MODEL FOR THE FAILURES ANALYSIS WITHIN THE LOGISTIC PLANNING MANAGEMENT

Lt.col.eng. Gheorghe NEGRU*, Ph.D.
MU 02512, Bucharest

The paper presents a model for the failures analysis as well as its application in a study case regarding the logistic planning management.

Keywords: Reliability, logistic planning, maintenance

Maintenance as part of the management of logistic support planning represents a combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to a state in which it can perform the required function or combination of functions which are considered necessary to provide a given service.

This concept enables the following classification of the maintenance actions:

- actions oriented to retaining the technical and operational capabilities of a system;
- actions oriented to restoring the technical and operational capabilities of a system.

Retaining and restoring represent different types of actions which are objectified by the preventive and corrective maintenance. Based on these criteria, the European Union’s standard for maintenance presents a series of maintenance types according to figure 1.

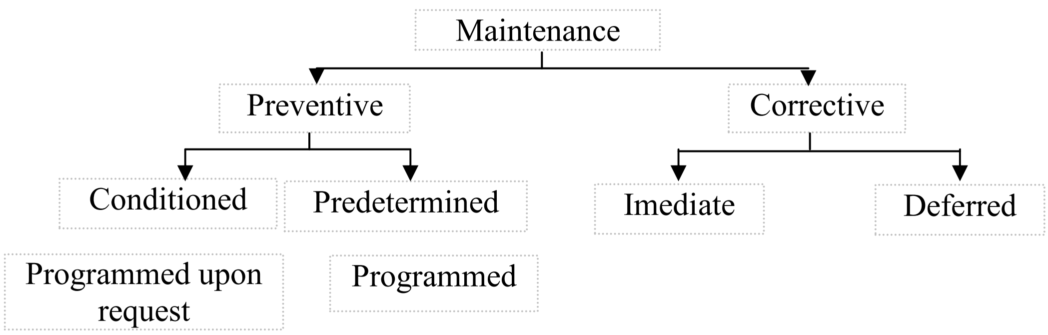

Fig. 1 *Maintenance types according to EN 13306: 2001*

* e-mail: *gnegru@acttm.ro*

Basic Functions for the Failure Models

The followings basic functions will be taken into consideration regarding the systems/equipment failures:

Table 1

Values significance

Value	*Significance*
f(t)	Failure probability density function
F(t)	Failure probability distribution function
R(t)	Reliability function
$\lambda(t)$	Failure rate

The basic functions are given by

$$f(t)=R(t-1)-R(t), \quad 1)$$

$$\lambda(t)=f(t)/R(t-1) \quad 2)$$

$$F(t)=1-R(t), \quad 3)$$

Transforming previous basic functions of discrete time intervals into probability functions in continuous time, we can define them as follows:

- *R(t) is* the probability to function until time *t*.
- $\lambda(t)dt$ is the failure probability in the interval [*t, t+dt]* assuming that the equipment functions until time *t.*

Thus [1]

$$\lambda(t)dt=f(t)dt/R(t) \quad 4)$$

where *f(t)dt* is the probability of failure in the interval [*t, t+dt]*, with *f(t)* as failure probability density function.

[1] Adolfo Crespo Márquez, *The Maintenance Management Framework*, Springer-Verlag London Limited, 2007.

The failure rate is given by:

$$\lambda(t) = f(t)/R(t) \qquad 5)$$

Taking the integral in equation 1, in the interval **[***0,t***]**, the following will be obtained:

$$\int_0^t f(t)dt = 1 - R(t) \qquad 6)$$

Taking derivatives in equation 6, we will obtain [2]:

$$f(t) = \frac{-dR(t)}{dt} \qquad 7)$$

Replacing equation (7) in equation (5), the following is obtained:

$$-\lambda(t) = \frac{dR(t)}{dt}\frac{1}{R(t)} \qquad 8)$$

Taking the integral in equation (8) it is obtained:

$$-\int_0^t \lambda(t)dt = \int_1^{R(t)} \frac{dR(t)}{R(t)} \qquad 9)$$

The integration limits of the failure rate are between 0 and *t*, while 1/*R(t)* is integrated with respect to *R(t)*, and therefore when *t*=0, *R(t)*=1, and in *t* the reliability is *R(t)*.

Taking the integral in equation 9 it is obtained:

$$-\int_0^t \lambda(t)dt = \ln R(t) \Big|_1^{R(t)} = \ln R(t) - \ln 1 = \ln R(t) \qquad 10)$$

Thus [3]

$$R(t) = \exp\left\{-\int_0^t \lambda(t)dt\right\} \qquad 11)$$

In case we have a constant failure rate over time, *i.e.* the failure has a totally random behavior, given by:

$$R(t) = e^{-\lambda t} \qquad 12)$$

[2] *Ibidem*
[3] *Idem.*

Study Case

Input Data

A logistic support structure deployed within a theatre of operations, conduct missions with five identical trucks purchased at the same date and entered into the inventory at the same date. After approximately 10 months the failures analyses of the trucks is conducted. It was observed that some rubber components belonging to the engine had a significant number of failures. These are presented in table 2.

Table 2

Rubber components failures

Month	*Truck 1*	*Truck 2*	*Truck 3*	*Truck 4*	*Truck 5*
1		Failure		Failure	
2			Failure	Failure	
3					Failure
4	Failure	Failure		Failure	Failure
5			Failure		
6			Failure		
7	Failure		Failure		
8		Failure		Failure	Failure
9					
10	Failure	Failure			

Output Data

Based on the failure model basic function, the reliability level of the rubber components belonging to the trucks engines of the logistic support structure will be assessed.

The following flow will be applied:

- assessment of the failure probability distribution/function;
- assessment of the failure rate for the rubber components;
- graphic representation of the failure model basic functions.

The estimations resulted regarding the failure probability distribution function as well as the failure rate for the rubber components is shown in table 3. The results belonging the table 3 were obtained based on the data from the table 4. Table 4 is obtained form table 2 by grouping the failures from the data base according to the estimated life time of the rubber components. In this study case, according to the producer recommendations, the rubber components could be in the followings situations:

- Period 1: functioning reserve is 90%;
- Period 2: functioning reserve is 70%;
- Period 3: functioning reserve is 50%;
- Period 4: functioning reserve is 30%.

The distribution of rubber components over these time periods is made according to the number of functioning hours registered in the technical documents of the trucks.

Table 3

Obtaining the basic functions values

Life time period of the rubber components	*f(t)*	*F(t)*	*R(t)=1-F(t)*	*λ(t)= f(t)/R(t-1)*
Period 1	6/18=1/3	1/3	12/18=2/3	1/3
Period 2	3/18=1/6	1/2	9/18=1/2	1/4
Period 3	5/18	7/9	4/18=2/9	5/9
Period 4	4/18=2/9	1	0	1

Table 4

The number of the failures/truck during the life time

The number of the failures/truck during the life time. Assumption: there is the same type of failure cause						
Life time period of the rubber components	*Truck 1*	*Truck 2*	*Truck 3*	*Truck 4*	*Truck 5*	*Total*
Period 1		1	2	2	1	6
Period 2		1	1	1		3
Period 3	2	1	1		1	5
Period 4	1	1		1	1	4
						18

The details for the *F(t)* calculus (according the data from table 2) are shown within the table 5.

Table 5

F(t) calculus

	Period 1	*Period 2*	*Period 3*	*Period 4*
Failures number	6	3	5	4
Cumulated failures number	6	9	14	18
F(t)	6/18=1/3	9/18=1/2	14/18=7/9	18/18=1

According to the data presented in the table 3, Figure 1 contains the graphic presentation of the functions *f(t)*, *F(t)*, *R(t)*, *λ(t)*.

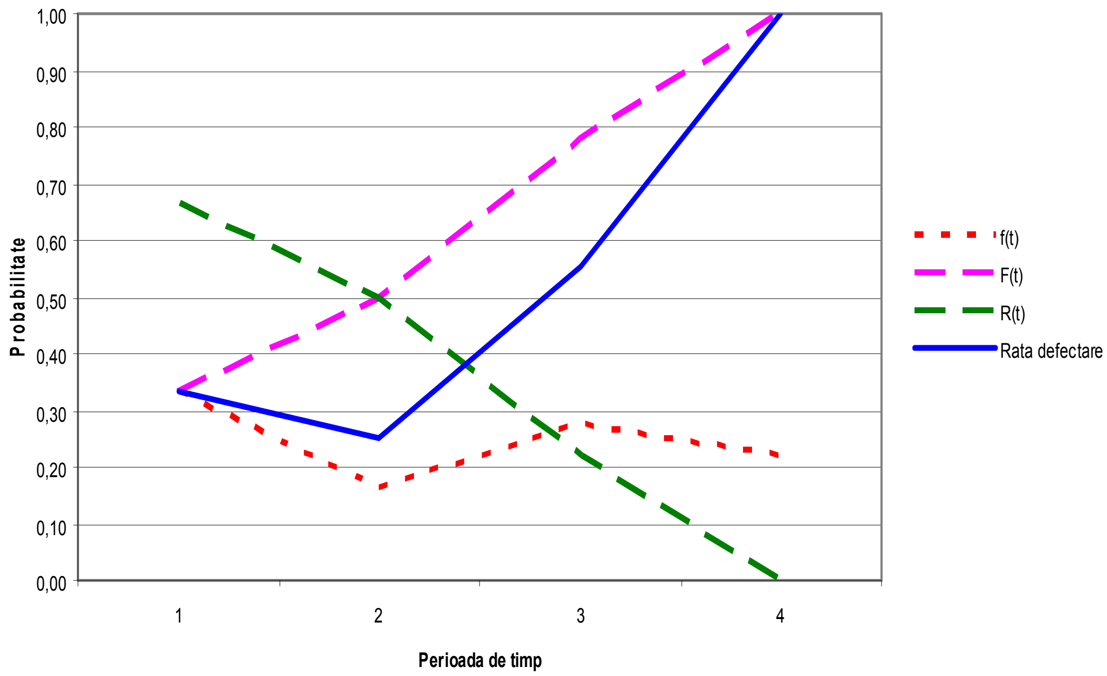

Fig. 2 *Failure model basic functions*

Resulted Interpretation

According the calculus made and graphic presentation in figure 2 the followings were identified:

1. The value of failure probability distribution function, *F(t),*is high due to the predominance of the rubber components belonging to the 3rd and 4th period which are at the limit of normal functioning cycle.

2. The reliability of the rubber components, *R(t*), is extremely low which is confirmed by the above mentioned observation.

3. The failure rate, *λ(t),* at the rubber components level is high which represents a confirmation for the values obtained for *F(t)* and *R(t).*

Conclusions

The study case emphasized the utility of the basic function of the failure model within the logistic planning management. These enable a precise identification of the subsystem/components which could influence the level of the complex technical systems reliability as well as their operational status. In the current budgetary constraints, it could constitute an efficient support in order to justify the maintaining/discontinuing of a technical system.

BIBLIOGRAPHY

Barlow RE, Hunter LC, *Optimum preventive maintenance policies. Operations Research,* 1960.

Barlow RE, Hunter LC, Proschan F, *Optimum checking procedures.* Journal of the Society for Industrial and Applied Mathematics , 4:1978-1095, 1963.

Duffuaa SO, *Mathematical Models in Maintenance planning and scheduling*, in Ben-Daya M, Duffuaa SO, Raouf A (eds.), Maintenance Modeling and Optimization, Kluwer, Boston, USA, 2000.

Duffuaa SO, Raouf A, Campbell JD *Planning and control of maintenance systems: modeling and analysis*. Wiley, NY, 1999.

Woodhouse J, *Managing industrial risk.* London: Chapman Hill, 1993.

Woodward DG, *Life cycle costing theory. Information, acquisition and application.* International Journal of Project Management, 15(6): 335- 344, 1997.