The Applications of Reliability Models in Road Safety

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Abstract : In this Paper, a Reliability model has been successfully developed by designing the roadways and its sections as a system with mixed Series and Parallel configurations to determine the System Reliability and the knowledge of which ensures the safety of roads and travelling in certain routes and thus helps to make corrective measures to prevent accidents.

Keywords: **Reliability, Series Configuration, Parallel Configuration, Mixed Configuration and Poisson Distribution.**

I. Introduction

Reliability Analysis is based on repairs and failures of a System. The Theory of Reliability is a science which studies laws of occurrence of failures in Technical equipments and complex systems.[4]

There is a need for collecting and analysis the traffic accident data to understand the behavior of traffic accident rate. Road traffic is increasing enormously and posing many traffic problems like accident, traffic jams etc., and this also makes air and noise pollution (sound). India is no exception for accident and more than 1.3 lakh people died on Indian Roads.

The Purpose of Analysis is (i) to identify accidents data (ii) to identify hazardous routes in a region (iii) to estimate accidents rate and Reliability of different routes. And routes can be classified into (i) Road way and (ii) Highways. Some routes are risky because of hairpin curves, ghat roads and steep ups and downs. Based on this nature of Road Accident rate, risky factors can be identified and Reliabilities of Road accidents are determined.

In the Analysis of traffic accident frequency, no attempt has been made to consider the process of occurrence of traffic accidents from the aspect of System Reliability by considering an highway as System and its Sections as units and applied the system reliability models for the analysis of traffic accident frequency. In this paper, a system reliability model to the traffic flow and its safety has been constructed with the help of mixed series and parallel configuration.[7]

The paper is summarized as follows, In section 1, we give the General Introduction, In section 2, we deal with basic concepts and definitions, In section 3, we constructed the model involved in our study, In section 4, we present the numerical illustration and finally in section 5, we draw the conclusion.

II. Definition

PoissonDistribution

This distribution is used quite frequently in Reliability analysis. It can be considered an extension of the binomial distribution when n is infinite. It can be used to approximate the binomial distribution when $n > 0$ and $p \le 0.05$

If events are Poisson distributed, they occur at a constant average rate and number of events occurring in any time interval are independent of the number of events occurring in any other time interval for exponential the number of failures in a given time would be

$$f(x) = \frac{e^{-\lambda} \cdot (\lambda)^x}{x!} \tag{1}$$

x -Number of failures.

λ - expected number of failures

For the purpose of Reliabilityanalysis, this becomes

$$f(x:\lambda,t)=\frac{(\lambda t)^{x}\cdot e^{-\lambda t}}{x!}$$

λ - Failure rate.

t - Length of time being considered.

x - Number of failures

and Reliability is given by,

$$R(t)=\sum_{x=0}^{r}\frac{(\lambda t)^{x}\cdot e^{-\lambda t}}{x!} \tag{2}$$

Reliability

Reliability is the probability of a device or system element performing its intended function under stated conditions without failure for given period of time.

Reliabilityis defined by

$$R(t)=1-F(t)$$

$$R(t)=e^{-\int_{0}^{\infty}\lambda(t)dt} \tag{3}$$

where $R(t)$ is the Reliability at time t.

Series Configuration

It is the simplest and probably the most commonly occurring or assumed configurations in reliability evaluation of engineering systems. The success of the system depends on the success of all its elements. If any one of the elements fails, the system fails. Fig.1 shows the block diagram of a series system.

Series configuration

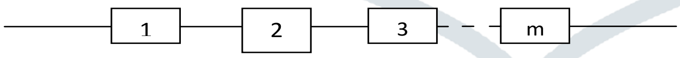

Fig. 1 Block diagram of m unit series system

In Series System reliability is expressed by

$$R(S)=\prod_{i=1}^{n}P(X_i) \tag{4}$$

Parallel Configuration

In this case, all units are active and at least one unit must perform successfully for the system success. Fig.2 shows the block diagram of a parallel system, each block represents a unit.

Parallel configuration

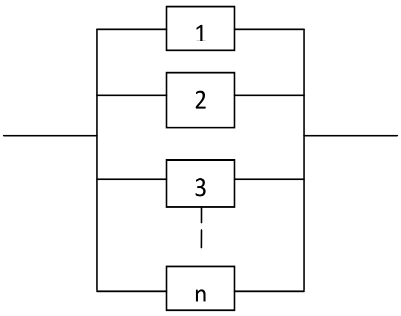

Fig. 2 n units parallel system

In parallel system Reliability is expressed by

$$R(S) = 1 - \prod_{i=1}^{n}(1 - P(X_i)) \tag{5}$$

III. Parallel Series (PS)System

Consider a system with 2 units connected in parallel, each unit has 3 sub units connected in series. All the units involved in this system are independent and the Reliability of the System based on the Reliability of the components in the System given by

$$R_{ij}(t) = \frac{\left(\lambda_{ij}t\right)^{x_{ij}} \cdot e^{-\lambda_{ij}t}}{x_{ij}\,!} \tag{6}$$

The Reliability of **PS** configuration System which are given by

$$R(s) = 1 - \prod_{i=1}^{m}[1 - \prod_{j=1}^{n} R_{ij}] \tag{7}$$

Here, $i = 1,2 \ and \ j = 1,2,3$

$$R(s) = 1 - \prod_{i=1}^{2}[1 - \prod_{j=1}^{3} R_{ij}] \tag{8}$$

$$= 1 - \prod_{i=1}^{2}\left[1 - \left(R_{i1}R_{i2}R_{i3}\right)\right]$$

$$= 1 - \left\{\left[1 - \left(R_{11}R_{12}R_{13}\right)\right]\left[1 - \left(R_{21}R_{22}R_{23}\right)\right]\right\}$$

The Reliability of the System for no more than n accident in each place, using equation (6)

$$R(s) = 1 - \left\{ \begin{array}{l} \left[1 - \sum_{x_{11}=0}^{n} \frac{\left(\lambda_{11}t\right)^{x_{11}} \cdot e^{-\lambda_{11}t}}{x_{11}\,!} \cdot \sum_{x_{12}=0}^{n} \frac{\left(\lambda_{12}t\right)^{x_{12}} \cdot e^{-\lambda_{12}t}}{x_{12}\,!} \sum_{x_{13}=0}^{n} \frac{\left(\lambda_{13}t\right)^{x_{13}} \cdot e^{-\lambda_{13}t}}{x_{13}\,!}\right] \\ \left[1 - \sum_{x_{11}=0}^{n} \frac{\left(\lambda_{11}t\right)^{x_{11}} \cdot e^{-\lambda_{11}t}}{x_{11}\,!} \cdot \sum_{x_{12}=0}^{n} \frac{\left(\lambda_{12}t\right)^{x_{12}} \cdot e^{-\lambda_{12}t}}{x_{12}\,!} \sum_{x_{13}=0}^{n} \frac{\left(\lambda_{13}t\right)^{x_{13}} \cdot e^{-\lambda_{13}t}}{x_{13}\,!}\right] \end{array} \right\} \tag{9}$$

With no more than two accidents per zone, $x_{ij} = 0,1,2$

IV. Numerical Example

To move from City A to City B. We have either route 1 with 3 main places connected in series or we have route 2 with 3 main places connected in series. The model is developed in such a manner that the model can be viewed as a Parallel-Series model.

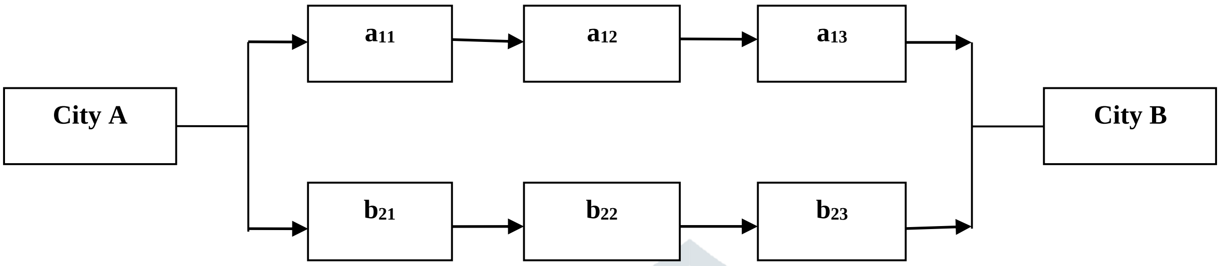

Fig. 3

Our aim is to determine the Reliability of the System of Roadways, that is travel from City A to City B to be free of accidents so thatsome safety measures can be taken by the Roadways Department in the near future to maintain a public safe highways to travel.

Let x_{ij} be the number of accidentsoccurring at the specified main places, n denotes the maximum number of accidents occurring in each place.

To determine the Reliability of the System.(i.e., Road travel from City A to City B)by considering minimum number of accidents at each place we denote the average number of accidents at the particular place say a_{ij} every 30 months be r number of accidents.

Since by equation (8),

$$R(s) = 1 - \prod_{i=1}^{2}[1 - \prod_{j=1}^{3} R_{ij}]$$

Where in each route, let the Reliability of the number of accidents occurring in the path ij be R_{ij} . For the purpose of Reliability Analysis, let us consider the Reliability function or the probability function for x failures in time t in the specific path $i \to j$ be $R_{ij}(t)$.

Which can be modeled as,

$$R_{ij}(t) = \sum_{x_{ij}=0}^{n} \frac{(\lambda_{ij} t)^{x_{ij}} \cdot e^{-\lambda_{ij} t}}{x_{ij}\,!} \qquad (10)$$

Sub the value of λ_{ij} from the table and time period $t = 1$yr (i.e., 365 days) and x_{ij} taking values from 0 to 2, we determine the Reliability of the system i.e., traveling from A to B with no more than 2 accidents occurring at each place for the time period of 1 year.

Suppose, if there are no accidents occurring then $R_{ij}(t) = e^{-\lambda_{ij} t}$, where λ_{ij} denotes the average number of failure per route and the Reliabilities of each route are calculated and tabulated below. Using equation (9)

City A to B	λ_{ij} per day	λ_{ij} per year	$R_{ij}(t)$ (i.e., No more than 2 Accidents at each main place)
a_{11}	0.0022	0.8111	0.9508
a_{12}	0.0033	1.2166	0.8757
a_{13}	0.0044	1.6222	0.7776
b_{21}	0.0011	0.4055	0.9908
b_{22}	0.0022	0.8111	0.9508
b_{23}	0.0066	2.4333	0.5607
Reliability			R(s)= 0.8337

From the above example, we observe that there is 83% of Reliability of the safer road travelling from City A to City B safely for the particular time period if minimum number of accidents would have occurred at the main places with available failure rates at each main place collected from the past records of data.

V. Conclusion

In this paper, we have focused our study to determine the System Reliability for the model of mixed series and parallel configurations. For Reliability Analysis we make use of the Poisson distribution and we can apply this model to any type of Roadways involving series and parallel connections in order to determine their Reliability for the purpose of road safety and preventive measures to avoid accidents.

References

1. L.S.Srinath, "Reliability Engineering" 4th Edition, East-West Press, Private Limited, New Delhi 2003.
2. M.Reni Sagayaraj, A.Merceline Anita, A.Chandrababu, S.GowthamPrakash, Markov Model in System Reliability with Applications, International Journal of Innovative Research Development , ISSN 2278-2011, Issue Nov-14, vol-3.
3. MarvianRausand, ArnljotHolyland.,2004 "System Reliability Theory-Models and Applications", 2nd Edition, John Wiley and Sons, Inc., Hoboken, New Jersey, USA, ISBN 0-471-47133-X.
4. Milton. J., and Mannering. F., 1998, "The relationship among highway geomentrics, traffic related units and motor vehicle accident frequencies",Transportion, 25(4), pp.395-413.
5. SujathaInginshetty "Analysis of traffic Accident Frequency and Reliability Using Appropriate System Reliability Model - A Simulation Approach", International Journal of Statistika and Mathematica, ISSN: 2277-2790 E-ISSN: 2249-8650, Vol 4 Issue 3.