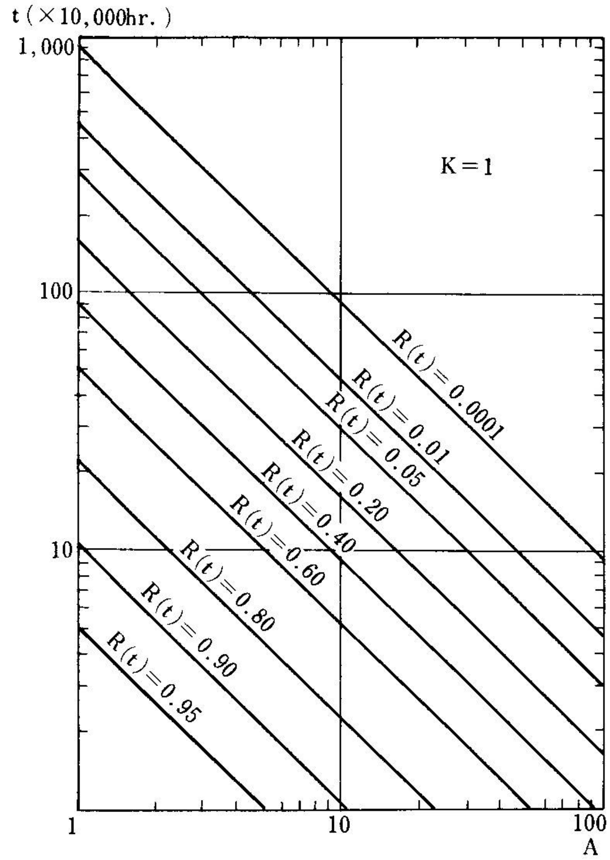


Fig.-6 Relation between $R_1(t)$, t and Accident Frequency Rate

accidents k=5 corresponding to various accident frequency rates. As shown in this figure, the relation between the time interval of accidents and the probability of its occurrence is explained by the distribution function for each combination of the accident frequency rate and the number of accidents.

Hence, for the purpose of measuring safety performance in working places, statistical evaluation of the time intervals between occupational accidents can be easily achieved by making use of these distribution functions. Namely, since equation(5) gives the probability that an accident will take place after the time period of t, the corresponding equation could be used for evaluating a time interval in which no accident has happened. Thus this equation is useful for planning a target of non-occurrence time period in which a safety committee of a firm attempts to avoid any accident from taking place (the so-called zero-accident campaign). In Fig.-6 the relation between $R_1(t)$ given by equation (5), time intervals between accidents and the accident frequency rate are illustrated. With the help of this material, setting a goal of non-occurrence period could be performed in accordance with the accident frequency rate in the working place. For example, a safety committee in an operating work place having an accident frequency rate 10.0, is thinking of promoting a zero-accident campaign and intends to set up a non-occurrence time period. The question is how many working hours should be set up as the goal of non-occurrence period. When we set up 46.1 (×10,000) hour as the goal of time period, no accident will take place within the same period with the probability of 1%, 30.0 hour with the probability of 5 %, and so on. The amount of the probability that must be chosen in the process of setting the goal period, is a problem that depends upon the attitude of the manager or the safety committee in the firm.

Also, as another example, statistical significance tests for the accident frequency rate can be applied to discover whether there is any significant tendency for changing accident risk situation in succeeding intervals of time, by making use of these distribution functions. This is described as an application of a test of hypothesis to the accident frequency rate by use of the time intervals between occupational accidents. The procedure for the tests of hypotheses to the accident frequency rate is depicted as below;

1) present a null hypothesis of the accident frequency rate

   $H_0 : A = A_0$ (A_0 : initial accident frequency rate)

2) specify an alternative hypothesis of accident frequency rate such as;

   a) $H_1 : A = A_1 > A_0$ (one-sided alternative)

   b) $H_1 : A = A_1 < A_0$ (one-sided alternative)

   c) $H_1 : A = A_1 \neq A_0$ (two-sided alternative)

Here, let's take Case "a" first, as an alternative hypothesis against the null hypothesis, which is considering a worse case in an accident risk situation. This test is asking if the accident frequency rate is getting larger in comparison to the initial rate. Then,

3) compute a critical time period $T\alpha_1$, at a significant level α. Equation(6) gives the time of $T\alpha_1$ as follows;

$$\sum \frac{(A_0 T\alpha_1/100)^i}{i!} \exp\{-A_0 T\alpha_1/100\} = 1 - \alpha \quad \text{--------(8)}$$

4) make a decision by comparing $T\alpha_1$ with an actual time of the sum of k successive intervals T_K. If the actual time T_K is smaller than $T\alpha_1$, say $T_K < T\alpha_1$, then we can reject the null hypothesis and conclude that the accident frequency rate at the time T_K may have a higher rate than the initial one, so that the accident situation is becoming worse. Fig.-7 demonstrates the relationship between A_0 and $T\alpha_1$, corresponding to the number of accidents, assuming the significant level is α= 5%. Accordingly, this diagram can be employed with reference to this testing hypothesis to the accident frequency rate. Namely, if the actual time T_K is below (inside) the critical time represented by each line in this figure, then we can draw the conclusion mentioned above.

On the other hand, suppose Case "b", as another alternative hypothesis against the null hypothesis which, in this case, is considering a better condition of the accident situation. This test is asking if the accident frequency rate is becoming smaller rate compared with the initial rate. Then,

3') critical region of time $T\alpha_2$, in this case, satisfies the equation(7) as;

$$\sum \frac{(A_0 T\alpha_2/100)^i}{i!} \exp\{-A_0 T\alpha_2/100\} = \alpha \quad \text{-----------(9)}$$

4') comparison $T\alpha_2$ with an actual time T_K yields the decision. If the actual time of the sum of the k successive intervals T_K is longer than $T\alpha_2$, say $T_K > T\alpha_2$, then we can reject the null hypothesis and conclude that the accident frequency rate changes into a smaller rate than the initial one. Consequently the accident situation has been improved. Fig.-8 illustrates the relation between $T\alpha_2$ and A_0,

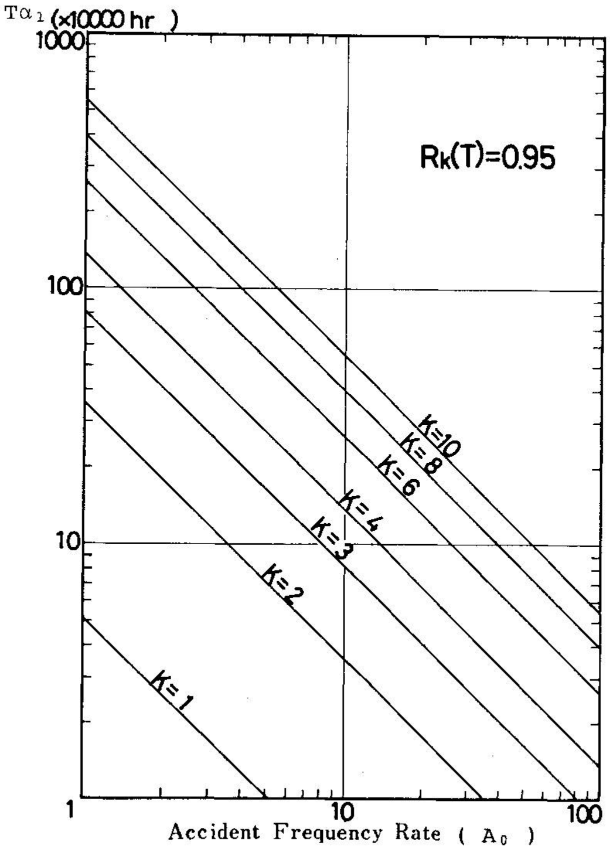


Fig.-7 Relation between A_0 and $T\alpha_1$ ($A_0 < A_1$)

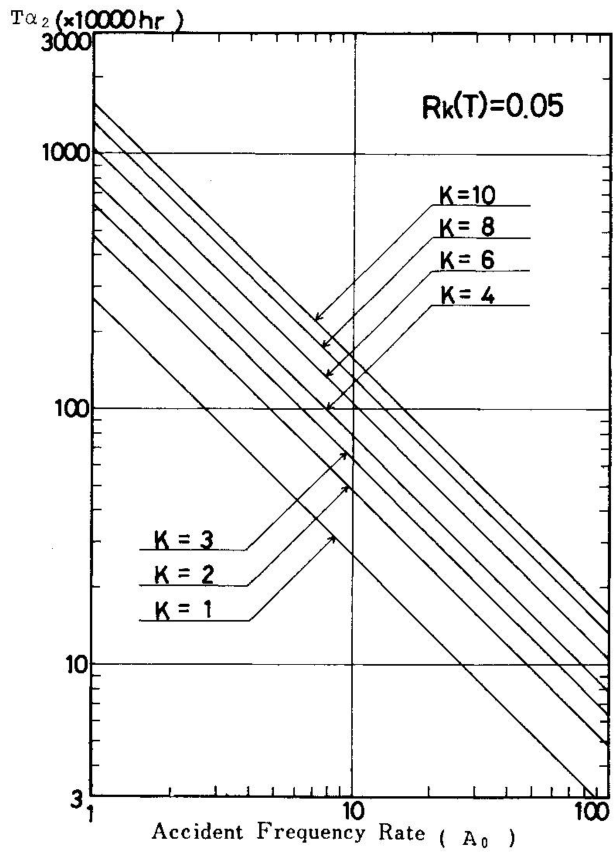


Fig.-8 Relation between A_0 and $T\alpha_2$ ($A_0 > A_1$)

Table-1 Accident Frequency Rates and Severity Rates in Construction Sectors

Industry \ Classification	1979 Frequency Casualties	1979 Frequency Deaths	1979 Severity rate	1980 Frequency Casualties	1980 Frequency Deaths	1980 Severity rate
All industries	3.65	0.02	0.36	3.59	0.02	0.32
Construction (general)	6.92	0.13	1.47	6.67	0.08	1.47
Civil engineering	8.20	0.30	2.79	8.75	0.10	2.79
River engineering	12.43	0.12	5.12	9.48	–	1.52
Railway construction	10.71	–	0.39	5.66	–	7.16
Bridge construction	4.79	0.09	1.06	5.53	0.05	0.59
Tunnel construction	19.72	0.99	8.45	15.90	0.22	1.61
Hydro station etc. new construction	6.58	0.26	2.30	7.06	0.35	3.06
Subways new construction	5.21	0.22	1.81	8.62	0.29	2.63
Roads new construction	4.36	0.20	1.72	5.10	–	0.50
Other construction	5.25	0.13	1.09	7.66	0.05	0.60
Building works	6.09	0.02	0.60	5.87	0.07	0.79
Other building	10.99	0.04	0.55	9.70	0.13	1.22
Machinery installation	1.11	–	0.07	2.37	0.08	0.68
Electrical works	2.87	0.06	0.50	2.91	0.10	0.85
Piping (excluding well excavations)	6.51	–	0.14	5.79	0.04	0.45

corresponding to the number of accidents at the significant level α=5%. Similar to the previous instance, relying upon this figure, we can reach the above conclusion if the actual time T_K exceeds (outside) the critical time region represented by each line in this figure.

Table-1 shows the accident frequency rates and the accident severity rates in various construction sectors in Japan for the year 1979 and 1980. This table will be useful for estimating an initial accident frequency rate A_0 in conducting the test of hypothesis to the accident frequency rate.

4. INTERVAL ESTIMATION OF ACCIDENT FREQUENCY RATE USING TIME INTERVALS [7]

Another important reserach area in connection with the use of the time intervals between occuaptional accidents is to estimate the unknown exact accident frequency rate from a stochastic point of view.

Suppose the situation in an operating work place where k labour accidents have taken place at the time T (×10,000) hour (this implies k-1 accidents have already happened before T in advance), then the accident frequency rate is calculated as $A = k/T\times 100$ as usual. This sampled (in a statistical meaning) accident frequency rate analyzed in this way from the observed accident data should be regarded as a point estimate of the unknown exact value of the accident frequency rate from the statistical viewpoint. In fact, it can be shown that this sampled accident frequency rate calculated from the observed accident data, agrees with the maximum likelihood solusion derived from the exponential distribution. This sampling accident rate depends on the probability law as below;

If the time intervals between occupational accidents t, is distributed as frequently used exponential distribution expressed in equation(1), then a transformed random variable χ^2 (=$2\lambda t$=$At/50$) gives rise to a χ^2 distribution function having the degree of freedom ϕ = 2 as expressed in equation(10).

$$f(\chi^2) = \frac{1}{2}\exp\{-\chi^2/2\} \qquad \text{-----------------(10)}$$

Then the probability that the real unknown exact accident frequency rate exists in a range of A_1 and A_2 ($A_1 < A_2$) when an accident has occurred at a certain time t, can be calculated as in the following manner;

Suppose the variables as $\chi_1^2 = 2\lambda_1 t$, $\chi_2^2 = 2\lambda_2 t$ and keep t constant, then

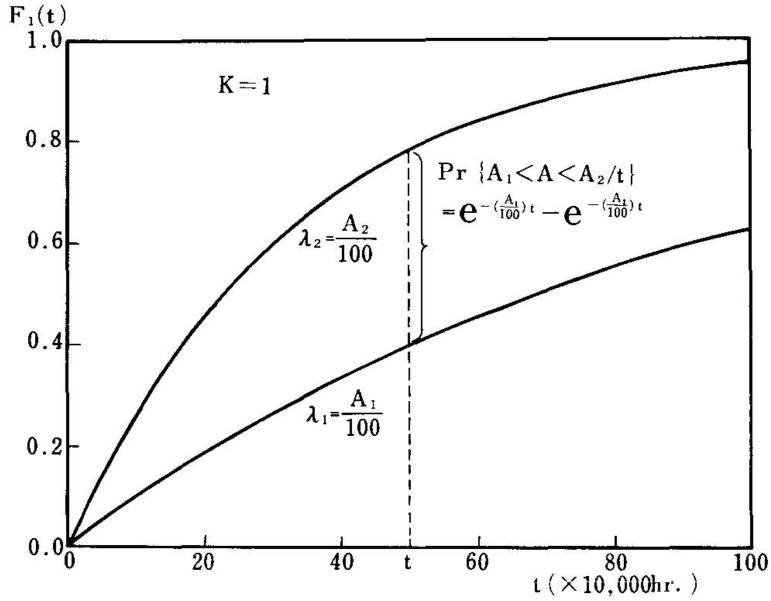


Fig.-9 Notional Sketch of the Probability of the Real Accident Rate in A_1 and A_2

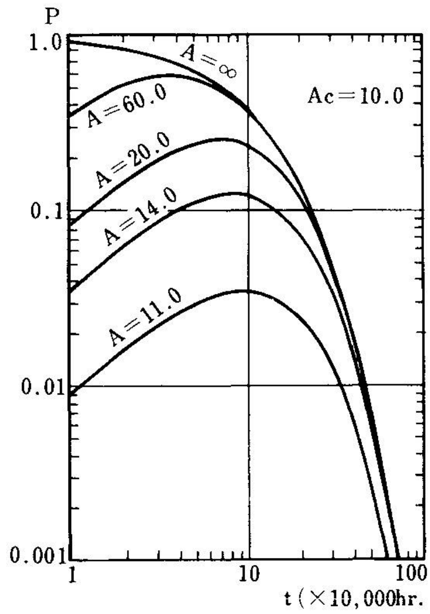


Fig.-11 Probability of Frequency Rate greater than Ac

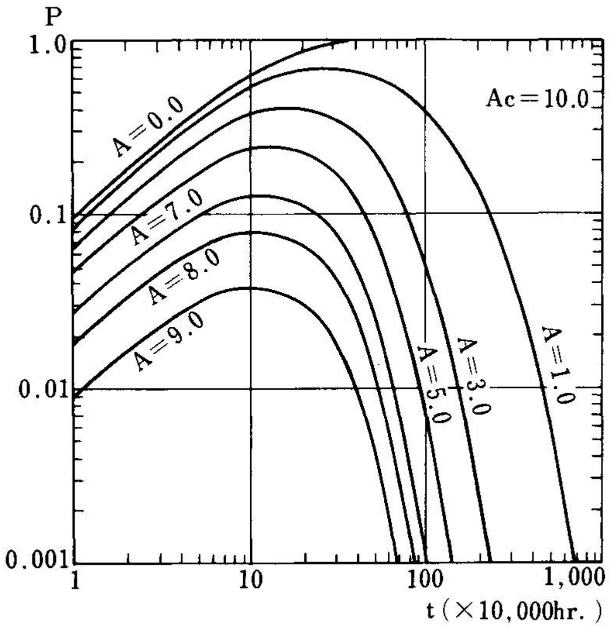


Fig.-10 Probability of the Frequency Rate less than Ac

$$\begin{aligned} &\Pr.(\ \chi_1^2 < \chi^2 < \chi_2^2\ ) \\ &= \Pr.(\ 2\lambda_1 t < 2\lambda t < 2\lambda_2 t\ ) \\ &= \Pr.(\ A_1 < A < A_2 \mid t\ ) \\ &= \exp\{-A_1 t/100\} - \exp\{-A_2 t/100\} \end{aligned}$$

------(11)

This mathematical deduction is shown in the sketch of Fig.-9 graphically, in which the probability of the real accident frequency rate stands between an interval of the accident frequency rate A_1 and A_2, is shown as the difference of two distribution functions of exponential distribution including the parameter of A_1 and A_2.

Also, suppose the situation in a work place where a number of k accidents have taken place at a particular time T, then the existing probability of the unknown exact accident frequency rate in a range of A_1 and A_2, can be analyzed through the transformation of the variables of gamma distribution similar to exponential distribution. This interval probability is derived in the same fashion as the exponential distribution. Namely, as shown in equation(12), the difference between two distribution functions of gamma distribution yields the probability discussing here.

$$\Pr.(\ A_1 < A < A_2 \mid T\ ) = \sum \frac{(A_1T/100)^i}{i!} \exp\{-A_1T/100\} - \sum \frac{(A_2T/100)^i}{i!} \exp\{-A_2T/100\}$$

------------------(12)

Fig.-10 shows several examples of the probability that the unknown real accident frequency rate stands between Ac and other different frequency rates less than Ac. In the case of A = 0.0 in this figure, which representing the probability Pr.(0.0 < A < Ac), is equal to the probability less than Ac. Also Fig.-11 illustrates several examples of the probability of the real accident frequency rate exists between Ac and other rates greater than Ac. In this figure, the case of A = ∞, indicating Pr.(Ac < A < ∞) is the probability greater than Ac. From the consideration above, it can be said that the evaluation of any arbitrary interval of accident frequency rate in reference to a probability, can be performed by making use of equation(11) and (12).

On the other hand, the so called statistical interval estimation (for accident frequency rate) is depicted in the reverse way of thinking as discussed above. That is, define the probability α first, which is quoted as a level of significance. Then estimate an interval of accident frequency rate in which the exact real accident frequency rate exists with the probability 1-α. To do this a sampling χ^2 distribution is used.

Let's consider the simple case k=1 first. As previously mentioned, the time intervals between occupational accidents t, can be transformed to a χ^2 (=2λt = At/50) random variable which depends on the χ^2 distribution with the degree of freedom φ = 2. Thus from an existing χ^2 table we can easily find both the upper $\chi^2_{\alpha/2}$ and the lower $\chi^2_{1-\alpha/2}$ points which satisfy the χ^2 distribution function as;

$$\Pr.(\ \chi^2_{1-\alpha/2} < \chi^2 < \chi^2_{\alpha/2}\ ) = 1-\alpha$$

Then the confidence interval for the unknown exact accident frequency rate corresponding to a certain significant level α could be obtained as in equation(13).

$$(\ A_{LL}\ ,\ A_{UL}\ ) = \left[\frac{50\chi^2(2;1-\alpha/2)}{t}\ ,\ \frac{50\chi^2(2;\alpha/2)}{t} \right] \quad \text{------(13)}$$

where : $\chi^2(\phi;\alpha)$ is χ^2 point with upper probability α, degree of freedom φ

Fig.-12 exhibits the confidence intervals for the accident frequency rate at the significant level α = 1, 5 and 10 % respectively. From the figure, for example, if an accident takes place at 10 (×10,000) hour, then we can estimate the confidence interval as 0.5 < A < 30.0 with the level of significance α = 10%.

Meanwhile, let's consider the distribution of the mean time interval between

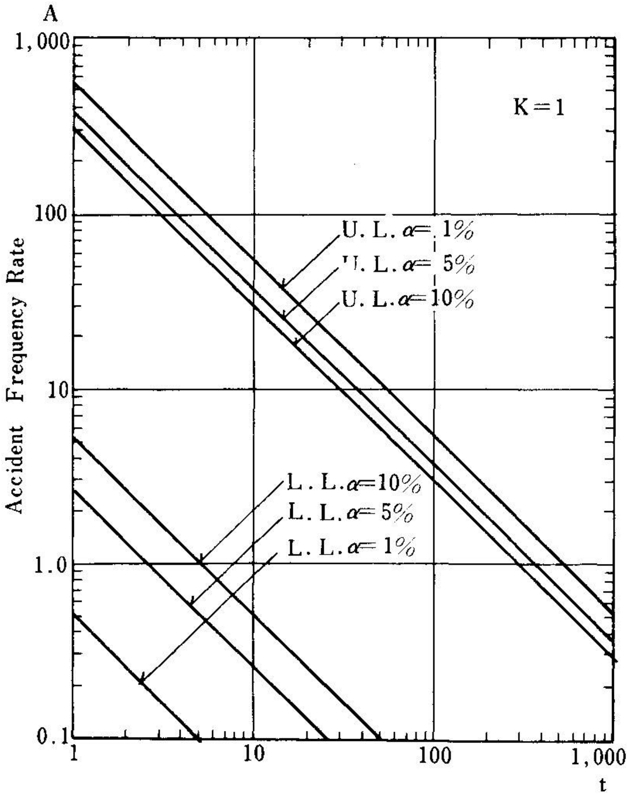


Fig.-12 Interval Estimation of Accident Frequency Rate (k=1)

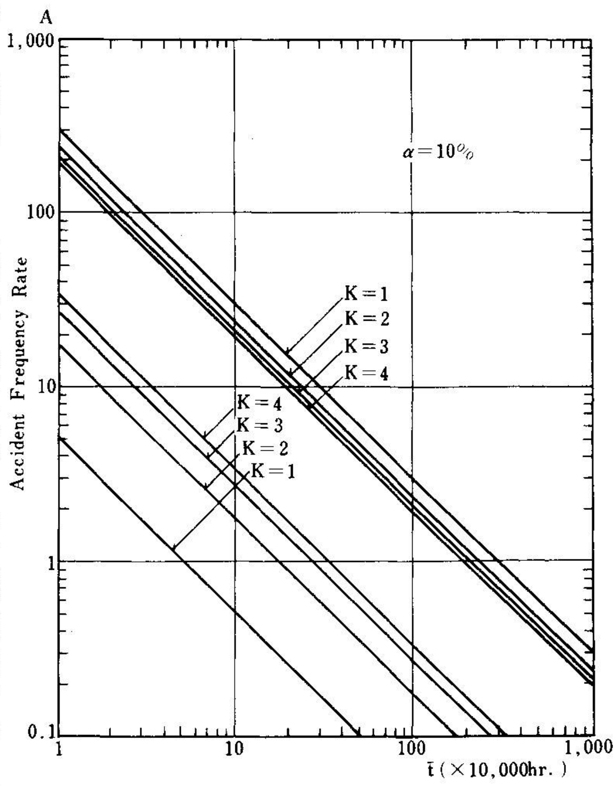


Fig.-13 Interval Estimation of Accident Frequency Rate (α =10%)

occupational accidents $\bar{t}$ here, in order to implement the estimating of the confidence intervals of the accident frequency rate for the case of a number of accidents. It is well known that the distribution of the mean of k successive intervals becomes Erlang distribution as written in equation(14), provided the time intervals between accidents is exponentially distributed.

$$f_K(\bar{t}) = \frac{(k\lambda)^k}{(k-1)!}\,\bar{t}^{(k-1)}\exp\{-k\lambda\bar{t}\} \quad \text{---------(14)}$$

$$E_K(\bar{t}) = 1/\lambda \quad , \quad V_K(\bar{t}) = 1/k\lambda^2$$

Now it can be followed from Erlang distribution that a transformed random variable $\chi^2(=2k\lambda\bar{t}=Ak\bar{t}/50)$ becomes χ^2 distribution with the degree of freedom $\phi=2k$ as shown in equation(15).

$$f_K(\chi^2) = \frac{(\chi^2/2)^{2k/2-1}}{2(k-1)!}\exp\{-\chi^2/2\} \quad \text{---------(15)}$$

Then a χ^2 probability table can be employed in the analysis for estimating the confidence intervals of the unknown exact accident frequency rate. Through the same procedure as of k=1, we can get the confidence intervals for the accident frequency rate in the case of a number of k accidents as ;

$$(A_{LL}, A_{UL}) = \left(\frac{50\chi^2(2k;1-\alpha/2)}{k\bar{t}}, \frac{50\chi^2(2k;\alpha/2)}{k\bar{t}}\right) \quad \text{---(16)}$$

Fig.-13 illustrates the confidence intervals of the accident frequency rate assuming the significant level α = 10 %. As shown in this figure, the more the accidents occur, the narrower the width of the confidence intervals of the accident frequency rate becomes, owing to the increment of the information about the accident situation in work places.

5. SUMMARY AND CONCLUSION

From the study mentioned above, it can be summarized and concluded as follows:

1) If the occuaptional accidents are taking place at random, then the frequency distribution of occurrence of accidents in a fixed interval of time have the poisson distribution and the time intervals between successive accidents becomes the exponential distribution. From several observational investigations of accidents in various construction sectors, it was recognized that the frequency distribution of fatal accidents had become as poisson distribution and all injury accidents on a certain tunnel construction site had an approximate exponential distribution. Consequently, exponential/gamma distribution, to at least a rough approximation, can be used for the analysis of evaluating safety performance.

2) Accident frequency rate that indicates the accident risk potential, can be connected to the parameter of the exponential and gamma distribution. Then the probability whether some accidents will occur or not within a particular time for a certain accident frequency rate can be calculated by the probability distribution functions.

3) Statistical significant tests to the accident frequency rate , as a typical application of test of hypothesis, can be achieved by making use of the time periods between accidents, to explore whether there are any significant changes in the accident situation in succeeding intervals of time.

4) Transformation of exponential and gamma distribution into χ^2 sampling distribution make it possible to evaluate the probability that the unknown real accident frequency rate exists within an arbitrary interval of accident frequency rate. Also, the statistical estimation of the confidence intervals of the accident frequency rate was proposed by means of stochastic treatment of the time intervals between occupational accidents.

In conclusion, it is apparent that the time intervals between occupational accidents can be used as a valuable measurement for evaluating safety performance in working places. It can be used especially as an early indication of significant changes in the accident situation by means of the statistical significant tests to the accident frequency rate. Also interval estimation of the accident frequency rate using time periods between accidents will provide a safety committee with much useful information in order to implement various types of safety programs.

Finally the author wishes to express his appreciation to those government officials who had given assistance in conducting the accident investigations.

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