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Reliability Engineering Opportunities in Industry 4.0

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ABSTRACT

Industry 4.0 is based on the internet of things, this means, that in industries or companies the value chain, including processes, products, hardware, and software, among others, exists the necessity to implement new knowledge technologies to implement and control Industry 4.0 interactions, in other words, with the advantages of industry 4.0 such as the used of real-time data, big data, blockchain, human-machine interaction, cyber-systems, among others, the electronic devices that allowed this interaction and electronic data interchange centralize, need to be in the highest possible reliability perform, aiming to be able to carry out all these activities safely and effectively. In this research, the objective is to introduce some general advantages of Industry 4.0 and how reliability engineering is an important ally in the performance of the functions of Industry 4.0. Then, this manuscript presents the necessary knowledge and applications of reliability engineering that can be implemented in Industry 4.0 as stress-strength analysis in the case of equal shape parameters $\beta_{s=}\beta_S$; stress-strength analysis $\beta_{s\neq}\beta_S$; Nonnormal capability index and Weibull Capability index, by using Weibull++ Software and mathematical procedure. Another target of this research is to demonstrate that by using reliability engineering it is possible to have better control in such a way that efficiency and productivity stay and even can increases. Also, reliability engineering represents security and stable processes. Finally, with the merging of Industry 4.0 and reliability engineering, the making decision process is more reliable decision-making.

KEYWORDS

Reliability engineering, Weibull distribution, Capability process, Stress-strength, Robust sample size, Mechanical probabilistic design, Industry 4.0.

1. INTRODUCTION

Thanks to technological advances, each time more possible the connection between devices [1]. This is now capable of using internet protocols that allow systems, devices, and human resources, among others, the opportunity to process bid data quantity in real-time to perform in an efficient way the making decision process and information to operate each aspect of any company [2]. However, these advantages without high reliability or security in every process can even stop all companies or industries processes. Because of this is very important to possess devices like hardware, connections, software, etc. that can carry out the necessary operations, processes, and systems, in real-time and every time [3].

On the other hand, the adoption of the internet of things in companies took advances never seems before and is even so important that now this technology method is called the fourth industrial revolution [4].

Industry 4.0 introduces industries or companies to get more control over their processes, their products, human resources, the supply chain and logistics, including the final disposition of the products [5].

Moreover, the main issue is the development of infrastructure with physical systems and models to management in an easy way the industry 4.0 facilities [6]. This makes companies need to learn, understand and implement fasts this technology and be prepared for the progressive technology change and process transformation [7]. In this manuscript, the main subjects of Industry 4.0 are presented, like, as the internet of things, blockchain analysis, the big data adoption, among others.

On the other side, an objective of this research is to explain how reliability engineering can be adopt in Industry 4.0 in order to have a reliable device, connections, hardware, etc. this, using reliability engineering methods and tools, like, stress-strength analysis, Weibull analysis, capability index non normal, etc., [8]. In that sense, the use of engineering reliability methodologies presents a powerful option for companies to implement in Industry 4.0 with the object of measuring accurately both efficiency and productivity [9].

The structure of the paper is as follows. Section 2 presents the Industry 4.0; section 3 shows big data and block chain analysis; in section 4 reliability engineering in Industry 4.0 is presented; section 5 presents the generalities of Weibull distribution: in section 6 Reliability engineering method applied in Industry 4.0 is presented and presents the numerical applications; section 7 presents the conclusion and finally, references is present in section 8.

2. INDUSTRY 4.0 INTRODUCTION AND CONCEPT

Industry can be defined has the integration of information, technology, process, cyber systems, etc., with an interdisciplinary engineering facility and all coordinated into a seamless connect [10]. Then, Industry 4.0 demand more mobile connection technology [11]. On other hand, Industry 4.0 allows the manufacturing companies become digitized by built sensing devices or hardware in all manufacturing components, tools, final products and in process products [12]. Therefore, the Industry 4.0 concept, is not it's not as simple as it seems and can be used in a such a different contexts [13]. The terms that involve the concept of Industry 4.0 are defined as follow and the integration of this concepts together create a whole new system of capabilities for industries.

One of the concepts concern to the creation of smarts factory, connecting since individual productions, planning stages to physical development [14].

Another concept refers to cyber physical systems and the integration of internet or networks, physical controls processes are integrations of computation, networking, and physical processes (see Figure 1). Computers and networks monitor and control physical processes with continuous feedback [15].

However, the concept of Industry 4.0 until now is not universally, essentially, the term can be considered as the integration of cyber-physical systems into production, processes, devices, software, internet of things connection and services [16].

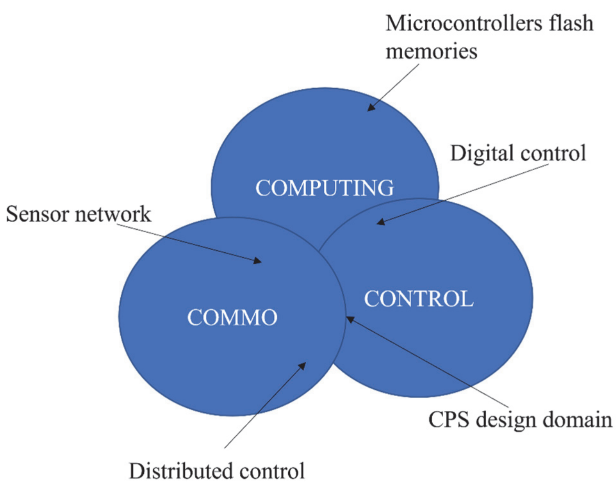

Figure 1: Cyber-physical systems representation.

3. BIG DATA AND BLOCKCHAIN

In this time, we live in a big data era, where, organizations, government, stores, among others, know a consider and increasing data items aspects that in previous times that aspects were considered private [17]. Moreover, electronic devices to transfers, collects, store and process information each time become more faster and cheaper, than technology advances affect companies and everyone in daily life [18].

The concept of big data even it is used continuously, there is not a unanimous definition. Big data is usually associated with a complex dataset which used special devices, tools and methods to performed data interaction that derive in better decision making process [19]. To be more specific big data presents five essential characteristics.

The first refers to the volume, this is, the data size, the quantity of data generate and the store of information, and has its named mentioned big data volume most be massive i.e., gigabytes, terabytes, petabytes and exabyte [20]. The second characteristic is variety, it is to say, the type of different data, as the structure of it. Big data ranges from audio, images, text, video and this can be structure, semi-structured or unstructured. Also, variety can refer about the sources where data was obtained, for example, social media, market devices, house devices, smartphone or another technology [21]. Third feature is the velocity in other words, the time needed to generate and process information. Information must stream quickly and the most possible to real time, that will generate a company advantage [22]. Fourth feature is the veracity, this is, data quality and reliability, something essential is possesses a way to detect errors, false or incomplete data [23]. Finally, the fifth characteristic is the value of data, i.e., value arises from the development of actionable information [24].

3.1. Blockchain

The blockchain is a database that can be shared by many users in a peer-to-peer manner and that allows information to be stored (see Figure 2) in an immutable and orderly manner [25].

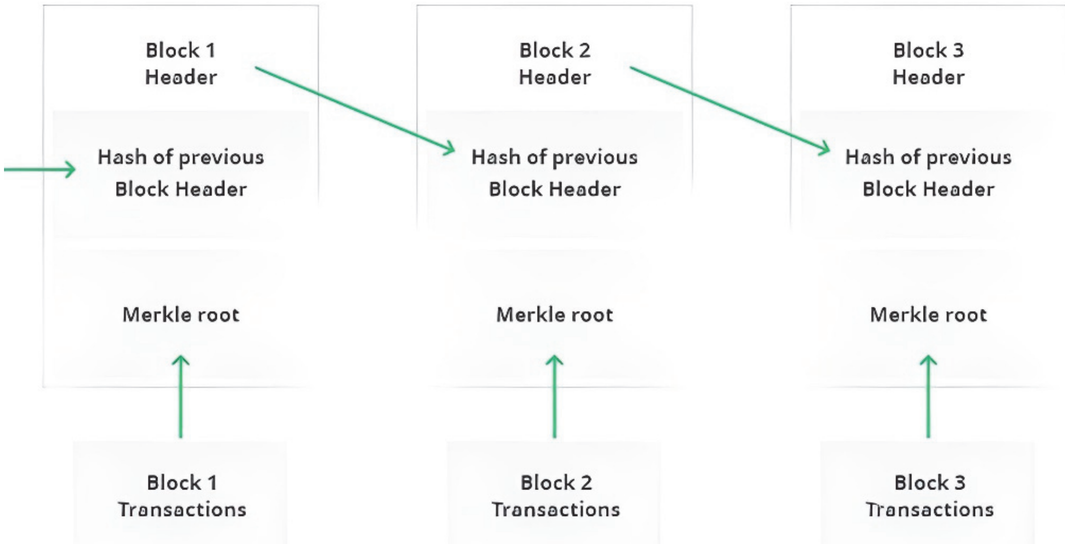

Figure 2: Blockchain industry

The information can only be added to the blockchain if there is an agreement between many of the parties. After a certain time, it can be assumed that the information added in a block can no longer be modified. The blockchain stores a large amount of data and its size also grows over time since only information is added to it. Therefore, it is advisable to have some mechanism that allows an efficient query to the blockchain [26]. The creation of a robust blockchain must guarantee two fundamental properties. Availability: It ensures that an honest transaction that has been issued ends up being added to the block chain, preventing a denial of service from occurring by corrupt nodes. Persistence: When a node gives a transaction as stable, the rest of the nodes, if they are honest, they will validate it as stable by making it immutable [27].

4. RELIABILITY ENGINEERING IN INDUSTRY 4.0

The future of factories should work according to Industry 4.0, the use of Industry 4.0 has many benefits but also the implementation and functionality become with some requirements for the correct function, productively and efficiently. These requirements are the integration, distribution, monitoring and control, cyber-physical environments, and integration of human resources with the necessary software and hardware, among others.

Also, in companies or factories, the Industry 4.0 implementation and control needs both for one part all the intangible software and the physics devices with the intention of integrated work and becoming smart factories. In that sense, companies to implement Industry 4.0 and even more important [28]. Maintaining the operation and quality within the necessary ranges makes reliability engineering a significant tool that must be considered in companies [29]. Then, reliability engineering can define the reliable requirements, lifecycle, and optimization [30], in other words, reliability engineering means quality through time, and in this sense, the application of reliability engineering in Industry 4.0 represents the opportunity to perform according to quality specifications and the and how to maintain that level of quality over time to have optimal performance in both the software and the hardware used in the implementation and operation of Industry 4.0 in companies.

The efficiency of the connections and the device, also, with the products and services performed in optimal conditions support over time depends on the reliability of the components that act in the structure of Industry 4.0, moreover, is well known that electronic devices, wireless devices intercommunication, and data transmission, depends of a frequency at which the devices are connected [31], it is to say, the used signal to connect devices like, smartphones, computers, smart buildings, among others, is possible through the use of stochastic processes [32], which means, that connections in devices and the wireless technology are representing by a probability density function [33]. More there, the Weibull distribution is widely used to represent the behavior of electronics products and internet connections [34]. The Weibull distribution provides better goodness-of-fit to real-world data and as it is known, in reliability engineering [35]. Weibull distribution is also widely used to estimate reliable indexes. Then, a methodology to determine the reliability of devices is presented in the framework of the Industry 4.0 approach [36]. Reliability predicts analysis and optimizes products, and device systems, among others [37]. This represents an opportunity in Industry 4.0 to be efficient and increase productivity over connections, devices, products, data transmission, etc., this is because reliability methods respond to the optimal work of devices like hardware, software, and connectivity [38]. Then, the structures of Industry 4.0 are due to a lack of reliability estimates [39]. Uncertainty is one of the main challenges in both virtual and physical applications, the uncertainty cannot be eliminated because of knowledge lack and uncontrollable processes, but it can be managed using reliability engineering [40]. Reliability engineering implementation in Industry 4.0 is very important to deal with uncertainty.Moreover, to say that an electronic device or product is safe for use and qualified as reliable is necessary to identify significant factors and conditions that affect the device's performance and find the failure mode. Using this failure mode the lifetime of the device can be estimated with a high-reliability level [41].Thus, it is important to understand the mechanisms that cause the failure and identify what factors accelerate or decelerate the failure mechanism to accurately estimate and predict life [42] (see Figure 3). In the next section reliability concepts and generalization are presented.

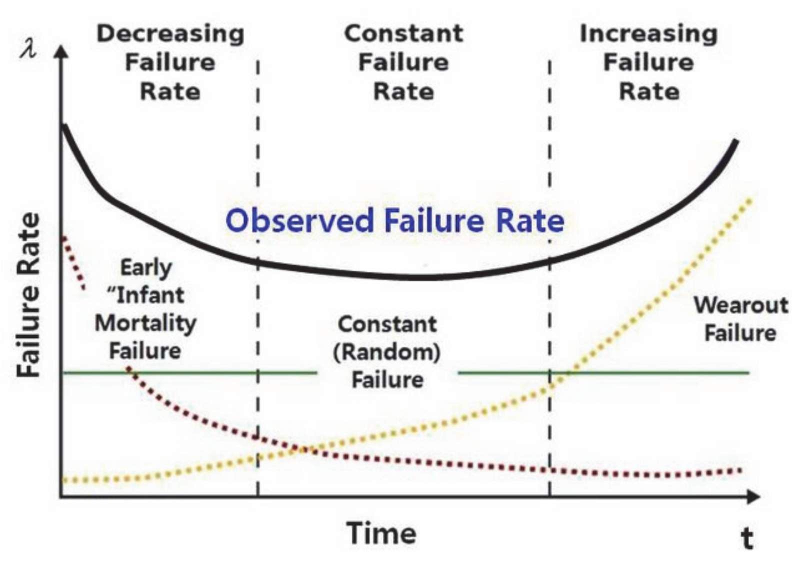

Figure 3: Reliability Engineering Concept

4.1. Reliability Engineering Concepts

Reliability engineering is defined as the probability of a product operation in a specific time under conditions given. several methodologies whose objective is to predict how a product, element, or device, is going to work overtime according to specific parameters that the product needs to function and predict how the reliability of the product will change as time pass. In other words, the function for which it was created, under the conditions and operational environment established for a given period [39]. It is necessary to remember that reliability only applies once the process is in control, that is, stable and predictable over time, highlighting that it is met only for the given conditions and environment [43]. On the other hand, one of the most used distributions in reliability engineering to model the life of any product whose deterioration is due to physical phenomena is the Weibull Distribution and as was mentioned above Weibull distribution is wide usage to determine electronic devices [29]. In other words, reliability engineering in Industry 4.0 is considered the use of the Weibull distribution due to Weibull distribution can model all the lifetime of a product or element and in this way, is possible to get a reliable design over some time (t) of given conditions [44]. The Weibull distribution generalities are presented in the next section.

4.2. Weibull Distribution Generalities

The Weibull distribution is flexible this is, according to the shape parameter β the behaviour of the Weibull distribution could be like a lognormal distribution, normal distribution, and exponential distribution (see Figure 4). Also, the Weibull distribution is widely used in reliability analysis because is capable to model all the lifetime of a product or element [36].

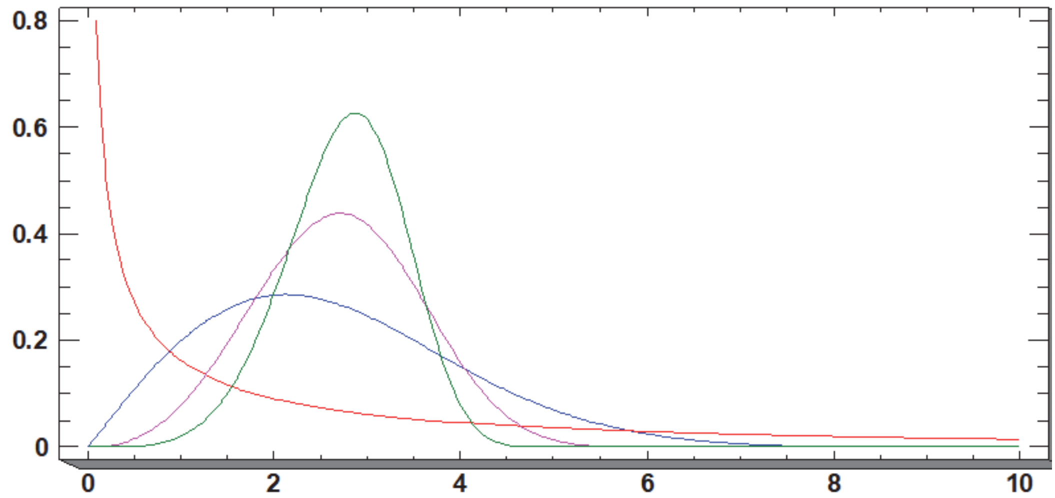

Figure 4. Weibull Distribution Behavior

The compound Reliability Weibull/Weibull stress/strength probability density function is based on the Weibull distribution [45] given by:

$$f(t)=\frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta-1} e^{-\left(\frac{t}{\eta}\right)\beta} \tag{1}$$

with cumulative failure function and reliability function given by:

$$F(t)=1-e^{-\left(\frac{t}{\eta}\right)^{\beta}} \tag{2}$$

$$R(t)=e^{-\left(\frac{t}{\eta}\right)^{\beta}} \tag{3}$$

where the estimation of the β and η parameters is performed by using the linear form of eq. (2) as

$$Y_i=\ln\left(-\ln\left(1-F\left(t_i\right)\right)\right)=-\beta\ln\eta+\beta\ln t_i \tag{4}$$

which represents the linear model given by:

$$Y_i=b_0+\beta X_i \tag{5}$$

with $Y_i=\ln(-\ln\left(1-F\left(t_i\right)\right)$, $b_0=-\beta\ \ln(\eta)$, and $x_i=\ln\left(t_i\right)$. In practice $F\left(t_i\right)$ in Eq. (4) is estimated by the median rank approach to estimate the corresponding reliability of a data set and is given by [16]:

$$F\left(t_i\right)=\frac{1-0.3}{n+0.4} \tag{6}$$

In eq. (7), form [2], the sample size n is determined to ensure the desired reliability index as:

$$n=\frac{-1}{\ln\left(R(t)\right)} \tag{7}$$

The next section presents some of the methodologies used in reliability engineering that can be applied in Industry 4.0 such as stress-strength analysis and capability non-normal index. Each methodology is presented with its corresponding application for Industry 4.0 as shown in the following sections.

5. STRESS-STRENGTH MODELS IN INDUSTRY 4.0

The products or element possesses an inherent strength to support the stress level to which these products are subject. Thus, if the stress level becomes higher than the strength level, failure will present. Also, is important to remember that failure mode is divided into two principal sections with their subsequent failure mode [46]. This principal failure mode is the failure by cumulative stress and the other one is the failure by shock. In the case of a product subject to stress until failure, the shock mode is applicated [47]. The representation of the methodology stress-strength is as follows. If a random variable X represents the stress and a variable Y is the strength, then, the stress-strength reliability is denoted by the probability of Y>X $\left[R = P(Y < X)\right]$ [48]. Remembering that the stress level is the load that produces the failure, and the strength is the inherent force to support that stress [49]. On the other hand, in the stress-strength methodology, the interference between the distribution with the strength distribution represents the failure rate. In other words, when the probability density functions of both stress and strength are known, the component reliability may be analytically determined by its interference (see Figure 5). based on the $f(x,y)$, the reliability of the component is estimated as

$$R = P(X < Y) = \iint_{-\infty}^{x} f(y,x)dxdy \tag{8}$$

Where $P(X < Y)$ is the probability that the strength exceeds the stress and $f(y,x)$ is the joint pdf of Y and X (see Figure 4) [50].

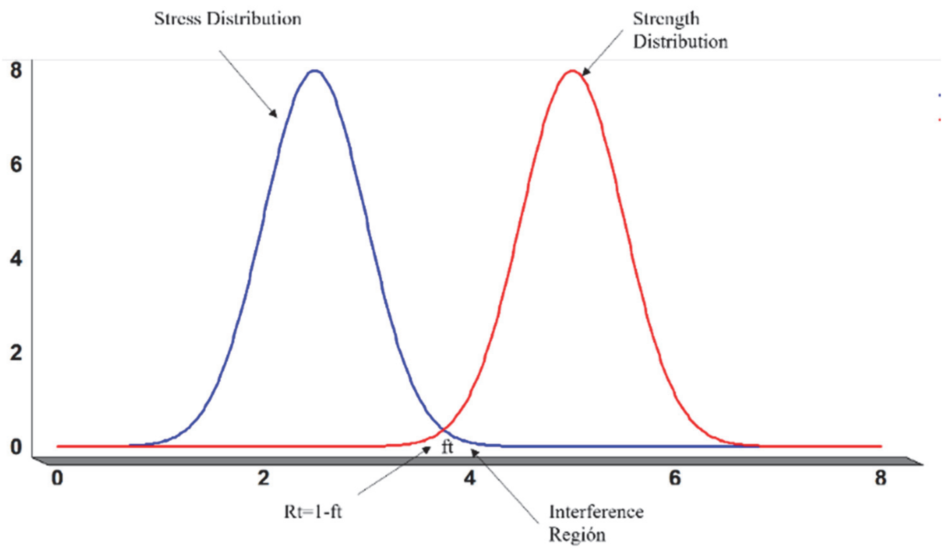

Figure 5: Stress-Strength.

There are some applications where product reliability depends on their physical inherent strength. Thus, if a stress level is higher than the strength then the product or element will fail by shock [51]. On the other hand, it is known that the behavior of failures in electronic products or devices is almost always of the Weibull Distribution type [52]. Then, the methodologies stress-strength for both cases equal shape parameters $\beta_s = \beta_S$ and for different shape parameters $\beta_s \neq \beta_S$ are presented in next section and a numerical application for Industry 4.0 is showed.

5.1. Stress-Strength Model for $\beta_s = \beta_S$ and $\beta_s \neq \beta_S$

The methodology to determine the reliability Weibull-Weibull in the $(\beta_S = \beta_s)$ case is defined as

$$R = P(Y > X)$$

$$R(t) = \int_0^\infty f(x)\left[\int_t^\infty f(y)dy\right]dx \tag{9}$$

$$R(t)=\frac{\eta_y^{\beta}}{\eta_y^{\beta}+\eta_x^{\beta}} \tag{10}$$

For stress variable $X_1 = X$ and the strength variable X_2=Y holds only for $\beta_S = \beta_s$. Therefore, the fact that the stress-strength Weibull-Weibull reliability function, for $\beta_S \neq \beta_s$ is given as

$$R(t)=P(Y>X)$$

$$R(t)=\int_0^{\infty} f(x)\left[\int_x^{\infty} f(y)dy\right]=\int_0^{\infty} f(y)\left[\int_x^{\infty} f(x)dx\right]dy \tag{11}$$

$$R(t)=1-\int_0^{\infty} e^{-\left[W+\left(\frac{\eta_y W^{\frac{1}{\beta_y}}}{\eta_x}\right)\right]}dW \tag{12}$$

6. METHODOLOGY USED FOR THE APPLICATION IN INDUSTRY 4.0

Is well known that quality in components is very important to ensure the correct function in different aspects of Industry 4.0 and internet protocol, such as the performance of the routers, the bandwidth, the people knowledge, the data process, etc. [31]. On the other hand, these conditions need to work in a time period design to ensure a good quality level i.e. what is the probability of a component performing the function for which it was designed in a period of time without failures [53]. Here is where reliability engineering is very helpful to prevent these failures and to know the reliability index of any component [54]. In such a way, Industry 4.0 works with very significant factors that can be a success key but also a problem that affects the value chain in the Industry 4.0 performance [55]. Then, using reliability methodologies in Industry 4.0 will help industries to get better quality over time and to have the best knowledge about their supply, helping to prevent possible failures [56]. In the next section, a methodology to estimate the real reliability of different kinds of components is presented and applied to a set of data of routers experiment just like an example of the efficiency of the methodology.

A stronger Wi-Fi signal means a more reliable connection. This allows us to take advantage of internet speeds. The Wi-Fi signal strength depends on some factors, such as the dastans from the router, the connection type 2.4 or 5ghz connection, and the wall materials. The most advanced method to measure and ensure a good or excellent connection consists in verifying the Wi-Fi and router strength, this measure almost always is made by the relation of a decibel per milliwatt (dBm).

The signal strength can be measured in some ways, however, the most consistent and accurate is in decibels per milliwatts (dBm). The first thing to know is that dBm measurements will be displayed in negative numbers. The scale goes from -30 to -90. If the measure is -30, the connection can be considered perfect and is likely standing next to the router or connected directly to the router. However, if the detected Wi-Fi signal is at -90, the service is so weak that you probably will not be able to connect to that network. An excellent connection is -50 dBm, while -60 dBm is good enough for streaming, handling voice calls, and anything else.

In this study according to Eq. (7), the number of routers strength to measure is 20, to assure the reliability level desired. Also, Because the measurements are in negative numbers, a change in the measurement of variables was considered, taking 70 as a perfect connection and 30 as a very poor connection. Once the data has been analyzed, the interpretation of the results will be carried out according to the measurements emitted by the signal strength of the routers. On the other hand, the Wi-Fi measures were considered as the strength level in the stress strength analysis and the measures made by ethernet connection as the stress level, to determine the real reliability level of the data set.

6.1. Numerical Application for Stress-Strength With $\beta_s = \beta_S$

As mentioned above, the data shown in Table 1 represents the values of the signal strength through a Wi-Fi connection to measure the true power and the probability of a good connection.

Table 1: Wi-Fi Signal Potency

Strength	**Stress**	**Strength**	**Stress**
45.7687	68.209079	49.396935	61.095694
53.882661	58.095201	56.312116	62.583785

50.037914	59.794951	52.724512	62.942897
61.485811	64.665409	60.340289	66.589206
33.162151	65.031939	38.155684	68.313501
49.288363	67.918014	53.612109	61.910494
65.369726	61.007549	39.508272	66.345333
53.157877	58.950731	42.176662	60.680839
46.757264	70.039242	58.681067	67.458765
50.426473	67.153635	66.286346	61.52779

The scale value for the stress is $\eta_S = 35$, the scale value for the strength is $\eta_s = 70$ and for both the stress and the strength the shape value $\beta_s = 2.5$.

Since from this data the Weibull stress parameters are $\beta_s = 2.5$, and $\eta_s = 35$ and the Weibull strength distribution parameters are $\beta_S = 2.5$ and $\eta_S = 70$, then, from eq. (10) the reliability index is $R(w) = 0.8497789$. This means that the probability of non-overlap signals is 84.97%. Then, the failure probability is 0.150221105 or 15.022%.

6.2. Numerical Application for Stress-Strength With $\beta_s \neq \beta_S$

Since the Weibull distribution does not have a closure property, that is, the algebraic sum of Weibull variables with parameters of different forms, the result obtained will not follow a Weibull distribution. Therefore, a closed solution methodology for stress-strength analysis with differently shaped parameters $\beta_s \neq \beta_S$ is shown below. Similarly, the data of the WiFi signal strength is shown in table 2.

Table 2: Wi-Fi Signal Potency

Strength	**Stress**	**Strength**	**Stress**
20.13477	4.3152539	52.376827	30.933065
27.451057	14.914502	54.688259	32.860377
32.933513	17.070878	66.041495	34.508135
33.312375	17.810757	76.235607	36.731113
34.505169	19.627432	83.777148	42.37115
37.032409	20.101771	88.041595	42.79704
37.886057	24.158096	95.673448	43.394011
44.58759	27.556933	111.32042	46.398071
49.160259	27.61323	118.24926	52.170288
51.847048	30.306621	119.83997	54.616305

The scale value for the stress is $\eta_S = 54$, the scale value for the strength is $\eta_s = 65$ and for the stress and the strength the shape value consequently is $\beta_S = 3.22$ and $\beta_s = 6.5$.

6.3. Proposed Method to Estimate the Design Reliability for $\beta_s \neq \beta_S$

1. Collect the set of n data using

$$n = \frac{-1}{\ln(R(t))} \tag{13}$$

2. Determine the average (µ)
3. Determine the logarithm of each one of the collected data and determine their log-average values as

$$\mu_X = \sum_{i=1}^{n} \ln Xi / n \tag{14}$$

4. Then determine the exponential of the average of the estimated logarithms as

$$\mu_y = Exp[\sum_{i=1}^{n} \ln Xi / n] \tag{15}$$

5. With the average of step 2 and step 4 calculate the corresponding $Ratio$ as

$$Ratio = (\mu^2 - \mu_y^2)^\wedge 0.5 \tag{16}$$

6. By using the result of step 5 estimate the maximum and minimum stresses σ_{max} and σ_{min} values of the stress and the strength data as

$$\sigma_{max} = \sigma_1 = \mu + Ratio \tag{17}$$

$$\sigma_{min} = \sigma_2 = \mu - Ratio \tag{18}$$

7. By using the median rank approach estimate the average of the generated n y_i elements as

$$\mu_{yi} = \frac{\sum_{i=1}^{n} \ln\left(-\ln(1-(i-0.3)/(n+0.4))\right)}{n} \tag{19}$$

8. Using the maximum and minimum stress σ_1, σ_2 and μ_y values (Piña-Monarrez, 2018), determine the corresponding Weibull shape β value as

$$\beta = \frac{-4 \cdot \mu_{yi}}{0.99 \cdot \ln(\sigma_1 / \sigma_2)} \tag{20}$$

9. By using the estimated β value of step 10, determine the corresponding Weibull scale η parameters as

$$\eta = Exp\left(\ln \mu_y - \frac{\mu_{yi}}{\beta}\right) \tag{21}$$

10. Estimate de strength eta parameter with

$$\eta_S = \eta_s \frac{\mu_M}{\mu_c} \tag{22}$$

11. With the Weibull family estimate the design reliability as

$$R(t) = \frac{\eta_{S^{\beta_s}}}{\eta_{S^{\beta_s}} + \eta_s^{\beta_s}} \tag{23}$$

6.4. Numerical Application Results for $\beta_s \neq \beta_S$

1. Collect the set of n data using

$$n = \frac{-1}{\ln(0.95)} = 19.4957 \approx 19$$

2. Determine the average (µ) of the stress and the strength a

$$\mu_{strength} = 61.754$$

$$\mu_{stress} = 31.012$$

3. Determine the logarithm of each one of the collected data and determine their log-average values as

$$\mu_{ln-strength} = 3.998$$

$$\mu_{ln-stress} = 3.31$$

4. Next, determine the exponential of the average of the estimated logarithms as

$$\mu_{exp-strength} = 961.79$$

$$\mu_{exp-stress} = 2970.86$$

5. With the average of step 2 and step 4 calculate the corresponding $Ratio$ as

$$Ratio_{strength} = 29.0305$$

$$Ratio_{stress} = 14.492$$

6. Determine the maximum and minimum strength and stress as Strength maximum and minimum.

$$Ratio_{strength} = 29.0305$$

$$Ratio_{stress} = 14.492$$

$$\sigma_1 = 123.37$$

$$\sigma_2 = 0.1295$$

Stress maximum and minimum

$$\sigma_1 = 45.505$$

$$\sigma_2 = 16.52$$

7. Estimate the Y_i elements and the average

$$\mu_{yi} = -0.5444$$

8. Calculate the corresponding shape parameter β using equation (17) as follow

$$\beta_{Strength} = 0.320697204$$

$$\beta_{Stress} = 2.170883359$$

9. By using the estimated β value of step 8, determine the corresponding Weibull scale η parameters as

$$\eta_{strength} = 297.6315554$$

$$\eta_{stress} = 35.2330332$$

10. With the Weibull family of both the stress using, the strength of steps 8 and 9, and the desired reliability, estimate the common β_c that represent the corresponding strength and stress.

$$\beta common = \frac{[\ln R(t_w) / F(t_w)]}{\ln\left[\frac{\eta_{Strength}}{\eta_{stress}}\right]} = 1.379857199$$

11. Using the common β and the η of the strength and stress calculated the corresponding reliability as

$$R(t / x, y) = 0.95$$

This means that the real reliability of the system speed received with the router is 94.99% and even more the probability safety factor can be estimated by using equation (24) like is showed above. In table 3 a resume of the methodology and estimations is given.

$$S_{fW} = \frac{\eta_{strength}}{\eta_{stress}} \tag{24}$$

$$S_{fW} = \frac{21809.1249}{11590.615} = 8.447514403$$

Table 3: Estimation Resume

Strength	Stress	ln Strength	ln Stress	n	F(ti)	Yi	Strength μ
20.13477	4.3152539	3.002448171	1.4621562	1	0.03431	-3.3548	**61.7547138**
27.451057	14.914502	3.312404674	2.702334	2	0.08333	-2.4417	**Stress μ**
32.933513	17.070878	3.494490772	2.837374	3	0.13235	-1.9521	**31.01275145**

33.312375	17.810757	3.50592895	2.8798026	4	0.18137	-1.6088	**ln Strength μ**
34.505169	19.627432	3.541109139	2.9769282	5	0.23039	-1.3399	**3.998304892**
37.032409	20.101771	3.611793448	3.0008079	6	0.27941	-1.1157	**exp Strength μ**
37.886057	24.158096	3.634583155	3.1846196	7	0.32843	-0.921	**54.50567865**
44.58759	27.556933	3.797455569	3.3162542	8	0.37745	-0.7467	**ln Stress μ**
49.160259	27.61323	3.895085553	3.318295	9	0.42647	-0.5871	**3.311210594**
51.847048	30.306621	3.948298	3.4113662	10	0.47549	-0.4381	**exp Stress μ**
52.376827	30.933065	3.958464261	3.4318257	11	0.52451	-0.2965	**27.41829781**
54.688259	32.860377	4.001649043	3.4922676	12	0.57353	-0.1599	**Ratio Strength**
66.041495	34.508135	4.190283257	3.5411951	13	0.62255	-0.026	**61.62514288**
76.235607	36.731113	4.333828637	3.6036242	14	0.67157	0.10744	**Ratio Stress**
83.777148	42.37115	4.428160273	3.7464677	15	0.72059	0.243	**14.4923**
88.041595	42.79704	4.477809373	3.7564689	16	0.76961	0.38388	**Strength Max**
95.673448	43.394011	4.56094081	3.7703214	17	0.81863	0.53486	**123.3798**
111.32042	46.398071	4.71241271	3.8372579	18	0.86765	0.70423	**Strength Min**
118.24926	52.170288	4.772794769	3.9545131	19	0.91667	0.91024	**0.129571**
119.83997	54.616305	4.786157269	4.0003325	20	0.96569	1.21557	**Stress Max**
				μ=	**0.5**	**-0.5445**	**45.505**
							Stress Min
							16.5204
							S_{fW}
							8.447514403
							R(t)
							0.95

6.5. Weibull Capability Index in Industry 4.0

In this section an application of the proposed method for the Calculation of Weibull Capability Indices is presented and compared with the Clements percentile methods, which is used in Minitab and with the method for normal data; In order to make a comparison between the three methods and identify differences in the results, a reliability level R(t) and a scale value η are set, and different values for β are used.

6.6. Application Specifications

Suppose that for an accelerated life analysis with Weibull behavior, the customer specifications are: reliability $R(t)=96\%$, at the desired time of $t=1500$ hours and the values of the shape parameter to be used are $\beta=0.5,3.5$ and 5. The specification limits will be taken from the Weibull data, where the maximum value is the USL upper specification limit (t_{max}) and the lowest data value is the LSL lower specification limit (t_{min}).

Application Development:

1. Determine the replica number according to the reliability level desired $R(t)=0.96$, with

   $n=\dfrac{-1}{\ln(0.96)}=24.49\approx 25$ replicas.

2. Determine the η value for the different β values; para $\beta=0.5$ the η value it was equal to $\eta=24.49^{1/0.5}\cdot 1500=900124.9896$; for $\beta=3.5$ the value of η will be $\eta=24.49^{1/3.5}\cdot 1500=3740.92$ and finally $\beta=5$ the value of $\eta\eta=24.49^{1/5}\cdot 1500=2843.88$.

3. The Weibull families are:

$W(1500,0.5), W(1500,3.5)\, y\, W(1500,5)$.

4. σ_{ev} y μ_{ev} values are estimated with the corresponding values of $\beta = 0.5,\ 3.5\ y\ 5$, with $t = \eta = 1500$. The mean and the standard deviation of extreme value are: $\mu_{ev} = 7.3132\, and\, \sigma_{ev} = 2$; $\mu_{ev} = 7.3132\, and\, \sigma_{ev} = 0.2857$ and $\mu_{ev} = 7.3132\, y\, \sigma_{ev} = 0.2$
5. Estimated the values of $\mu_{\gamma}\, y\, \sigma_{\gamma}$, con $\mu_{\gamma} = \mu_{ev} - \gamma\sigma_{ev}\, y\, \sigma_{\gamma} = \frac{\pi}{\sqrt{6}}\sigma_{ev}$. With the values of $\mu_{\gamma} = 6.1588,\ 7.1483\ y\, 7.2077$ and $\sigma_{\gamma} = 2.565,\ 0.3664\ y\ 0.2565$ respective.

Simulated the data with Alta 10, and with the estimation of $\eta\ y\, \beta$, from step 2 for the Weibull families get in step 3. The β values are:

Table 4: Weibull with Beta=0.5, 3.5 y 5 with Alta 10.

Tiempo de Falla Beta=0.5	**Tiempo de Falla Beta=3.5**	**Tiempo de Falla Beta=5**
203.4228697	1127.548763	1228.349945
345.6452199	1216.257256	1295.224911
507.6423756	1284.908503	1345.977871
694.5263048	1343.753055	1388.836121
910.2144398	1396.685915	1426.909749
1159.710739	1445.866436	1461.898098
1450.035712	1492.758197	1494.927059
1782.345261	1537.415805	1526.094112
2172.543725	1581.516494	1556.607024
2623.399988	1624.699895	1586.238857
3148.372326	1667.594753	1615.439663
3772.624852	1711.248282	1644.926493
4511.866592	1755.556573	1674.625724
5394.549685	1800.944765	1704.81655
6458.328628	1847.850422	1735.77787
7754.295596	1896.762015	1767.813184
9393.694307	1949.449533	1802.045596
14222.63454	2068.458446	1878.365653
17981.16945	2138.922602	1922.931999
23464.01631	2221.811086	1974.796589
32027.16608	2322.787274	2037.201486
47559.74537	2457.768709	2119.366597
83328.60345	2662.775317	2241.617681
232034.5909	3082.275609	2483.346991

The data presented in the table above are randomly generated; however, Alta 10 sorts them according to failure time. The estimated Weibull capability indices $(C_{pw}\, y C_{pkw})$ of the application for the different values of $\beta = 0.5, 3.5\, y\, 5$, are shown as follows:

Table 5: Cp y Cpk Weibull Proposed Method.

Beta (β)	C_{pw}	C_{pkw}
0.5	0.40257392	0.10961257
3.5	0.40257392	0.10961257
5	0.40257392	0.10961257

7. CONCLUSION

Industry 4.0 is one of the most relevant advances in modern industry, by adding, the transmission, reception, and process of big data which include not only characters but also the transmission of all type of information is possible, even in industry 4.0 the use of tools or methods like blockchain, is allow thanks to the technology advances, the blockchain has a lot of uses like the verification of data from different sources and it is almost impossible to use false data. On the other hand, Industry 4.0 depends on its good functionality and because of this, the use of methodologies and tools like reliability engineering is indispensable to maintain the quality over time, i.e., the possibility of a component gift work in the design way over some time, due to, this component has been used for a given time. As is shown in this study, the reliability engineering methodologies allow us to determine the possibility of failure over time, and with the use of a method like stress strength Weibull and capability, indices are possible to determine the reliability of the components that are used in Industry 4.0. this is important to highlight because the efficiency of both hardware and software depends on their reliability or their ability to perform correctly over time, and with this reliability level the making decision process will be more effective, and the bias is reduced.

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