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# Adaptive Risk Management and Resilience in Automated Electronics Industry

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**Abstract** The electronics industry stands as one of the largest sectors in the United States, encompassing the design, manufacturing, testing, and sale of electronic products. Within this industry, the production section plays a pivotal role, involving numerous workers in the generation of various electronic components or complete products. However, this sector is not without its challenges, as various risks pose threats that can lead to accidents, adversely affecting worker health, safety culture, and the overall working environment. This research aims to assess incidents of risk, analyze related accidents, and identify high-impact misfortunes by assigning risk scores. The focus is on creating a comprehensive risk analysis worksheet to establish effective control measures. Another crucial objective is the evaluation of the Risk Priority Number (RPN) by considering extremity, detection, and occurrence data to identify more severe accidents. Utilizing these methodologies, the research seeks to bring immediate attention to potential concerns within the production section, fostering a proactive approach to reduce injuries and enhance the safety culture among workers in this specific segment of the electronics industry.

**Keywords** Safety, Production culture, Electronics Industry.

## 1. Introduction

The electronics industry in the United States is a critical component of the nation's manufacturing sector, contributing significantly to economic growth, technological innovation, and job creation. However, like any complex and dynamic sector, the production of electronic goods is not immune to risks that can impact operational efficiency, financial stability, and overall sustainability. Recognizing the need for proactive strategies to mitigate and manage these risks, an effective approach to risk management is paramount in ensuring the resilience and long-term success of the electronics industry in the USA. In recent years, the electronic production sector has faced a myriad of challenges, ranging from supply chain disruptions and geopolitical uncertainties to rapid technological changes and regulatory shifts. These challenges underline the inherent vulnerabilities that can disrupt the smooth flow of production processes and, consequently, pose threats to the industry's competitiveness. In response, adopting a comprehensive risk management framework becomes imperative, one that not only identifies potential risks but also formulates strategies to mitigate their impact and capitalize on emerging opportunities. The approach to risk management in the production sector of the electronics industry involves a multifaceted strategy that encompasses several key elements. First and foremost is the identification and assessment of various risk factors, including supply chain vulnerabilities, market fluctuations, and geopolitical tensions that may affect the industry's operations. Utilizing advanced risk assessment tools and methodologies, stakeholders can gain a deeper understanding of the potential threats, allowing for informed decision-making. Moreover, an effective risk management approach involves the development of contingency plans and resilience strategies. By anticipating potential disruptions and developing robust contingency plans, the industry can enhance its ability to respond swiftly and effectively to unforeseen events, minimizing downtime and ensuring a more resilient production ecosystem. This proactive stance not only mitigates risks but also positions the industry to adapt to changing circumstances and emerge stronger in the face of challenges.

From the investigation, it was identified that occupational hazards exist in various sectors within the shipbuilding industry, encompassing tasks such as painting, production, and welding, among others [4]. Another publication emphasized that local shipyards cater to diverse demands, constructing ships ranging from approximately three thousand to five thousand deadweights, with some shipyards capable of fabricating vessels up to ten thousand deadweights [5].

Numerous research endeavors have been undertaken in the domain of risk management. One study delved into the risks associated with purchasing electronics from marketplaces, revealing that risks and trust concerns were linked to the purpose of the purchase [5]. Another research focused on accident analysis and prevention, highlighting that risks were influenced by the perceived abilities of male drivers based on their ages [6]. Additionally, a model was developed to explore motivational factors and their impact on drivers' decision-making processes, aiming to analyze and prevent accidents [3]. In the electronics industry's production department, a study identified the necessity for robust prevention measures to mitigate inherent risks in production processes. Various techniques, including Failure Mode and Effect Analysis (FMEA), were employed to manage risks associated with a range of failures [6]. Cross-cultural variations in risk analysis and treatment were considered in another research project, revealing that the risk management process differed across cultures, particularly in the context of drivers and accident mitigation [7]. A study indicated that risk-taking behaviors and risk prevention activities varied across different managerial perspectives. In certain industries with distinct sections, each managed by a designated team, managerial responsibilities were assigned to ensure comprehensive risk management [8]. Noman et al. (2020) and (2024) executed a notable project on data retrieval approaches, highlighting the pivotal role of coding technology in adjusting various parameters in production environments for the purpose of identifying risks in this research [22-25].

Research was conducted to evaluate the prioritization of risk priority numbers for the effects of failure modes and criticality analysis, utilizing a ranking scale ranging from 1 to 10 [9]. Another study focused on assessing hazards to workers' health and fostering safety awareness among garment workers to ensure their safety and mitigate risks. The research identified causes of health hazards and implemented preventive measures [10]. Buian et al. (2024) and Iqtiar et al. (2024) discussed issues related to car production and parking using sensor technology, along with the significant impact of new manufacturing operations technology on production [27-30]. Molla et al. and Hasan et al. explored how risk factors can profoundly impact the automated industry, providing valuable insights for our analysis [31,32]. Research work distinctly highlighted the differences between risk management and knowledge management [11]. An investigation analyzed life-threatening health problems resulting from exposure to polycyclic aromatic hydrocarbons due to specific risk events, outlining a risk assessment procedure [3]. Several studies focused on process selection and supplier selection to facilitate risk identification for increased factory profitability. Molla et al. identified optimal scenarios for production data analysis and risk identification, contributing to our research [16,18,19,20,21]. Mustaquim (2024) contributed to two different papers on remote sensing methods in land surface interpretation, presenting valuable insights for water treatment process optimization work, with risk identification using the RPN method as a future motivation [26].

In another research endeavor, a model was developed to explore perceived risk and intended risk-mitigating activities [4]. A study investigated whether different welders were at a higher risk of respiratory infections and, if so, outlined preventive measures [2]. Additionally, a study examined subjective probabilities of accidents for various risks, revealing that mitigation processes varied based on age and behavior [1]. The studies illustrate the impact of perceived usefulness and perceived ease of use on the intention to adopt Artificial Intelligence (AI), with these factors being influenced by elements within both the internal and external environments. Their findings indicate that internal factors such as competency, complexity, readiness, and compatibility, along with external factors like competitive advantage and partner support, contribute to shaping the perceived usefulness of AI adoption [33,50]. They have discussed in detail how breast cancer, brain cancer, and other diseases are diagnosed using deep learning and machine learning algorithms [35-40]. In this example, the authors explain sentiment analysis and real-time scenarios using predictive simulation modeling software, which can perform highly secure encryption of real-time voice signals and ensure nuclear reactor safety [41-48]. In the age of the Internet of Things (IoT) and Industry 4.0, there is a growing trend of interconnecting machines and devices. However, this increased connectivity brings along security vulnerabilities and potential threats to these devices. Unlike traditional IT systems where updates are regularly provided to address vulnerabilities, industrial automation, and control systems, particularly those in mass production, often rely on legacy systems. Updating these systems can result in downtime, posing a challenge as maintaining availability is a paramount objective. In instances of cybersecurity threats, halting machine operations is frequently deemed too costly [34]. Conversely, only internal factors like complexity and external factors such as competitive advantage impact the perceived ease of use. It is noteworthy that these investigations span diverse contexts, yet they offer limited insights into the realm of risk management.

## 2. Procedure

In conducting this study, two methods were utilized: a risk evaluation worksheet and a risk priority number. Tables were created to analyze the risk priority number and risk evaluation worksheet.

### 2.1 Sample Size

To determine and assess hazardous incidents and accidents in the electronic part of an industry. An interview and survey were carried out to uncover risk incidents and accidents in the manufacturing department of the electronics sector among workers with diverse characteristics such as gender, education levels, ages, work experience, and accident knowledge. Two methods employed in this study were the risk evaluation worksheet and the risk priority number. Tabular formats were developed to analyze the risk priority number and risk evaluation worksheet.

- Open-ended questions were employed to determine the hazards, accidents, detentions, and magnitude of these incidents.
- Multiple-choice questions were utilized for assessing the frequency of these accidents on a weekly, quarterly, monthly, or yearly basis.

### 2.2 Data Collection

The age of the workers was between 25 and 50 years. Sample employees are the following: (1) section manager; (2) executives; (3) supervisor; (4) operator; (5) foremen; and (6) workers. Both male and female workers were taken as a sample size. Using equation (1) (Odunaiya, Owonuwa and Oguntibeju 2014), the sample size was calculated. Here, N = population size, n = anticipated sample size, and $e$ = level of accuracy. In this study, N = 120, $e$ = 5% at 95% confidence level.

$$n = N/(1+Ne^2) \qquad (1)$$

Thus, it was found that 92 or more people made up the required sample size. Thus, 95 personnel were considered.

## 3. Data Analysis

The data analysis is discussed as follows:

A comprehensive risk analysis worksheet was formulated to identify potential adversities, their underlying causes, preventive measures, and the assessment of both the likelihood and severity of hazards. Plausibility and extremity measures, crucial for assigning risk scores, are presented in Tables 1 and 2 [9]. Additionally, Table 3 provides a detailed risk assessment worksheet [9], offering a structured framework for evaluating and managing risks. This systematic approach enhances our ability to assess the probability and severity of potential misfortunes, contributing to a robust risk management strategy.

**Table 1:** Plausibility scale

| Plausibility of Cause | Eventuality of Cause | Rating |
|---|---|---|
| Very frequently | Once per every month or more often | 5 |
| Frequently | Once per every year | 4 |
| Occasionally | Once per every ten years | 3 |
| Very rarely | Once per every thousand years | 2 |
| Never | Once per every ten thousand years | 1 |

The risk assessment scale delineates five levels of extremity associated with potential occurrences, each with corresponding causes and ratings. At the highest level, "Catastrophic" signifies that a breakdown could result in serious harm or death, receiving a rating of 5. "Critical" follows, indicating a breakdown leading to minor injuries and receiving a rating of 4. The "Moderate" level denotes a breakdown resulting in a medium or high level of exposure without causing injury, garnering a rating of 3. "Minor" suggests a breakdown with low exposure but no injuries, assigned a rating of 2. The lowest level, "Negligible," signifies a breakdown resulting in negligible exposure, receiving a rating of 1. This structured scale enables a nuanced evaluation of potential risks, aiding in the formulation of targeted risk management and mitigation strategies based on the severity and likelihood of occurrences.

**Table 2:** Extremity scale

| Extremity | Causes of occurrence | Rating |
|---|---|---|
| Catastrophic | Breakdown results in serious harm or death. | 5 |
| Critical | Breakdown results in minor injury | 4 |
| Moderate | Breakdown results in a medium or high level of exposure without resulting in any injury | 3 |
| Minor | Breakdown results in a low level of exposure but does not cause any injury | 2 |
| Negligible | Breakdown results in a negligible exposure | 1 |

Rahman et al. (2023) elucidates the functioning of line balancing within production environments, highlighting the interplay between efficiency, associated costs, and the overall profitability of a company. This insightful information has been instrumental in shaping our research methodology, particularly in the context of risk assessment. We have incorporated this valuable knowledge into our approach, leveraging simulation optimization across various scenarios to enhance the optimization of production lines [17]. Jamil et al. (2024) describes the criteria for their supply chain determinants in a very innovative way and this concept is used in our Risk evaluation worksheet [49]. By integrating risk assessment into the optimization process, we aim to identify and mitigate potential risks that may impact the efficiency, cost-effectiveness, and ultimately, the overall profitability of the company. This ensures a comprehensive approach that not only focuses on improving operational efficiency but also considers and addresses potential risks inherent in the production environment.

**Table 3:** Risk Evaluation Worksheet

| S. No. | Risk events | Coincident | Possible causes | Plausibility (P) | Extremity (E) | P*E | Control measure |
|---|---|---|---|---|---|---|---|
| 1. | Environment and Surroundings (ES) | Hazardous fumes | • Problems involving gases from exhaust disposal | 2 | 4 | 8 | 1. Appropriate training and education<br>2. Effective gas disposal unit<br>3. Adequate space<br>4. Proper ventilation system |
| | | Noise contamination | • Vibration generated by machinery.<br>• Overly loud engine noise | 4 | 2 | 8 | |
| | | Inadequate ventilation | • Unanticipated construction<br>• Congested spot for the production | 3 | 3 | 9 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Poor lighting system | • Issues with the connection of the electronic devices | 1 | 3 | 3 | |
| | | Excessive amounts of heat | • Continuous operation of the engine | 3 | 3 | 9 | |
| 2. | Health of Personnel (HP) | Physical damage | • Lifting excess weight<br>• Falling from a height, slipping, and tripping | 2 | 5 | 10 | 1. Proper training and counselling<br>2. Accessibility of first aid appliances<br>3. Ensuring personal protective equipment (PPE) uses<br>4. Proper hygiene across the workplace |
| | | Chronic as well as acute diseases | • Flammable substance<br>• Unhygienic condition of the workplace | 3 | 3 | 9 | |
| | | Trouble with vision | • Improper lighting system | 2 | 3 | 6 | |
| | | MSDs | • Sever tissue damage.<br>• Incorrect posture<br>• Working extra hours | 2 | 5 | 10 | |
| | | Suffocation | • Unbearable temperature and humidity | 2 | 4 | 8 | |
| | | Stress and anxiety | • Excess workload<br>• Lack of resting period | 4 | 2 | 8 | |
| | | Trouble in concentration | • Work stress.<br>• Personal problems | 3 | 3 | 9 | |

**3.1 Calculation of Risk Priority Number (RPN):**

Risk priority number or RPN number was calculated by multiplication of extremity, eventuality and detection for each accident caused by risk incident. Table 4 and Table 5 show extremity, eventuality, detection ranking scale and risk priority number calculation according to [10].

**Table 4:** Extremity, Eventuality and Detection ranking scale

| **Extremity** | | **Eventuality** | | **Detection** | |
|---|---|---|---|---|---|
| **Rank** | **Effect** | **Rank** | **Effect** | **Rank** | **Effect** |
| 7 | High risk without warning | 7 | Very high: Failure is almost inevitable | 7 | Absolute uncertainty |
| 6 | High risk with warning | 6 | | 6 | Remote |
| 5 | High | 5 | High: Repeated failures | 5 | Low |
| 4 | Moderate | 4 | Moderate: Occasional failures | 4 | Moderate |
| 3 | Low | 3 | Low: Relatively few failures | 3 | Moderately High |
| 2 | Minor | 2 | | 2 | High |
| 1 | None | 1 | Remote: Failure is unlikely | 1 | Almost Certain |

**Table 5:** Determining RPN (Risk Priority Number) through Eventuality, Extremity and Detection

| Risk events | Coincident | Eventuality (E) | Extremity (E) | Detection(D) | E*E*D(RPN) |
|---|---|---|---|---|---|
| Environment and Surroundings (ES) | Hazardous fumes | 3 | 6 | 3 | 54 |
| | Noise contamination | 6 | 4 | 1 | 24 |
| | Inadequate ventilation | 5 | 7 | 4 | 140 |
| | Poor lighting system | 3 | 5 | 2 | 30 |
| | Excessive amounts of heat | 4 | 5 | 3 | 60 |
| Health of Personnel (HP) | PhysicalProblem | 3 | 7 | 5 | 105 |
| | Chronic as well as acute diseases | 5 | 4 | 4 | 80 |
| | Trouble with vision | 4 | 5 | 5 | 100 |
| | MSDs | 4 | 7 | 6 | 168 |
| | Suffocation | 3 | 6 | 3 | 54 |
| | Stress and anxiety | 5 | 3 | 2 | 30 |
| | Trouble in concentration | 4 | 5 | 2 | 40 |
| Economic | Issue with budget | 1 | 6 | 5 | 30 |
| | Lack of productivity | 3 | 5 | 6 | 90 |
| | Degradation of infrastructure | 2 | 4 | 4 | 32 |
| | High employee turnover rate | 4 | 6 | 5 | 120 |
| | Unjustifiable timetable | 2 | 6 | 4 | 48 |
| Machines and Equipment (ME) | Failure | 3 | 7 | 4 | 84 |
| | Excessive idle time | 4 | 5 | 5 | 100 |
| | Underutilization | 3 | 6 | 2 | 36 |
| | Excessive error | 1 | 6 | 4 | 24 |
| Technology Related (TR) | Poor execution | 3 | 5 | 3 | 45 |
| | Technical malfunction | 4 | 7 | 5 | 140 |
| | Time lag | 5 | 5 | 4 | 100 |
| Production Procurement (PP) | High cost | 2 | 6 | 3 | 36 |
| | Excessive inventory turnover | 3 | 6 | 3 | 54 |
| Quality of Product (QP) | High number of faults | 3 | 6 | 4 | 72 |
| | Large return rate | 2 | 7 | 3 | 42 |
| | Decrease in company goodwill | 1 | 7 | 4 | 28 |
| | Low quality | 3 | 6 | 2 | 36 |
| Management of Materials (MM) | Serious damage to the body | 2 | 7 | 4 | 56 |

| | | | | | |
|---|---|---|---|---|---|
| Others | Overly time-consuming | 4 | 5 | 6 | 120 |
| | Explosion of fire | 2 | 7 | 4 | 56 |
| | Security concern in production | 1 | 5 | 6 | 30 |
| | Electrical ignition | 2 | 7 | 3 | 42 |

**4.Result Analysis and Discussion**

The data analysis from risk evaluation worksheet (Table 3) shows caused coincident corresponding to their relevant risk events. It also discusses possible causes and necessary control measures. From risk evaluation work sheet, we found that the total number of coincident pertaining to risk events, including those concerning the Environment and Surroundings (ES), Health of Personnel (HP), Economic, Machines and Equipment (ME), Technology Related (TR), Production Procurement (PP), Quality of Product (QP), Management of Materials (MM) and Others, is as follows: 37, 56, 27, 37, 10, 21, 26, 13, 13 and summation of Risk Priority Number (RPN) from Table- 5 are 308, 577, 320, 289, 140, 190, 178, 176 and 128 respectively. Figure 1 depicts the Illustration of Multiplication of Plausibility and Extremity. This figure indicate that the following is the sequence of significant risk incidents: Health of Personnel (HP), Environment and Surroundings (ES), Machines and Equipment (ME), Economic, Quality of Product (QP), Production Procurement (PP), Management of Materials (MM), Others, and Technology Related (TR). Figure 2 illustrates the Assessment of the Risk Priority Number. It demonstrates that accidents resulting from Health of Personnel are the most dangerous while those caused by others are the least dangerous.

The following are recommendations or tips to prevent coincident:

- Implementing control measures as outlined in the risk evaluation worksheet.
- Raising awareness among the individuals.
- Strict laws should be implemented for industries that violate preventive or control measures.

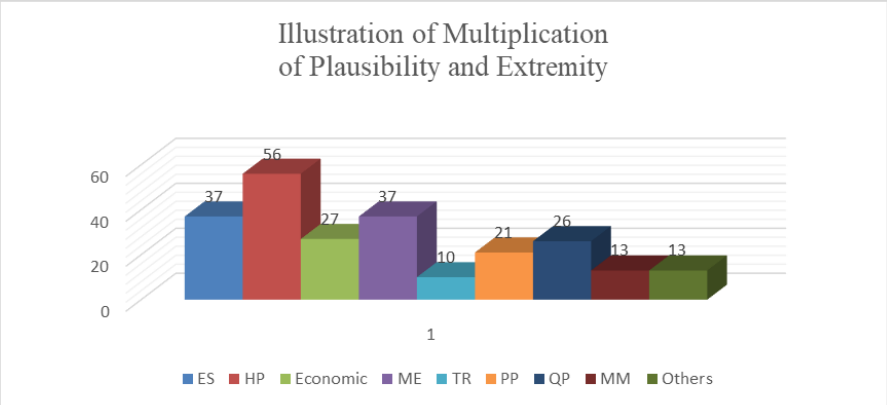


*Figure 1: Illustration of Multiplication of Plausibility and Extremity*

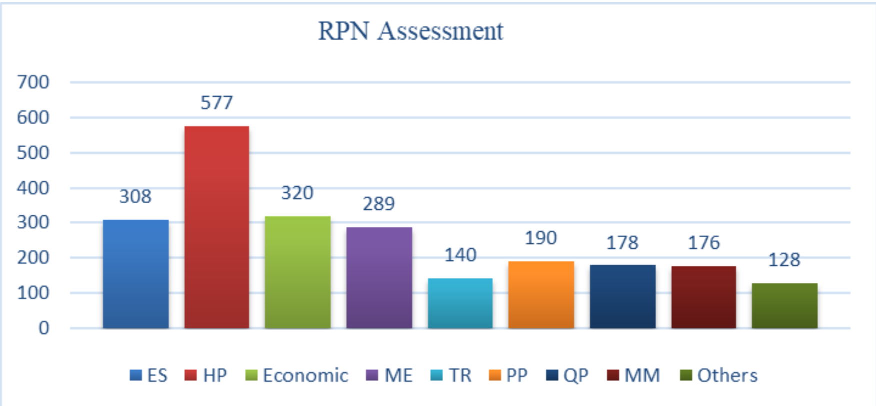


*Figure 2: Assessment of the Risk Priority Number*

## 5. Research Limitations

Regulatory endorsement plays a crucial role in shaping the perceptions of managers and fostering user acceptance of emerging technologies in a broad context. The uncertainties and lack of comprehension surrounding technology adoption can be mitigated by policies that encourage organizations to provide training and allocate resources, facilitating a smoother transition to the integration of emerging technologies for effective risk management. This, in turn, could prompt policymakers to institute additional initiatives aimed at supporting companies in their digital transformation endeavors, with the goal of promoting regional development and establishing resilient organizations capable of navigating challenges in the digital manufacturing era. Stakeholder influence emerges as a key factor in helping organizations recognize the value of technologies. Insights from various supply chain stakeholders, including customers, suppliers, and competitors, prove instrumental in assessing the advantages of incorporating emerging technologies for risk management [33]. This discovery offers an impetus for managers to advocate for transparency, sharing best practices with their supply chain counterparts to unlock benefits and showcase the transformative impact of Industry 4.0 technologies in their operational processes. Furthermore, prioritizing investments in organizational resilience can foster a greater inclination toward technology adoption for risk management. Organizations that comprehend their vulnerabilities and anticipate the potential consequences of disruptions are more likely to appreciate the prospective benefits of disruptive technologies. Leveraging capabilities such as flexibility and adaptability becomes pivotal in supporting the implementation of technologies like blockchain and AI. This outcome underscores the managerial recognition of the intricate relationship between heightened organizational capabilities and the advantageous outcomes associated with the adoption of technology.

## 6. Conclusion

In conclusion, implementing an effective risk management approach is imperative for the sustained success and resilience of the electronics production sector in the USA. Recognizing the intricate challenges posed by factors such as supply chain disruptions, geopolitical uncertainties, and rapid technological changes is paramount. By fostering a proactive risk management culture, organizations can enhance their ability to identify, assess, and mitigate potential risks, thereby safeguarding production continuity and ensuring product quality. Strategic collaboration and information-sharing among industry stakeholders, government bodies, and research institutions are crucial components of a robust risk management strategy. This approach facilitates the development of anticipatory measures, regulatory frameworks, and industry standards that collectively fortify the sector against diverse threats. Embracing innovative technologies, such as advanced analytics and artificial intelligence, can provide real-time insights, enabling swift responses to emerging risks. Moreover, the incorporation of scenario planning and continuous risk assessment practices enables organizations to adapt to evolving circumstances. By fostering a resilient production ecosystem, the electronics industry in the USA can not only navigate uncertainties but also seize opportunities for growth and innovation. Ultimately, a comprehensive risk management framework serves as a strategic imperative, ensuring the long-term sustainability and competitiveness of the electronics production sector in the dynamic landscape of the 21st century.

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