JOURNAL
OF
APPLIED
QUANTITATIVE
METHODS

HUMAN RELIABILITY MODELING

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ABSTRACT:

As the complexity of reliability systems grew, they became increasingly dependent on the human factor. Major disasters like the one at Three Mile Island, the Challenger ship, Chernobyl, nuclear power plant accidents, aviation, industrial disasters, etc. have been attributed to the human factors. Hence the need to study the reliability of the human factor as a distinct element of the reliability of the technical and economic systems. After some conceptual clarifications, we are investigating the state of knowledge in the field of human reliability. The literature provides as usual solutions, description and calculation errors, mainly, Goel-Okumato models of class time-domain and time-domain class, where the most notorious is the model Jelinsnski-Moranda, both inspired by the reliability of the software. The study presented in this material, the suitability of a statistical model is able to capture, process, and faithfully carry out human error in "man-machine" system. The application is based on the data recorded from the testing human operators in the management of complex technical systems. Through generalization, the process can be extended to other complex systems such as "man-machine".

Key words: *errors, reliability, human factor, modeling, man-machine system.*

1. INTRODUCTION

It seems surprising but, as the complexity of electronic products increases, protection methods and control systems, are less prone to errors, especially human ones. Major events, some with catastrophic consequences, are becoming increasingly common. Most likely they are due to human errors.Recalling just a few (not mentioning those generated by natural disasters, or the mundane, such as car accidents): the sinking of the Titanic (14-15.04.1912) generated by a navigation error, the teaching profession with 1514 deaths; in July 1915, the SS Eastland, a cruise vessel was capsized while docked in the port of Chicago, 2,500 people were on board, and844 of them, as well as the crew, died; the power outage in the United States (9.11.1965) has affected over 30 million people (7 States) in the U.S. and parts of Southern Canada- caused by a trivial loss relay, achain connecting a wide range of national grid power supply was wrongly operated; in Bhopal, India, on December 2nd – 3rd1984, there was a serious industrial accident resulting in over 15,000 victims and over 500,000 people directly affected, generated by the release of over 45 tons of cyanide gas derivative in the atmosphere from a botched maneuver ; the Chernobyl nuclear accident on April 26th, 1986, was caused by poor management of a test, and , more recently, because of a human vessel negligence Costa Concordia was wrecked on the rocks (January 12, 2012); in 1987, the passenger ferry "Dona Paz" clashed with the tanker "Victor", in the Philippines, both ships sinking in an area full of sharks. Only 26 people have managed to survive. The sinking of the Haitian vessel Neptune, on February 16th, 1993 (800 dead and about 500 missing which have never been found), the ferry-boat Estonia, on September 27th, 1994 (837 dead), the ferry-boat Bukoba, on May 21st, 1996 (700 dead), the ship Le Joula, September 26th, 2002 (1.863 dead) and the ferry Al-Salam Boccaccio, on February 2nd, 2006 (1,000 dead). The plane crash on February 6th, 1958 in Munich, a disaster in which the players of the Manchester United team were involved , crashed on the runway during take-off, being almost entirely destroyed. The device tool-off in Belgrade, with 44 people on board, and had stopped at Munich to refuel. On March 27th, 1977, two Boeing 747 full of passengers collided on the runway in Tenerife, and 538 people died on the spot. In 1996 in India the largest collision in the air took place. A cargo plane from Kazakhstan collided with a Saudi Arabian passenger aircraft on top of Haryana. 349 people, from both devices, died. The accident happened due to an error of the cockpit.The latest air crash, produced in Russia (10 April 2010), decimated the political elite of Poland. In the accident which took place in strange conditions, the Polish President Lech Kaczynski, his wife and 94 other officials from the Polish political environment have lost their lives.The Tupolev-154 plane crashed into a forest near Smolensk in Western Russia, less than 19 kilometers from Katyn forest. And this at the 70th anniversary of the massacre of 22,000 Polish officers by the Russians during World War II. In Romania, the biggest naval tragedy occurred on 10 September 1989, when boat Mogosoaia sank in the vicinity of Galaţi. 215 people were killed then. The disaster at Certej (Romania) took place on Saturday, October 30th, 1971, due to the breakage of the mountain dike slipping in the tailings management facility of the Certej mine exploitation, in Hunedoara County. The dike broke over a width of 80 meters from the pond and within minutes, 300,000 cubic meters of sterile were expelled..Sterile acid waves ate in a quarter of an hour and destroyed six blocks of dwellings with 25 apartments each, a dorm with 30 rooms, numerous other dwellings. The disaster caused about 100 deaths and many were seriously wounded . In January 30th, 2000, a Lake dam near Bozânta (Romania) gave away tospillings of 100,000 cubic meters of cyanide contaminated water (approximately 100 tons of cyanide) over fields and the local river basin system. Five weeks later, another leak, this time with heavy metals, hit the region. A levee gave way in Baia Borșa (Romania) and 20,000 cubic meters of water contaminated with zinc, lead and copper have been discharged into the River Tisa, up to the Danube. An overwhelming majority of the casualties were due to human errors. A whole decade's worth of methods and design of reliability have been focused on the technical part (design, raw materials and processing). Frequent accidents and disasters are proof of this flawed approach. In dealing with reliability, the persistence of a close approach of technical elements is imposed. The reliability of modern systems of production, management, socio-economic macro-systems significantly depend on the measure of the reliability of the human factor. Usually, in the situation where reliability is inadequate technique, the human factor is considered an aggravating element of system status and to a lesser extent improver reliability. The major goal of the reliability of the system "technical-human operator" must be to reduce errors. The human factor may be non-agent, but reliability and dependability are. "Live broadcast" of the human element of the procedures, methods and indicators used in describing the reliability of technical systems is risky and has limited values, since "human" behavior is distinct from that of technical systems.

2. HUMAN ERROR AND RELIABILITY

As a rule, when we talk about the reliability of the human factor we consider either the human as being a partner of a complex technical system, or as the human operator integrated in the socio-technical system created by himself. In this case, the human factor is often regarded as a "non-secure" element, generator of non-reliability and less like keeper (or recovery) of the reliability of the tandem "man-machine". Human reliability is defined – according to Neboit et al. Al. (1990) as the probability that an individual, a team or an organization (human) to carry out a mission within the limits of the data, the conditions needed for a certain period of time. The main difference of this wording – from classical reliability (technical) – lies in the extension references from individual to team and defines the limits of acceptability. The latter term, however, is quite vague: it is understood that we can talk about the reliability of the human factor in a situation where "circumstances" have certain limits (noise variance) acceptable for individual, team or organization.

All Neboit et al. say, in the article cited above, is that there are two approaches concerning the reliability of the human factor, namely:

- ✓ The traditional version, which aims to determine the human operator error probabilities,the emphasis being placed mainly on non-performance of these operators, human factors suspected of being at the origin of faults in the system; technical system and the behavior of the human factor are considered to be very similar and this is why this approach does not take into account the management aspect, the fact that human factors can (often) prevent deflection of the functioning of the system, as well as that of correcting its own errors;
- ✓ The modern version, which sees man as part of the tandem, "technical system-the human factor", so as to improve the reliability of the vector system and as a non-reliable source; This approach considers that there is a clear distinction between errors of action (decision) and the cognitive in nature (stemming from shortages of knowledge). The first official European settlement in this area is from 1986 (Embrey, 1987) by the European Economic Community (EEC) adopted the following definition: "the body of knowledge relating to the analysis, prediction and reduction of human errors, centering on man's role in the design, operation, maintenance and operation of the system."Reliability approach was first in the technical field. Thus, as shown Blischke and Murthy (2000, p. 285): "Basic definitions of reliability and of most of the terms used in the analysis have appeared < acceptance of hardware >. A significant portion of these terms was transferred to study the reliability of the software, but the concepts are often interpreted differently and there is no unanimity in terms of their significance in the context of software. In reality, the opinions vary enormously – many authors consider that the definitions, concepts and models of reliability of hardware can be transposed directly (or with minor changes) in the case of software, while others considered that the idea of rate in the case of software failures does not make sense ".

Gradually, along with the evolution of computers, software reliability was established as a separate branch of the reliability in the broadest sense. Reliability software evolution continued and became a new area of study in the field of computer security (Leveson,1995).

In the development of software reliability research on evolution has been spectacular, of the most frequently cited contributions, let us mention: Nelson (1978), Govil (1984), Jelinski & Moranda(1972), Blischke & Murthy (2000). The evolution of the research to the regulations through standards like IEEE STD 730/1989: Standard for software quality assurance plans, IEEE STD 1044/1993: Standard for classification of annomalies software. IEEE STD 1059/1993: Guide for software verification and validation plans.

Gradually, researchers' attention was directed to the non-availability, source and tried to separate the approach, evaluation of reliability of technical system (car) to the human factor, is now being a new field of research – human reliability (HR). To quote and contributions from limbo, we recall the works of: Mihalache (1995), Iosif (1996), Isaic-Maniu &Voda (2002), Nitu (2009), Costea (2005).After numerous catastrophes, nuclear and aviation in particular, distinct research directions have been developed, concerning human identification, reliability modeling and preventing errors which generate such accidents (Swain & Guttman (1983), Cappelli,M., Gadomski,A., Sepielli, M.(2011), Dhillon ,B(2009). For example, the top 10 nuclear accidents indicate human factor errors as agravator element of the incidents turning disaster accidents (Idaho, SUA-1961, Jaslovske Bohunice, Slovacia-1977, Tomsk, Rusia-1993, Tokaimura, Japonia-1999, Fukushima, Japonia-2011, Chalk River, Canada-1952, Windscale Pile, Marea Britanie-1957, Three Mile Island, USA-1979, Kyshtym, Russia-1957, Cernobil, Ukrain-1986).

As a result, the human resources management plan were bolstered research in the field of risk evaluation and impact behaviour of human errors in managing incidents. In the 1970s, studies on the safety of the air traffic system indicated that human error had contributed to approximately 90% of incidents of air traffic management (Kinney &,1977). According to some, as the degree of automation and computerization of flights increases, the human factor becomes aggravating factor of safety compared to the less automated devices (Bowers, Deaton, Oser, Prince, Kolb, 1994; Lee, Moray -1994; Jones-1999, Senders & Moray-1991). The variability of human behavior is more than a technical system and occurs as intra-individual variability (generated by various factors such as stress, fatigue, attention, etc.) as well as intra-team variability, resulting from the combination of these individual or intra-organization variabilities. Tthe study and management of human errors (Parry1996) was thus formed, while still a branch of scientific research. When an individual or a team loses the ability to perform the functions required under specified conditions, then we are dealing with human error. A classification of the possible errors that may occur in the process of the interaction between man and a technical system errors by omission – which arise from failure to perform all phases of the tasks (missions); runtime errors - which occur through non-compliance with procedures; sequencing errors generated by breaking the order of operations;delay-induced errors of late execution of an operation. Obviously there are various specific errors, such as, programmers having syntax, semantic, logical or plain errors. It must be stressed that an error is not always synonymous with failure: a human operator can make the case for one or more errors, without it involving compulsory system loss.

An equivalent term "falling" (especially technical systems) viability theory, generated by a falling human error is the undesirable event, which can be graded according to its effects as incident, crash, and catastrophe.

Reliability analysis of socio-technical systems requires a clarification of human error sources and their limitations. Human error sources are found in the multitude of factors that determine the behavior of the people. Addressing human errors is mainly done in two directions: the psychological and management with ergonomic-applicability in the various types of technical and economic processes.

From the psychological point of view, the error can be defined as an offense or is not carried out as a function of purposeful intention. This approach is supported by the analysis of the cognitive mechanisms of generating various types of errors, internal and external conditions facilitating production errors. Among the remarkable psychological approaches to human error we can mention: Hollnagel (1998), a special type of presence, cognitive errors.

The notion of cognitive error was introduced by Tversky & Kahneman (1981) in 1972 demonstrating that in many cases the judgment and human decision deviates from the theory of "rational choice". Joseph (2010) performs a version of classification and description of cognitive errors and similarly carried out another classification criterion of human interaction after operator and technical system, Hollnagel (1998) focuses on the analysis of human error, and Wilson (1993) developed a methodology for the analysis of human error. In the area of managerial errors approach we recall the work of Mihalache (1994), a collection of essays titled "Chance to fail", which captures, in an original manner, human reliability issues, reviewing it in terms of its relationship with technology. He believes that reliability is a "Science of systems degradation laws, independent of their nature". The concept of reliability is "failure", defined by the author as the top "when at least one of the system's performance stands out of the allowable values. In the light of the definitions, the "people", as well as their relationship with the "machine" represents a failure of the source of any flexible manufacturing. Grabowski and Roberts (1996) develop human errors related to major socio-technical systems, while Reason (1990) fundamentally covers the issues of human errors, Iosif & Marhan (2005) explore human-computer interaction from the standpoint of human errors, and Wiegmann & Shappell (2003) examine the issue of human error in aviation accidents.

3. ECONOMETRIC MODELING OF HUMAN RELIABILITY (RH)

The concepts, definitions and reliability modeling appeared and developed in technical systems, or how Blischkeand & Murthy (2000) define as „the context hardware”. The approach splits software reliability from human reliability. Between the two big branches of reliability (H & S) there are numerous distinctions (Table 1 presents some of them).

Major differences between the reliability of the H and S

Table 1

DIFFERENCES BETWEEN RELIABILITY	
Hardware (H)	Software (S)
1. Design and production have an essential role in achieving a certain reability	1. The design almost exclusively determines reliability
2. Failure can be described and explained by causes (laws) of the physical - chemical properties	2. There are in this case such laws
3. The actual causes of failures are numerous and can be found in the project, execution mode, the maintenance activity or improper operation	3. Power failures are due almost exclusively to design deficiencies
4. Maintenance, if executed correctly, improves reliability	4. "Reprogramming" eliminates some errors, but it can be the source of new errors
5. Redundancy can increase reliability.	5. Redundancy may have a null effect
6. Currently uses standardized components	6. There are no such components
7. The interface is done with physical structures of the same type	7. The interface is conceptual only
8. Sometimes the design uses quotients of tolerance limits	8. There are no such coefficients in systems programs
9. A minor flaw may have a negligible effect on the reliability (or not affect it at all)	9. Even a "bit" can block the whole system of programs.

Practical requirements imposed, to settle, and the research literature offers today's profile on a wide range of statistical models for analysis and prediction of human reliability. To summarize, we present some of the most popular models of reliability, with mention of their essential properties.

- *Generalized exponential model*

  As it is well known, the exponential distribution is obtained from the classical relation:

$$f(x) = z(x) \cdot \exp\left\{-\int_0^x z(u)du\right\} \quad (1)$$

By choosing substitutes $z(x) = \theta \rangle 0$ (constant) leads us to the density:

$$X : f(x) = \theta \cdot \exp\{-\theta x\}, x \geq 0, \theta \rangle 0 \quad (2)$$

Exponential random variable has the specific feature $CV(X) = 1$ because $E(X) = \frac{1}{\theta}$ question $Var(X) = \frac{1}{\theta^2}$.

Distribution function is $F(x)=1-e^{-\theta x}$ and the reliability, $R(x)=e^{-\theta x}$.

When the order is centered $2/\theta^3$ while the order IV, $9/\theta^4$. In these situations, the coefficient of skewness is $\sqrt{\beta_1}=2$, and the excess coefficient, $\beta_2=9$.

• *Goel – Okumato Model* (1979) assumes that the error can be removed even without having to remove the latent error which caused the system to malfunction.

The number of failures does not coincide with the number of errors removed. The likelihood of an error to be deleted is smaller than 1, and will be boted *p*. Process failures is considered separately as the elimination of errors.

If we note with $M_d(t)$ the number of failures in the range (0,t), the initial number of errors (which, in this case, is no longer equal to the number of errors removed) and the number of remaining errors no longer satisfy the relation:

$N=M_d(t)+N(t)$,but the relation:

$$N=M_c(t)+N(t) \quad (3)$$

where: $M_c(t)$ is the number of errors removed in the range (0, t)

Either $P_r(t)=P[M_c(t)=r]\rightarrow$ distribution of the number of errors removed (0, t).Mathematically, the result is that this distribution is an exponential distribution, of the form:

$$\mathrm{P}_r(t)=C_N^r\left(e^{-p\Phi t}\right)^{N-r}\left(1-e^{-p\Phi t}\right)^r \quad (4)$$

with $\mathrm{r}=1,2,\ldots\ldots\mathrm{N}$

It is observed that $e^{-p\Phi t}$ is the probability that a latent error may not be corrected in (0,t), and $1-e^{-p\Phi t}$ is the probability that a latent error to be corrected within is the probability that a latent error to be corrected within (0,t).

So the distribution parameters are: N şi $1-e^{-p\Phi t}$. The average number of errors removed in the range (0, t) is:

$$H_c(t)=N\left(1-e^{-p\Phi t}\right) \quad (5)$$

In the expression of the distribution, the number of errors corrected is, easily, the distribution of the number of errors remaining:

$$Q_k(t)=P\left[N(t)=k\right]=C_N^k\left(e^{-p\Phi t}\right)^k\left(1-e^{-p\Phi t}\right)^{N-k} \quad (6)$$

It is observed that the number of errors remaining is distributed with a binomial parameter N and $e^{-p\Phi t}$. As a result, the average number of errors remaining in the range (0, t) is:

$$M_{N(t)}=Ne^{-p\Phi t}. \quad (7)$$

The probability at time *t* the number of errors remaining will be less than or equal to the default value is:

$$P\left[N(t)\le A\right]=\sum_{k=0}^{A}Q_k(t)=\sum_{k=0}^{A}C_N^k\left(e^{-p\Phi t}\right)^k\left(1-e^{-p\Phi t}\right)^{N-k} \quad (8)$$

The likelihood that all errors may be corrected (A = 0) in the range (0, t) is:

$$Q_0(t)=P\left[N(t)=0\right]=\left(1-e^{-p\Phi t}\right)^N \quad (9)$$

The last relationship you can calculate the required test time so that, with probability, the system does not contain any error:

$$t_{Q_0}=\frac{1}{p\varPhi}\ln\frac{1}{1-Q_0^{1/N}}$$

The average time to remove all the errors:

$$D=\frac{1}{Np\varPhi}+\frac{1}{(N-1)p\varPhi}+\dots\dots\dots+\frac{1}{p\varPhi} \quad (10)$$

As I pointed out, the number of failures M_d (*t*) in (0,t) is equal to the number of errors in this range and is greater than the number of errors corrected $M_c(t)$ at the same time (0,t).

- *Jelinski-Moranda Model*. The assumptions of this model (Jelinski-Moranda-1972) are the following:
  - The time intervals between successive failures are treated as random variables;
  - Failures rate is proportional to the number of errors and depends on time;
  - At each fall is running a proper action of negligible duration, which removes the error generating this fall.

In the interval between the falls i-1 and i, the number of errors is $N(t)=N-i+1$ and the density of probability range attached X_i it is – in the model J-M:

$$f_i\left(x_i|N,\theta\right)=(N-i+1)\theta^{-1}\exp\left[-(N-i+1)x_i/\theta\right] \quad (11)$$

where : θ is the parameter function.

There have been attempts to improve this model by introducing hypotheses on the distribution of the errors. Thus, for example, Schick and Wolverteon (1978) found a distribution of exponential type and Blischke & Murthy (2000) a Weibull-type, and Isaic-Maniu and Voda (2002), Costea (2005) they rebuilt the model for behavior after an exponential distribution errors overall. In this latter case the shape is:

$$X:\mathrm{f}(\mathrm{x};\theta;\mathrm{k})=\frac{k}{\theta^{1/k}\Gamma(k)}\exp\left\{-x^{k/\theta}\right\},\ \mathrm{x}\ge 0,\theta,\mathrm{k}\ge 0 \quad (12)$$

A form that, for k = 1 leads to a classic exponential, while for k = 2 semi-normal, so the form attached to the interval becomes:

$$f_i\left(x_i \middle| N,\theta,k\right)=\frac{k\cdot\left(N-i+1\right)^{1/k}}{\theta^{1/k}\Gamma\left(1/k\right)}\cdot\exp\left\{-\left(N-i+1\right)x_i^k\ /\theta\right\} \quad (13)$$

Note that for k=1 version (13) the mdel becomes J-M, the density given in (11). In Tolle (11), $\Gamma(*)$ is Euler's Gamma function.

In version (13) of the model and the reliability of the human factor appears as a process of renewal with the failure rate descending: each failure (generated by a human error) this rate decrease, so it eliminates the sequentially one error (not repeating the same assumptions errors). Goel-Okumoto-model is in the class called "time-domain" which is based on the idea of attaching the reliability of the human factor, reliability system and differ from time-domain-class "or its main content errors. Of the same class of models are homogeneous Markov models:-heavy snowfall and describing their errors as being dependent on the "chain" of each other, Jelinski-Moranda model (1972) – which starts from the premise that errors occur randomly and that all have the same meaning and consequences on the reliability of the system, and that errors can be completely removed from the source with the Littlewood model (1996) effect - somewhat similar to Jelinski-Moranda, the difference being the manner of treating the error considered as having different importance and different system reliability track "man-machine". In short, about the characteristics of these models.

4. APPLICATION – THE ERRORS COMMITTED AT THE HELM OF AN AUTOMATED SYSTEM

Into a training center of a system of high technical complexity, the periodical training, the errors recorded by 9 employees - table 2 were presented.

The succession of major errors

Table 2

1	0	4	6	5	7	10
4	7	7	0	5	3	0
6	2	3	0	1	8	9
1	7	1	5	0	1	1
6	3	0	4	3	0	2
4	3	1	1	8	9	0
7	2	3	7	1	0	9
2	9	5	1	10	8	7
0	0	2	0	7	3	3
5	1	0	4	1	4	0
0	6	4	3	5	7	6
7	4	0	4	6	0	2
3	8	7	0	5	5	8
1	0	2	1	5	7	1
4	3	0	5	9	0	-

Processing through descriptive statistical indicators leads to the following results (table 3):

Descriptive indicators

Table 3

Statistic	**Value**	**Percentile**	**Value**
Sample Size	104	Min	0
Range	10	5%	0
Mean	3.625	10%	0
Variance	8.8774	25% (Q1)	1
Std. Deviation	2.9795	50% (Median)	3
Coef. of Variation	0.82193	75% (Q3)	6
Std. Error	0.29216	90%	8
Skewness	0.3657	95%	9
Excess Kurtosis	-1.0678	Max	10

Average errors committed: 3.63, with dispersion 8.9. Asymmetry and kurtosis series, as well as the significant difference between arithmetic average and median creates doubts over the possible normal distributions (Gauss) error, as it would be the first option. Any frequency distribution series of errors does not suggest a Gauss-type distribution (fig.1):

None of the classic patterns of errors (Goel-Okumoto, exponential, or Jelinski-Moranda) were confirmed through statistic testing.

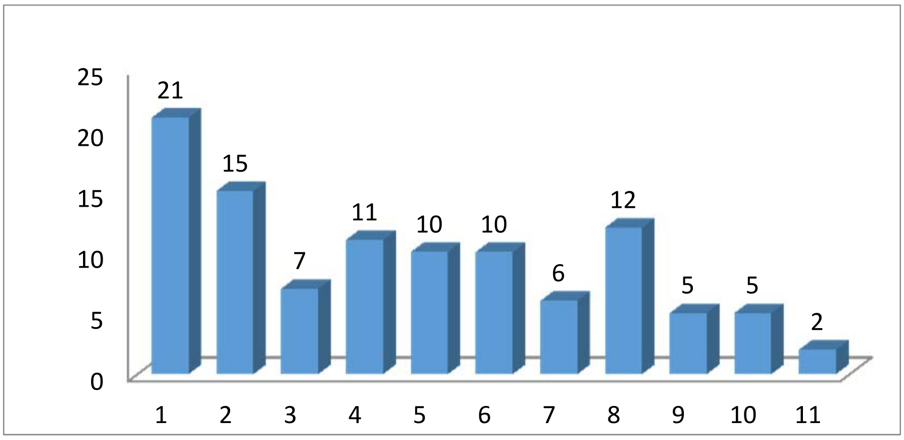

Figure 1: **Series histogram**

We use and test for confirmation χ^2. The null and the alternative hypotheses are:

- H_0: the data follow the specified distribution;
- H_1: the data do not follow the specified distribution.

The Chi-Squared test ($\chi 2$) is used to determine if a sample comes from a population with a specific distribution. Although there is no optimal choice for the number of bins (k), there are several formulas which can be used to calculate this number based on the sample size (N). For example, the data can be grouped into intervals of *equal probability* or *equal width*. The first approach is generally more acceptable since it handles peaked data much better.

- The application value of the $\chi 2$ test lead to computed:

$$\chi_c^{\ 2} = \sum_{i=1}^{k} \frac{(n_i - np_i)^2}{np_i} \tag{12}$$

where: $\mathbf{n}_i$ represent the experimental frequencies, **n** frequency and total, $\boldsymbol{p}_i$ – theoretical probabilities.

The resulting: $\chi 2_{calc.}$= 19.395,P-value =0.0035, and for α= 0.01- 0.2 critical value the computed value is exceeded, so the normal distribution assumption cannot be accepted. The *official* reason why people always assume a Gaussian error distribution goes back to something called the Central Limit Theorem. The Central Limit Theorem says that whenever a measurement is subject to a very large number of very small errors, the probability distribution for the *total* error is driven toward the Gaussian distribution. This is true regardless of the form of the original probability distributions of the individual errors. A proof - and it is a pretty one - can be found in any book on the theory of statistics. The *real* reason why people always assume a Gaussian error distribution is that, having made that assumption, we can then easily derive (and have derived!) exact mathematical formulae which allow us to compute directly the "best" values for the unknown parameters. This is not necessarily possible for other probability distributions. What would happen if, for instance, the error distribution for your data were not Gaussian? The fact is, with real data you don't know what the probability distribution of the errors is, and you don't even know that it has *any* particular mathematical form that is consistent from one experiment to another. Most likely, some formula like the Lorentz function - with a well-defined core and extended wings - is a more reasonable seat-of-the-pants estimate for real error distributions than the Gaussian is, because the Gaussian's wings fall off *very* quickly. As I said, we all know that two- and three-sigma residuals are far more common in real life than the Gaussian would predict. This is because a real observation is likely to contain one or two large errors in addition to a myriad of tiny ones.

Consequently, it was switched to other distributions to statistical hypothesis testing. Through successive tests were validated as a model of a Generalized Pareto Distribution.

Probability density function:

$$f(x,k,\sigma,\mu) = \begin{cases} \frac{1}{\sigma}\left(1 + k\frac{(x-\mu)}{\sigma}\right)^{-1-\frac{1}{k}} & k \neq 0 \\ \frac{1}{\sigma}exp\left(-\frac{(x-\mu}{\sigma}\right) & k = 0 \end{cases} \tag{13}$$

Cumulative distribution function :

$$F(x,k,\sigma,\mu) = \begin{cases} 1-\left(1+k\frac{(x-\mu)}{\sigma}\right)^{-1-\frac{1}{k}} & k \neq 0 \\ 1-\ exp\left(-\frac{(x-\mu}{\sigma}\right) & k=0 \end{cases} \quad (14)$$

Where:
k- shape parameter
σ- scale parameter (σ>0)
μ- location parameter
The variation of parameters:
$\mu \leq x < +\infty$ for $k \geq 0$
$\mu \leq x \leq \mu - \frac{\sigma}{k}$ for $k < 0$

Applied successively for validation, χ2 tests (relationship 12), Kolmogorov-Smirnov, Andersen-Darling. The tests to verify the hypothesis distribution, **Kolmogorov-Smirnov**, as follows: This test is used to decide if a sample comes from a hypothesized continuous distribution. It is based on the empirical cumulative distribution function (Fn). The empirical distribution function F_n for n observations X_i is defined as

$$F_n(x) = \frac{1}{n}\sum_{i=1}^{n} I_{X_i \leq x} \quad (15)$$

where $I_{X_i \leq x}$ is the indicator function, equal to 1 if $X_i \leq x$ and equal to 0 otherwise. The Kolmogorov-Smirnov statistic (D) is based on the largest vertical difference between the theoretical and the empirical cumulative distribution function:

$$D_n = \sup_x |F_n(x) - F(x)| \quad (16)$$

$F_n(x)$ where sup_x is the supremum of the set of distances. In practice, the statistic requires a relatively large number of data points to properly reject the null hypothesis. The P-value, in contrast to fixed α values, is calculated based on the test statistic, and denotes the threshold value of the significance level in the sense that the null hypothesis (H_0) will be The P-value can be useful, in particular, when the null hypothesis is rejected at all predefined significance levels, and you need to know at which level it *could* be accepted. The SDK calculates the P-values based on the Kolmogorov-Smirnov test statistics (D) for each fitted distribution.To confirm the decision has been applied and the **Anderson-Darling Test**.

This test procedure is a general test to compare the fit of an observed cumulative distribution function to an expected cumulative distribution function. This test gives more weight to the tails than the Kolmogorov-Smirnov test. The Anderson–Darling test assesses whether a sample comes from a specified distribution. It makes use of the fact that, when given a hypothesized underlying distribution and assuming the data does arise from this distribution, the data can be transformed to a Uniform distribution. The transformed sample data can be then tested for uniformity with a distance test). The formula for the test statistic A to assess if data $\{Y_1 < \cdots < Y_n\}$ (note that the data must be put in order) comes from a distribution with cumulative distribution function (CDF) F is

$$A^2 = -n - S\,, \tag{17}$$

where

$$S = \sum_{k=1}^{n} \frac{2k-1}{n} \left[\ln(F(Y_k)) + \ln\left(1 - F(Y_{n+1-k})\right)\right]. \tag{18}$$

The test statistic can then be compared against the critical values of the theoretical distribution. Note that in this case no parameters are estimated in relation to the distribution function F.

In the synthesis of the summary results of the fitting distribution table 1 is presented as follows (table 4):

The synthesis results **Table 4**

Statistical test	The value of the test statistic	Critical threshold value for α			P-value
		0.01	0.05	0.10	
Pearson's chi-squared test (χ2)	6.52	16.81	12.59	10.65	0.367
Kolmogorov-Sirnov	1.48	0.159	0.133	0.119	-
Anderson-Darling	0.11	3.91	2.502	1.929	0.165

Pareto distribution is known for optimum resource allocation purposes. Pareto parameter estimation problem of the distribution is treated by: Johnson & Kotz, Balakrishan (1994), Jantischi (2010), Arnold (2011), Popa (1999) and Singh & Guo (1995).

In case of application submitted, all calculations lead to only one conclusion: generalized Pareto model can be accepted.

The parameters of this model are the following:

k = - 0.5872
σ = 6.9771
μ = -0.77092

Applying the computed values of the parameters of the main function graphs are illustrated in Figure 2-5.

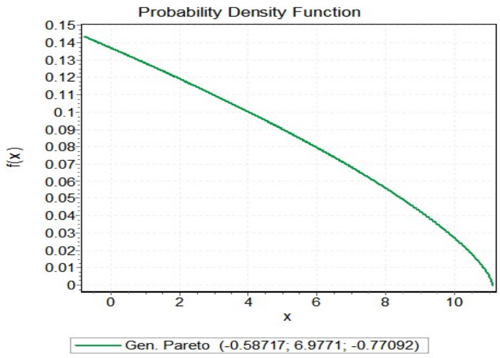

Figure 2

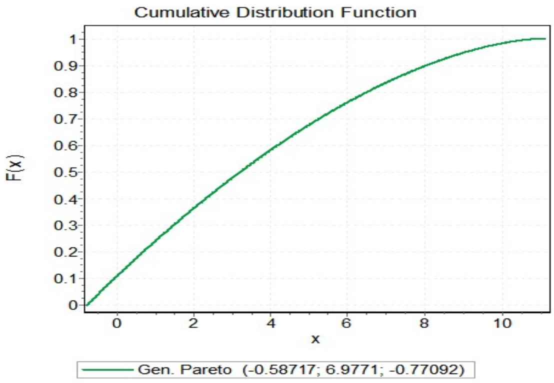

Figure 3

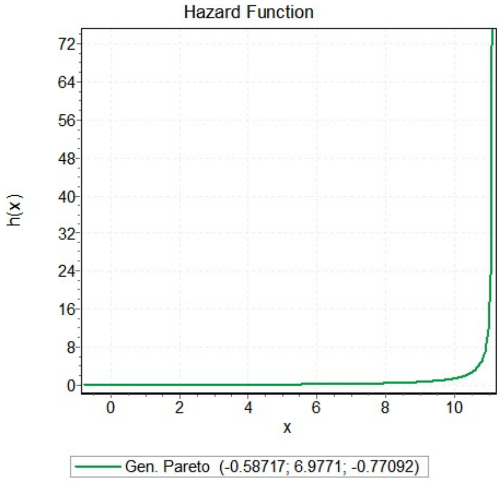

Figure 4

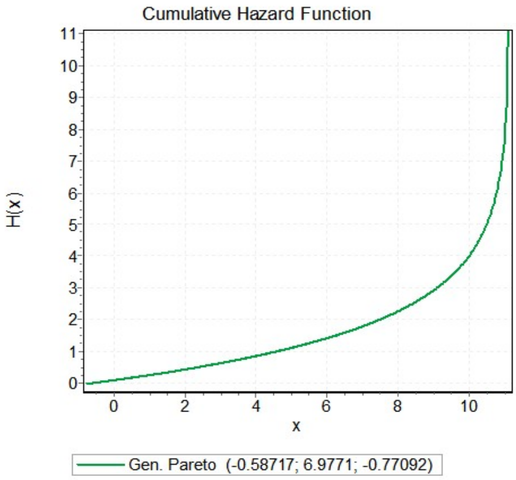

Figure 5

On the basis of indicators the estimated probabilities were determined based on a certain number of errors (table 5 include expected values of committing errors) in two assumptions (I1 and I2) determined by the values set for the x_1 and x_2 limits, these representing the number of errors that might occur.

The likelihood of errors (%) **Table 5**

Assumptions	Version A	VersionB	Version C	Version D
	$x_1=0$ $x_2=1$	$x_1=0$ $x_2=3$	$x_1 = 1$ $x_2= 5$	$x_1 = 0$ $x_2= 10$
P($x < x_1$)	10.79	10.79	24.03	24.03
P($x > x_1$)	89.24	89.24	75.97	75.97

P($x_1 < x < x_2$)	13.24	37.01	43.74	74.20
P($x < x_2$)	24.03	47.81	67.77	98.23
P($x > x_2$)	75.97	52.20	32.23	1.77

Experimental data indicate that the probability to register more than one error is almost 11%, and to register more than one error, but less than three is 37%. The likelihood that more than one error occurs is about 76% more than three errors, 52%, over five of 32 percent, while more than 10, 1.8% (Figure 6 shows the survival function).

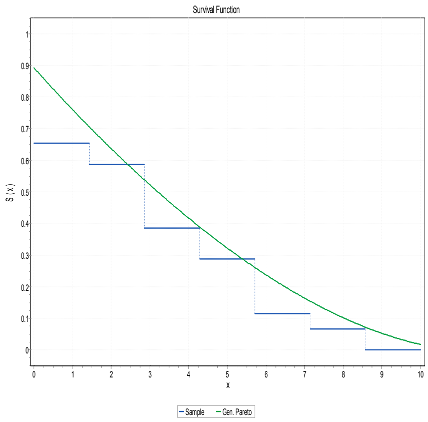

Figure 6. Survival function graph

CONCLUSIONS

The investigated literature indicates that in the recent years, of the many studies that have been carried out, some propose, on the one hand, to understand the nature of human error and the cognitive mechanisms that contribute to the production of various types of errors, and others, on the other hand, to make predictions, with probabilities as high over the chances of committing errors, and possible prevention.Moreover, resulting in the fact that the automated systems of error detection limits are important, given that, in fact, these machines cannot precisely identify the causes and motivations that guide the behavior of the operator.

The increasing interest both scientifically and practically, for the field of management of errors generated a powerful impetus for a new attitude to human error and to the role of human operator in control systems "man-machine".

The human operator can play, in some situations, a positive role in bringing a system to normal condition and at an optimal level of safety after making an error. All developments in the field of error management, and screening recovery methods have failed to keep up with research on the mechanisms underlying the production of human error.

A policy of "zero failure" – a major objective of safety – has been interpreted as meaning "zero error". Such an approach must factor in the fact that zero-errors is difficult to obtain, from a practical standpoint, because it ignores the existence of a large number of variabilities of the human behavior, and some types of errors are difficult to remove.

The case study presented, operators of a system of great complexity, in a process of training and testing, illustrate the frequency of errors in handling of perpetrating the system and may pose for upper management a guide over the chances of a fair system of managers.

Evaluations are more accurate in terms of identifying the adequate distribution that describes the type of error, and stochastic calculations allow not only reflection but also behavior and prediction of committing a certain type of error to intervene in limiting the generation managerial execution, both through further technical system protections, and by improving the training and selection of staff.

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