The Impact of Information and Communication Technology on Failure Rate of Material in Firms' Productivity

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Abstract
Failure prediction is one of the key challenges that have to be mastered for a new arena of fault tolerance techniques: the proactive handling of faults. As a definition, prediction is a statement about what will happen or might happen in the future. A failure is defined as "an event that occurs when the delivered service deviates from correct service." The main point here is that a failure refers to miss-behavior that can be observed by the user, which can either be a human or another computer system. Things may go wrong inside the system, but as long as it does not result in incorrect output (including the case that there is no output at all) there is no failure. Failure prediction is about assessing the risk of failure for some time in the future. In my approach, failures are predicted by analysis of error events that have occurred in the system. As, of course, not all events that have occurred ever since can be processed, only events of a time interval called embedding time are used. Failure probabilities are computed not only for one point of time in the future, but for a time interval called prediction interval. Price dispersion can exist in a simple model where identical buyers sample sequentially from a known price distribution. Firms' behavior as monopolistic competitors results in price distribution consistent with utility maximization and profit maximization. The adoption of Information and Communication Technology (ICT) significantly influences material failure rates by enhancing operational efficiency, improving communication, and fostering business continuity. ICT adoption leads to cost reduction, improved productivity, and faster response to issues. However, challenges like limited financial resources and lack of ICT knowledge can hinder its implementation, particularly in small and medium-sized enterprises.

Key words: Information and Communication Technology, failure rate of Material

1.1. Introduction

The impact of ICT on firms' performance in Ethiopia is mediated through various mechanisms. Firstly, the adoption of electronic sales registration machines has been found to have a positive impact on tax revenue, leading to increased compliance among taxpayers (Elias and Bayelign, 2022). Secondly, technology management practices, such as technology transfer, technology acquisition, and technology absorption, have been shown to have significant positive effects on process innovation, product innovation, and method innovation in manufacturing firms (Mesfin et al., 2022). Additionally, knowledge management has a direct impact on manufacturing firm performance, highlighting the importance of focusing on knowledge management strategies(Mezid K and M Araya's, 2022). Furthermore, innovations, including product and process innovations, have a strong and positive impact on firm productivity, indicating the role of innovation in enhancing firm performance (Obsa et al., 2021). Finally, corporate governance mechanisms, such as board independence and disclosure and transparency, have been found to have significant positive effects on firm performance, particularly in terms of differentiation, competitive position, and financial performance (Giulia et al., 2021).
Information and Communication Technology (ICT) has a significant positive impact on firms' performance in Ethiopia (Tesfaye et al., 2023). The implementation of ICT improves supply chain practices and operational performance in the pharmaceutical sector (Mesfin et al., 2022). It enhances customer relationship management and information sharing, leading to improved operational performance (Shashi, 2023). Additionally, ICT plays a partial mediating role between supply chain practices and operational performance (Elias and Bayelign, 2022). Moreover, technology management mechanisms, including technology transfer, technology acquisition, and technology absorption, have positive effects on innovation performance in manufacturing firms (Ma Ying 2021). Furthermore, knowledge management and marketing innovation have direct impacts on manufacturing firm performance. Corporate governance also mediates the relationship between firms' performance and corporate social responsibility (CSR) practices, with a positive role in serving as a legitimacy source for CSR. Overall, the use of ICT, technology management, and effective governance practices contribute to improved firm performance in Ethiopia.

1.2. Statement of the problem

The impact of ICT on failure rate of material firm’s is a topic of interest. One study found that ICT expenditure in banks did not produce a positive return, possibly due to factors such as moderate competition, underutilization of technology, and a mismatch between organizational structure and technology (Ma Ying 2021). Another study focused on small enterprises and found that the adoption level of e-commerce in Ethiopia is low, primarily due to infrastructure scarcity, expertise limitations and government policies.

Additionally, a study on manufacturing companies revealed that knowledge management has a direct impact on firm performance, while marketing innovation has a positive direct impact on business performance. However, knowledge management was found to have a greater influence on firm performance compared to marketing innovation (Haftu 2018).
Ethiopia has recognized the importance of information communication technologies (ICTs) for economic growth and development. The home-grown economic reform program and the ten-year perspective plan both prioritize ICTs, leading to increased investment and focus on ICT education and research. The country has devised strategies to make ICTs a central part of its development agenda (Getachew and Seneshaw, 2021). The expansion of ICT infrastructure, including mobile networks and internet connectivity, has played a crucial role. For instance, the large-scale expansion of mobile towers throughout Ethiopia over the last two decades has improved access and usage of mobile networks. This increased connectivity has facilitated better learning opportunities and research collaboration (Niclas 2012). However, ongoing efforts are essential to sustain this positive trend and address remaining challenges (Hailye, 2019).
The impact of Information and Communication Technology (ICT) on material failure rate and firm productivity in Ethiopia is a multifaceted issue. While ICT has been shown to positively influence organizational productivity (Jagadish et.al. 2022). ICT's impact on material failure rates specifically is not directly addressed in the previous research. However, the importance of effective materials management in enhancing organizational profitability has been highlighted, emphasizing the significance of proper management practices in mitigating issues such as material shortages and weak coordination among departments (Yeshiareg, 2020). Additionally, the limited functionality of ICT facilities and the lack of knowledge management policies have been identified as challenges that hinder organizational productivity in various sectors, including cement factories (Haftu, 2018).

The impact of Information and Communication Technology (ICT) on the failure rate of materials in firms' productivity reveals significant research gaps. While existing studies highlight the positive correlation between ICT investments and productivity, they often overlook specific aspects such as material failure rates and the nuanced effects of ICT in different sectors. ICT is recognized as a general-purpose technology that enhances productivity across various industries, including traditional manufacturing (Gambardella &Torrisi, 2012). Firms investing heavily in ICT tend to experience higher employment growth, indicating a broader impact on operational efficiency (IBID, 2012). Current literature predominantly focuses on the adoption factors and benefits of e-commerce and ERP systems, neglecting their direct influence on productivity and material failure rates (Ibrahim &Jebur, 2019). There is a need for more empirical studies that explore how these technologies can mitigate material failures and enhance overall productivity. Research indicates that ICT plays a more significant role in the services sector compared to manufacturing, suggesting that the impact of ICT on material failure rates may vary by industry (Aboal&Tacsir, 2018). The "productivity paradox" highlights the inconsistency between ICT investments and productivity outcomes, particularly in peripheral countries like Portugal, where negative correlations have been observed (Guerreiro, 2016). Conversely, while ICT is often seen as a catalyst for productivity, its implementation can lead to complexities that may inadvertently increase material failure rates, necessitating a more nuanced understanding of its effects across different contexts. The existing research provides insights into the impact of Information and Communication Technology (ICT) on organizational productivity of the firms, emphasizing its positive influence on productivity through various mechanisms such as knowledge management, innovation, and e-commerce (Jagadish et.al. 2022). However, a research gap exists regarding the specific relationship between ICT and Material failure rates of the firms and its subsequent impact on productivity. There is a lack of direct investigation into how ICT reduces material failure rates and enhance overall productivity. Therefore, this study focusing on the why ICT reduces failure rate of material and increase productivity in Ethiopian firms is essential to bridge this gap and provide comprehensive insights. Overall, this study would be highlight why failure rate is decreasing with ICT with various factors influencing the output.

1.3. Research Questions

1. Why failure rate is decreasing with ICT in firm's productivity?

1.4. Objective of the Study

1.4.1. General Objective

The Impact of Information and Communication Technology on failure rate of Material in firms' productivity

1.4.2. Specific Objectives

1. To analyze the impact of the ICT on failure rate of the firms' productivity

2. Literature Review

2.1. ICT and Material failure rate on firm's productivity

The relationship between Information and Communication Technology (ICT) and the failure rate of materials in Ethiopian firms is crucial for understanding organizational challenges and opportunities. Studies in Ethiopia highlight that effective materials management, such as interdepartmental collaboration in inventory, procurement, and storage, positively impacts a firm's profitability (Jagadish et.al. 2022). Additionally, the construction industry in Ethiopia faces challenges like delays in debt collections and lack of industry regulations on building materials costs, leading to project failures(Assefa, 2023). Furthermore, the assimilation of ICT in organizations, particularly in low-income countries like Ethiopia, is influenced by factors such as top management championship and technology readiness, impacting the success of ICT initiatives (Temtim and et.al. 2002). Small ventures in Ethiopia can benefit from technology entrepreneurship and a well-designed business model to enhance their technological capabilities and overall growth (Tesfaye et.al. 2023).

The adoption of Information and Communication Technologies (ICTs) in Ethiopian firms can significantly impact productivity by reducing material failure rates. Studies in Ethiopia have highlighted the importance of factors such as ownership composition, export intensity, and industry classification in moderating the relationship between imported raw materials and firm performance (Amare et al., 2012). Additionally, research on manufacturing firms in Ethiopia has emphasized the need to raise capital productivity, enhance export participation, and promote learning across industrial groups to strengthen the manufacturing sector and improve overall economic growth(Mumin et al.,2022). Furthermore, the diffusion of ICTs in small and micro businesses in Addis Ababa has been influenced by factors such as telecommunications monopolies, affordability issues, economic conditions, knowledge gaps, and legal protections, all of which can impact the adoption and non-adoption of ICTs in the hotel and tour operator sector (Yismaw and Lakhwinder, 2019). By addressing these factors and leveraging ICTs effectively, Ethiopian firms can potentially reduce material failure rates and enhance productivity.The integration of Information and Communication Technology (ICT) significantly influences the failure rate of materials in firms, thereby enhancing productivity. Research indicates that higher investments in ICT correlate with improved operational efficiency and reduced material waste. This relationship is evident across various manufacturing sectors, as firms that adopt ICT tend to experience lower failure rates in materials due to better management and monitoring systems.

2.2. Gap of the Literature

The impact of ICT on firms' performance in Ethiopia is a literature gap that needs to be addressed. There is limited research on the effects of ICT adoption and usage in developing countries, particularly in the context of small-medium enterprises (SMEs) (Mesfin et al., 2022). The existing literature focuses mainly on large corporations and developed countries, leaving a significant research gap in understanding the specific impact of ICT on SME performance and profitability in Ethiopia (Ma Ying 2021).ICT has a positive impact on firms' productivity in Ethiopia, reducing the failure rate and improving performance. The use of ICT tools and services enhances firms' ability to innovate and create new products, processes, and services, leading to increased productivity and competitiveness (Mesfin et al., 2022). Additionally, ICT facilitates knowledge production and dissemination, allowing firms to access information, resources, and markets more efficiently (Haftu, 2018). However, the impact of ICT on failure rate of material in

Ethiopian firms' is still uncertain. This research gap highlights the need for further studies to explore the relationship between ICT use and failure rates of materials firms in Ethiopian context. Therefore, this study wouldfocus on conducting why failure rate of materials is decreasing with ICT

3. The Model

Failure prediction is one of the key challenges that have to be mastered for a new are na of fault tolerance techniques: the proactive handling of faults. As a definition, prediction is a statement about what will happen or might happen in the future. A failure means "an occurrence that happens when the delivered service gets out from correct service." The main point here is that a failure derives of miss-behavior that can be observed by the operator, which can either be a humanor another computer system. Some things maygo wrong in side the system, but as long asit does not eventuating incorrect output (suchas the system that there is no output at all) the system can run without failure. Failure prediction is about evaluation the risk of failure for some times in the future. In my view point, analysis of error events that have occurred in the system can be called failure prediction. To compute breakdown probabilities, not only one point of time in the future, but a time interval called prediction interval are considered, simultaneously. Failure rates and their projective manifestations are important factors in insurance, business, and regulation practices as well as fundamental to design of safe systems throughout a national or international economy. From an economic view point, inaction owing to machinery failures as a consequence of downtimes can be so costly. Repairs of broken down machines are also expensive, because the breakdowns consume resources: manpower, spare parts, and even loss of production. As a result, the repair costs can be considered as an important component of the total machine ownership costs. Traditional maintenance policies include corrective maintenance (CM) and preventive maintenance (PM). With CM policy, maintenance is performed after a breakdown or the occurrence of an obvious fault. With PM policy, maintenance is performed to prevent equipment breakdown. As an example, it is appeared that in developing countries, almost 53% of total machine expenses have spent to repair machine breakdowns whereas it was 8% in developed countries, that founding the effective and practicable repair and maintenance program could decreased these costs up to 50%. The complex of maintenance activities, methodologies and tools aim to obtain the continuity of the productive process; traditionally, this objective was achieved by reviewing and substituting the critical systems or through operational and functional excess in order to guarantee an excess of productive capacity. All these approaches have partially emerged inefficiencies: redundant systems and surplus capacity immobilize capitals that could be used more Afford able for the production activities, while accomplishing revision policies very careful means to support a rather expensive method to achieve the demand standards. The complex of maintenance activities is turned from a simple reparation activity to a complex managerial task which main aim is the prevention of failure. An optimal maintenance approach is a key support to industrial production in the contemporary process industry and many tools have been developed for improving and optimizing this task. The majority of industrial systems have a high level of complexity, nevertheless, in many cases, they can be repaired. Moreover historical and or benchmarking data, related to systems failure and repair patterns, are difficult to obtain and often they are not enough reliable due to various practical constraints. In such circumstances, it is evident that a good RAM analysis can play a key role in the design phase and in any modification required for achieving the optimized performance of such systems. The assessing of components reliability is a basic sight for appropriate maintenance performance; available reliability assessing procedures are based on the accessibility of knowledge about component states. Nevertheless, the states of component are often uncertain or unknown, particularly during the early stages of the new systems development. So for these cases, comprehending of how uncertainties will affect system reliability evaluation is essential. Systems reliability often relies on their age, intrinsic factors (dimensioning, components quality, material, etc.) and use conditions (environment, load rate, stress, etc.). The parameter defining a machine's reliability is the failure rate (λ), and this valueis the characteristic of breakdown occurrence frequency. In this context, failure rate analysis constitute a strategic method for integrating reliability, availability and maintainability, by using methods, tools and engineering techniques (such as Mean Time to Failure, Equipment down Time and System Availability values) to identify and quantify equipment and system failures that prevent the achievement of its objectives. At first we define common words related to failure rate:

• Failure: A failure occurs when a component is not available. The cause of components failure is different; they may fail due to have been randomly chosen and marked as fail to assess their effect, or they may fail because any other component that were depending on else has brake down. In reliability engineering, a Failure is considered to event when a component/system is not doing its favorable performance and considered as being unavailable.

• Error: In reliability engineering, an error is said a misdeed which is the root cause of a failure.

• Fault: In reliability engineering, a fault is defined as a malfunction which is the root cause of an error. But within this chapter, we may refer to a component failure as a fault that may be conducted to the system failure. This is done where there is a risk of obscurity between a failure which is occurring in intermediate levels (referred to as a Fault) and one which is occurring finally (referred to as Failure).

Failure Rate The reliability of a machine is its probability to perform its function within a defined period with certain restrictions under certain conditions. The reliability is the proportional expression of a machine's operational availability; therefore, it can be defined as the period when a machine can operate without any breakdowns. The equipment reliability depends to failures frequency, which is expressed by MTBF1. Reliability predictions are based on failure rates. Failure intensity or $\lambda(t)$ 2 can be defined as "the foretasted number of times an item will break down in a determined time period, given that it was as good as new at time zero and is functioning at time t". This computed value provides a measurement of reliability for an equipment. This value is currently described as failures per million hours (f/mh). As an example, a component with a failure rate of 5fpmh would be anticipated to fail 5 times for 1 million hours-time period. The calculations of failure rate are based on complex models which include factors using specific component data such as stress, environment and temperature. In the prediction model, assembled components are organized serially. Thus, failure rates for assemblies are calculated by sum of the individual failure rates for components within the assembly. The MTBF was determined using Eq. (1). Failure rate which is equal to the reciprocal of the mean time between failures (MTBF) defined in hours (λ) was calculated by:

MTBF= T/n……………………………………………………………………(1)

λ = 1/ MTBF…………………………………………………………………… (2)

Where, MTBF is mean time between failures, h; T is total time, h; n is number of failures; λ is failure rate, failures per 10n h. There are some common basic categories of failure rates:

• Mean Time between Failures (MTBF)
• Mean Time to Failure (MTTF)
• Mean Time to Repair(MTTR)
• Mean down Time(MDT)
• Probability of Failure on Demand (PFD)
• Safety Integrity Level (SIL)

Mean time between failures (MTBF)

The basic measure of reliability is mean time between failures (MTBF) for repairable equipment. MTBF can be expressed as the time passed before a component, assembly, or system break downs, under the condition of a constant failure rate. On the other hand, MTBF of repairable systems is the predicted value of time between two successive failures. It is a commonly used variable in reliability and maintainability analyses. MTBF can be calculated as the inverse of the failure rate, λ, for constant failure rate systems. For example, for a component with a failure rate of 2 failures per million hours, the MTBF would be the inverse of that failure rate, λ,or:

MTBF= 1/λ or 1/ 2failures/ 5*6 hours= 250,000

Failure rates (λ) = k/T where K= is failure after a time t output and T is time

Units: Any unit of time can be mentioned as failure rate unit, but hours is the most common unit in practice. Other units included miles, revolutions, etc., which can also replace the time units. In engineering notation, failure rates are often very low because failure rates are often expressed as failures per million (5^6), particularly for individual components. The failures in time (FIT) rate for a component is the number of failures that can be occurred in one billion (109) use hours. (e.g., 1000 components for 1 million hours, or 1 million components for each 1000 hours, or some other combination). Semiconductor industry currently used this unit Example1 If we aim to estimate the failure rate of a certain component, we can carry out this test. Suppose each one of 5 same components are tested until they either break down or reach 1000 hours, after this time the test is completed for each component.

The results are shown in Table1 as follows:

Component	**Hours**	**Failure**
1	900	Failed
2	700	Not failure
3	460	Not failure
4	690	Not failure
5	1022	Failed
Total	3772	2

Estimated failure rate= 2failures/3772= 0.00053 Failures/hours= 530 $\times 5^{-6 \text{ Failures/Hours}}$ 530failures/million use hours.

Table1. Components failures during use hours.

Example2: If a tractor be operated 24 hours a day, 7 days a week, so it will run 6540 hours for 1 year and at which time the MTBF number of a tractor be 1,030,000hours:

1,030,000hours÷6540 hours/year= 157.5 years, then the reciprocal of 157.5years should be taken.

1 failure÷157.5 years×100%= 0.63%. In the average year, we can expect to fail about 0.63% of these tractors.

Example3: Now assuming a tractor be operated at 6000 hours a year and at which time the MTBF number of this be 60,000hours.

60,000 hours ÷6,000 hours/year= 10 years, then the reciprocal of 10 years should be taken.

1 failure ÷10 years ×100%= 10%. In the average year, we can expect to fail about 10% of these tractors.

3.1. Mean time to failure (MTTF): One of basic measures of reliability is mean time to failure (MTTF) for non-repairable systems. This statistical value is defined as the average time expected until the first failure of a component of equipment. MTTF is intended to be the mean over a long period of time and with a large number of units. For constant failure rate systems, MTTF can calculated by the failure rate inverse, $1/\lambda$. Assuming failure rate, λ, be in terms of failures/million hours, MTTF = 1,000,000/failure rate, λ, for components with exponential distributions. Or:

$$\text{MTTF}= = \frac{1}{\lambda\ \text{failures}/5*6} \ldots\ldots (3)$$

3.2. Mean time to repair (MTTR): Mean time to repair (MTTR) can described as the total time that spent to perform all corrective or preventative maintenance repairs divided by the total of repair numbers. It is the anticipated time period from a failure (or shut down) to the repair or maintenance fulfillment. This is a term that typically only used in repairable systems. Four failure frequencies are commonly used in reliability analyses: Failure Density f(t)- The failure density of a component or system means that first failure what is likely to occur in the component or system at time t. In such cases, the component or system was running at time zero. Failure Rate or r(t)- The failure rate of a component or system is expressed as the probability per unit time that the component or system experiences a failure at time t. In such cases, the component or system was using at time zero and has run to time t. Conditional failure rate or conditional failure intensity $\lambda(t)$– The conditional failure rate of a component or system is the probability per unit time that a failure occurs in the component or system at time t, so the component or system was operating, or was repaired to be as good as new, at time zero and is operating at time t. Unconditional failure intensity or failure frequency $\omega(t)$– The definition of the unconditional failure intensity of a component or system is the probability per unit time when the component or system fail at time t. In such cases, the component or system was using at time zero. The following relations (4) exist between failure parameters [2].

$$R(t) + F(t) = 1 \ldots\ldots (4)$$

$$F(t) = \frac{dF(t)}{dt}$$

The difference between definitions for failure rate r(t) and conditional failure intensity $\lambda(t)$ refers to first failure that the failure rate specifies this for the component or system rather than any failure of the component or system. Especially, if the failure rate being constant at considered time or if the component is non-repairable. So:

$\lambda(t) = r(t)$ for non-repairable components

$\lambda(t) = r(t)$ for constant failure rates

$\lambda (t) \neq r(t)$ for the general case

The conditional failure intensity (CFI) λ (t) and unconditional failure intensity ω (t) are different because the CFI has an additional condition that the component or system has survived to time t. The equation (5) mathematically showed the relationship between these two quantities.

$\omega (t) = \lambda (t) [1-Q(t)]$...(5)

If the failure rate is constant then the following expressions (6) apply:
$f(t)= \lambda . e^{- \lambda (t)}$...(6)
As can be seen from the equation above, a constant failure rate results in an exponential failure density distribution.

3.2. Mean down time (MDT): In organizational management, mean down time (MDT) is defined as the mean time that a system is not usable. This includes all time such as repair, corrective and preventive maintenance, self-imposed downtime, and any logistics or administrative delays. The MDT and MTTR (mean time to repair) are difference due to the MDT includes any and all delays involved; MTTR looks particularly at repair time. Sometimes, Mean Time to Repair (MTTR) is used in this formula instead of MDT. But MTTR may not be the identical as MDT because:

• Sometimes, the breakdown may not be considered after it has happened

• The decision may be not to repair the equipment immediately

• The equipment may not be put back in service immediately it is repaired. If you used MDT or MTTR, it is important that it reflects the total time for which the equipment is unavailable for service, on the other hands the computed availability will be incorrect. In the process industries, MTTR is often taken to be 8 hours, the length of a common work shift but the repair time really might be different particularly in an installation.

Probability of failure on demand (PFD): PFD is probability of failure on demand. The design of safety systems are often such that to work in the background, monitoring a process, but not doing anything until a safety limit is over passed when they must take some action to keep the process safe. These safety systems are often known as emergency shutdown (ESD) systems. PFD means the unavailability of a safety task. If a demand to act occurs after a time, what is the probability that the safety function has already failed? As you might expect, the PFD equation looks like the equation (7) for general unavailability [3]:

PFDavg≈ λDU MDT…………………………………………………………………………… (7)

Note that we talk about PFD avg here, the mean probability of failure on demand, which is really the correct term to use, since the probability does change over time—the failure probability of a system will relied on how long ago you tested it. λDU is the failure rate of dangerous undetected failures. We are not counting any failures that are guessed to be "safe," perhaps because they cause the process to shut down, only those failures which remain hidden but will fail the operation of the safety function when it is called upon. This is essential as it assures us not to suppose that a safety-related product is generally more reliable than a general purpose product. The aim of safety-related product design is to have especially low failure rate of the safety task, but its total failure rate (MTBF) may not be so efficient. So, the MDT for a safety function is defined as a dangerous undetected failure will not be obvious until either a demand comes along or a proof test would be revealed it. Suppose we proof test our safety function every year or two, say every T1 hours. The safety function is equally likely to fail at any time between one proof test and the next, so, on average it is down for T1/2 hours.

Types of Failure

Failures generally be grouped into three basic types, though there may be more than one cause for a particular case. The three types included: early failures, random failures and wear-out failures. In the early life stage, failures as infant mortality often due to defects that escape the manufacturing process. In general, when the defective parts fail leaving a group of defect free products, the number of failures caused by manufacture problems decrease. Consequently the early stage failure rate decreases with age. During the useful life, failures may related to freak accidents and mishandling that subject the product to unexpected stress conditions. Suppose the failure rate over the useful life is generally very low and constant. As the equipment reaches to the wear-out stage, the degradation of equipment is related to repetitious or constant stress conditions. The failure rate during the wear-out stage increases dramatically as more and more occurs failure in equipment that caused by wear-out failures. When plotting the failure rate over time as illustrated in Figure 1, these stages make the so-called "bath tub" curve.

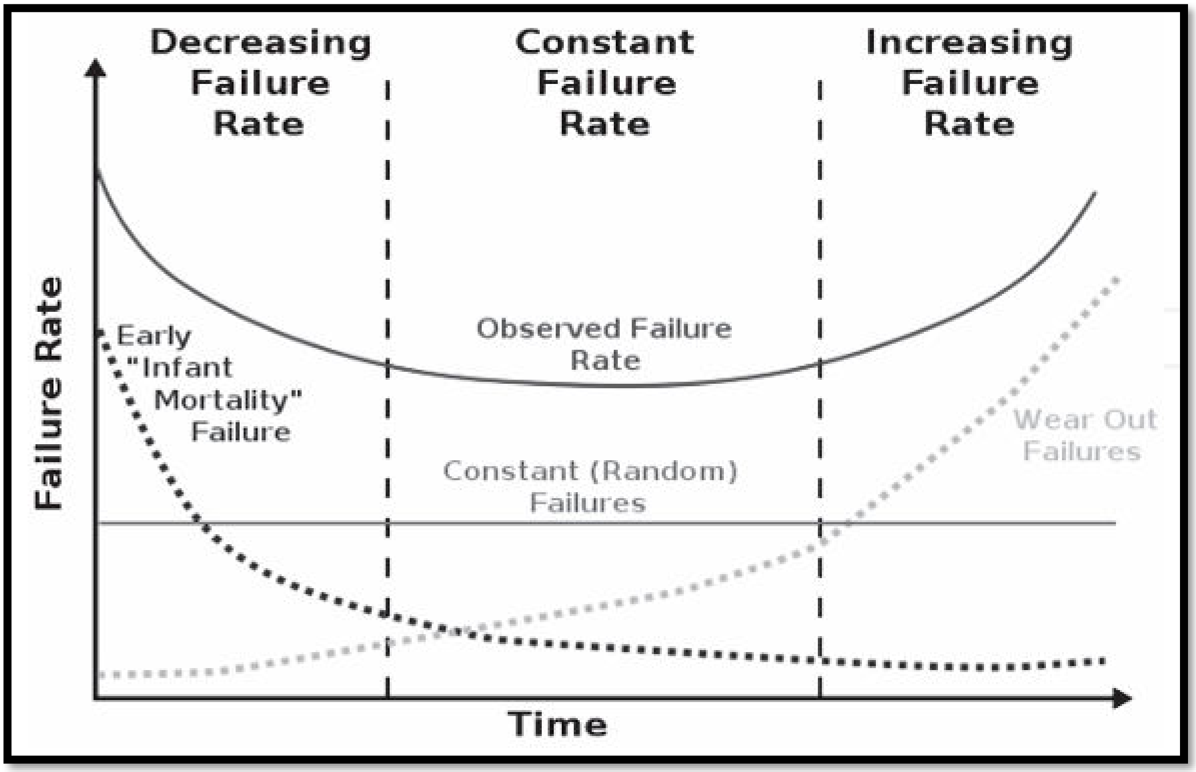

Figure 1. Curve for an ideal component

Useful life period: The maturity of product is caused that the weaker units extinct, the failure rate nearly shows a constant trend, and modules have entered what is considered the normal life period. This period is characterized by a relatively constant failure rate. The length of this period is related to the product or component system life. During this period of time, the lowest failure rate happens. Notice how the amplitude on the bathtub curve is at its lowest during this time. The useful life period is the most common time frame for making reliability predictions.

MTBF vs. useful life: Sometimes MTBF is mistakenly used instead of component's useful life. Consider, the useful life of a battery is 10 hours and the measure of MTBF is 100,000 hours. This means that in a set of 100,000 batteries, there will be about one battery failure every 1 hour during their useful lives. Sometimes these numbers are so much high, it is related to the basis calculations of failure rate in usefulness period of component, and we suppose that the component will remain in this stage for a long period of time. In the above example, wear-out period decreases the component life, and the usefulness period becomes much smaller than its MTBF so there is not necessarily direct correlation between these two. Consider another example, there are 15,000 18-year-old humans in the sample. Our investigation is related to 1 year. During this period, the death rate became 15/15,000 = 0.1%/year. The inverse of the failure rate or MTBF is 1/0.001 = 1000. This example represents that high MTBF values is different from the life expectancy. As people become older, more deaths occur, so the best way to calculate MTBF would be monitor the sample to reach their end of life. Then, the average of these life spans are computed. Then we approach to the order of 75–80 which would be very realistic.

Wear-out period: As fatigue or wear-out occurs in components, failure rates increasing high. Power wear-out supplies is usually due to the electrical components breakdown that are subject to physical wear and electrical and thermal stress. Furthermore, the MTBFs or FIT rates calculated in the useful life period no longer apply in this area of the graph. A product with a MTBF of 10 years can still exhibit wear-out in 2 years. The wear-out time of components cannot predict by parts count method. Electronics in general, and Vicor power supplies in particular, are designed so that the useful life extends past the design life. This way wear-out should never occur during the useful life of a module.

Sources of Failure

There are two major categories for system outages: 1. Unplanned outages (failure) and 2. Planned outages (maintenance) that both conducted to downtime. In terms of cost, unplanned and planned outages are compared but use the redundant components maybe mitigate it. The planned outage usually has a sustainable impact on the system availability, if their schematization be appropriate. They are mostly happen due to maintenance. Some causes included periodic backup, changes in configuration, software upgrades and patches can caused by planned downtime. According to prior research studies 44% of downtime in service providers is unscheduled. This downtime period can spent lots of money. Another categorization can be:

• Internal outage
• External outage

Specification and design flaws, manufacturing defects and wear-out categorized as internal factors. The radiation, electromagnetic interference, operator error and natural disasters can considered as external factors. However, a well-designed system or the components are highly reliable, the failures are unavoidable, but their impact mitigation on the system is possible.

Failure rate data: The most common ways that failure rate data can be obtained as following: •Historical data about the device or system under consideration.

• Government and commercial failure rate data. The available handbooks of failure rate data for various equipment can be obtained from government and commercial sources. MIL-HDBK-217F, reliability prediction of electrical equipment, is a military standard that provides failure rate data for many military electronic components. Several failure rate data sources are available commercially that focus on commercial components, including some non-electronic components.

• Testing: The most accurate source of data is to test samples of the actual devices or systems in order to generate failure data. This is often prohibitively expensive or impractical, so that the previous data sources are often used instead.

Derivations of failure rates equations: This section shows the derivations of the system failure rates for series and parallel configurations of constant failure rate components in Lambda Predict.

$R_S = R_1 . R_2 ... R_n$

Where R1, R2..., Rn are the values of reliability for the n components. If the failure rates of the components are $\lambda_1, \lambda_2, ..., \lambda_n$,

Therefore, the system reliability can be expressed in terms of the system failure rate, λS, as:

$R_S = e^{-\lambda_s t}$

Where $\lambda s = \sum_{i=1}^{n} \lambda i$ and λS is constant. Note that since the component failure rates are constant, the system failure rate is constant as well. In other words, the system failure rate at any mission time is equal to the steady-state failure rate when constant failure rate components are arranged in a series configuration. Its time derivative is:

$$\frac{dR_s}{dt} = -n\left(1-R_c\right)^{n-1}\frac{dR_c}{dt} \quad \text{.......8}$$

Substituting into the expression for the system failure rate yields:

$$\lambda_s = \frac{-n\left(1-R_c\right)^{n-1}\frac{dR_c}{dt}}{1-\left(1-R_c\right)^{n}} \quad \text{.......9}$$

For constant failure rate components, the system failure rate becomes:

$$\lambda_s = \frac{n\lambda_c e^{-\lambda_c t}\left(1-e^{-\lambda_c t}\right)^{n-1}}{1-\left(1-e^{-\lambda_c t}\right)^{n}} \quad \text{.......10}$$

Thus, the failure rate for identical constant failure rate components arranged in parallel is time dependent. Taking the limit of the system failure rate as t approaches infinity leads to the following expression for the steady-state system failure rate:

$^{\lambda}$steady state= nλc……………………………………………………………11

So the steady-state failure rate for a system of constant failure rate components in a simple parallel arrangement is the failure rate of a single component. It can be shown that for a k out- of-n parallel configuration with identical components:

$^{\lambda}$steady state= nλc……………………………………………………………12

4. Conclusions

The analysis of failure rates in Information and Communication Technology (ICT) projects reveals significant challenges across various sectors, particularly in public and emerging markets. High failure rates are attributed to factors such as inadequate project management, lack of user involvement, and insufficient training. Understanding these elements is crucial for improving project outcomes.

Inadequate Management and Planning: Poor budget planning and lack of risk management are prevalent issues leading to project failures.

Inadequate Training and Knowledge: Many educators lack the necessary training to effectively integrate ICT into their teaching practices, leading to a reliance on basic ICT literacy rather than comprehensive integration

Employee Competence and Training: A study indicated employee training as critical for success.

User Involvement: End-user engagement is essential

Infrastructure Challenges: Insufficient ICT infrastructure hampers the effective use of technology in educational settings, resulting in underutilization of available resources

High Failure Rates in Software Development: The failure rate of software projects often due to poor management and unclear objectives

Technological Reliability: ICT failures can significantly impact network reliability, increasing energy supply interruptions.

Implications of High Failure Rates

The persistent high failure rates in ICT projects not only hinder organizational performance but also affect overall economic growth. While some argue that the focus should shift towards better evaluation techniques and risk management strategies, the underlying issues of training and user involvement remain critical for success in ICT implementations

5. Recommendations

To reduce material failure rates, a multifaceted approach is recommended, integrating process improvements, material optimization, and quality management. This strategy involves addressing root causes of failures, optimizing design and production processes, and implementing continuous improvement practices.

Enhanced Training Programs: Implementing targeted training for educators and ICT staff can improve the effective use of technology.

Robust Policy Frameworks: Developing clear and adaptable ICT policies that consider local contexts can enhance compliance and effectiveness.

Stakeholder Engagement: Involving local stakeholders in the policy-making process can ensure that ICT initiatives align with community needs and capabilities.

While these recommendations aim to address the identified failures, it is essential to recognize that the dynamic nature of technology requires continuous adaptation and evaluation of ICT policies to remain relevant and effective.Conversely, while ICT can reduce material failure rates, over-reliance on technology may lead to complacency in traditional quality control practices, potentially increasing risks if not managed properly.

Conflict of interest: The authors declare that they have no competing interests and this paper is part of my PhD dissertation.

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