UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ

Colegio de Ciencias e Ingenierías

Risk Analysis in an Ammunition Company

.

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Ingeniería Industrial

Trabajo de fin de carrera presentado
como requisitopara la obtención del
título de
INGENIERA INDUSTRIAL

Quito, 20 de diciembre de 2022

UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ

Colegio de Ciencias e Ingenierías

**HOJA DE CALIFICACIÓN
DE TRABAJO DE FIN DE CARRERA**

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Quito, 20 de diciembre de 2022

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Lugar y fecha: Quito, 20 de diciembre de 2022

ACLARACIÓN PARA PUBLICACIÓN

UNPUBLISHED DOCUMENT

RESUMEN

Para las empresas de todo el mundo, la salud y la seguridad de los trabajadores debe ser una prioridad. Este es un concepto vital y para que se lleve a cabo, las empresas deben tomar medidas. Este documento tiene como idea principal ayudar con este noble objetivo. Este estudio contiene un análisis de riesgo de una fábrica de municiones de alto riesgo. Para realizar el análisis de riesgos se investigó metodologías de análisis de primeros riesgos y riesgos históricos en la industria. Se seleccionaron un total de 4 métodos. El primer método, ANACT, se utilizó para clasificar las áreas de mejora en función de las relaciones de área de trabajo. A continuación, a cada estación de trabajo se le asignó una puntuación basada en el método RNUR. Luego, se continuó con el análisis mediante la identificación de áreas problemáticas potenciales dentro de la línea de producción utilizando el método NTP 330. El último método utilizado, FINE, se utilizó para realizar un análisis económico y justificar las posibles soluciones generadas. Una vez completadas las metodologías, se entregó un conjunto de preguntas a los trabajadores para tener una visión de la cultura de seguridad existente. Con base en esos resultados, se identificaron múltiples acciones beneficiosas y se proporcionaron al equipo administrativo para su implementación.

Palabras Clave: Análisis de Riesgo, Salud, Seguridad, ANACT, RNUR, NTP 330, FINE

ABSTRACT

For companies all across the globe, the health and safety of workers must be a priority. This is a vital concept and in order to be brought to fruition, the companies must take action. This paper aims to assist with this lofty goal. This study contains a risk analysis of a high-risk ammunition factory. To carry out the risk analysis, first risk analysis methodologies and historic risks in the industry were researched. A total of 4 methods were selected. The first method, ANACT, was used to classify areas for improvement based on work-area relationships. Next, each workstation was given a score based on the RNUR method. Then, the analysis was continued by identifying potential problem areas within the production line using the NTP 330 method. The final method used, FINE, was utilized to perform an economic analysis and justify the generated potential solutions. After the methodologies were completed, a set of questions were provided to the workers to gain a view of the existing culture of safety. Based on those results, multiple beneficial actions were identified and provided to the administrative team for implementation.

Key Words: Risk Analysis, Health, Safety, ANACT, RNUR, NTP 330, FINE

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1. INTRODUCTION

The most critical component of a company is its human capital because not only is it the key to the production of goods or services, but it is also a sustainable concept that tremendously improves efficiency (Pasban, 2016). Thus, it is essential that within each company, the well-being and safety of each employee are guaranteed. This need is prevalent all around the world, making it a global issue. Often, safety in companies is not completely or adequately considered or managed, hence, work accidents occur, affecting the overall health and well-being of the people who collaborate within the company.

The International Labor Organization (ILO) estimates that every year, 2.78 million people die during their working hours as a consequence of accidents. This rate is equivalent to about 20 people dying from work-related incidents every day (ILO, 2020). In comparison, this estimation in 1999 was only about one million recorded deaths per year. These results show a major increase in work-related deaths in the last 20 years (ILO, 1999).

Companies in different industries have implemented less intensive prevention practices in their work areas, and therefore workers have not reinforced the idea of labor safety (Ivascu, 2019). The risk analysis performed in this article will begin with a previous general overview of the actual conditions of the company. Then, it will move on to the identification of the most relevant sources of risk and suggest economically achievable solutions for their adequate management. It will be complemented by reinforcing an accident-prevention culture that emphasizes the importance of occupational health and safety (Cole, 2013).

To analyze and generate solutions to this global issue, the scope of the problem should be focused more on the areas of interest. This outcome can be achieved by narrowing down the areas and industries that are being analyzed. To analyze this problem in Ecuador, a study was carried out on the working conditions in Ecuador, published by the Ministry of

Public Health. It concluded that beyond the direct costs of work accidents, there is a loss of between 4 to 10% of the gross domestic product (MSP, 2022). Similarly, in the 2018 Statistical Bulletin of Occupational Risks, the Ecuadorian Social Security Institute (IESS) reported the existence of a total of 3,521 records of occupational accidents. 96.1% of the records correspond to work accidents, while 3.9% of the records are related to occupational diseases (IESS, 2018). Note that for this study, a work accident and an occupational accident are considered equivalent.

In this article, we will develop a risk analysis at an Ammunition Company that produces explosive materials. Occupational accidents and risks occurring in industries handling and storing ammunition and explosives are not new in Ecuador. In 1997, there was an explosion in “La Balbina in the Battalion of Engineers No. 69 ‘Chimborazo’”. This explosion happened at a munitions storage facility and resulted in the deaths of 4 people and the destruction of many homes. In 2002, there was another explosion in the Armored Cavalry Brigade No. 11 "Galapagos" (Zahaczewsky, 2008). This facility was close to Riobamba. A grenade was accidentally detonated, causing 7 deaths and many more injuries. Also, in 2003, there was yet another explosion, but this time in the South Naval Base. This base is in Guayaquil. The explosion killed one person and injured 22 more people. The most recent explosion in this industry in Ecuador occurred in 2009 at the “Santa Bárbara” Ammunition Factory (Salazar, 2012). Like all of the previously mentioned accidents, it caused a loss of materials, a loss of human lives, and resulted in economic damage.

Based on the statistics about occupational accidents within this industry that were identified above and the fact that we live in a society that contains risks, it is mandatory to have a safe place to work. The purpose of this is to reduce risk levels and avoid fatal accidents (Beck, 1998). The present study aims to focus on the company, Santa Bárbara EP, specifically, the ammunition fabrication and storage area, an area involving workers in charge of operating different bullet assembly machines to supply ammunition to law enforcement. Although many different projects such as, “Protección y Seguridad de la Población Civil en el Almacenamiento y Manejo de Municiones y Explosivos de FF.AA.” (Protection and Safety of the Civilian Population in the Storage and Handling of Ammunition and Explosives of the Armed Forces), have been created to lower the number and magnitude of accidents in this type of industry, over the past couple of years the company in question has presented an economic loss due to occupational accidents. The aforementioned project was created by the Joint Command of the Ecuadorian Armed Forces. Its goal was to lower the chance of explosives accidentally detonating and reduce the risks posed to civilians and workers by this issue (Salazar, 2012).

2. GENERAL OBJECTIVE

Execute a risk analysis that allows the ammunition company to identify and manage existing risks while reducing the probability of workplace accidents and promoting a culture of safety.

3. SPECIFIC OBJECTIVES

- Run a diagnosis of the actual situation of risk factors in the ammunition department.
- Implement applicable risk analysis methodologies based on the characteristics of the company.
- Prioritize targeting the most critical and risk-prone conditions for workers.
- Find viable economic proposals to eliminate, mitigate, or control the identified risk, depending on their manageability.
- Present findings and proposed solutions to the company for their implementation.

4. LITERATURE REVIEW

Risk Analysis comes in many different forms and methods. This paper focuses on the ammunition sector in Ecuador, which has not been extensively researched and assessed. The article “Health, safety, and environmental unit performance assessment model under uncertainty (case study: steel industry)” investigates an industry with many case studies. It analyzes the steel industry because it is a risky industry worldwide and accidents are common and dangerous. “Health, safety, and environmental unit performance assessment model under uncertainty (case study: steel industry)” goes on to state the most influential HSE issues as control of disease, fire hazards, and air pollution (Shamaii, 2016). These are very important topics that are related to machine operation because of the similar hazards presented by the machines used in the ammunition industry to assemble various guns.

A separate article called “Identification of strategies to reduce accidents and losses in the drilling industry by comprehensive HSE risk assessment: A case study in the Iranian drilling industry” analyzes the petroleum drilling industry. (Amir-Heidari, 2016) These two articles are fairly similar. They do not contain the proper foundations to deal with the risks associated with the munitions industry, however, they establish a decent precedent to publish a risk analysis paper.

Another article, “Risk Analysis and Mitigation Strategy for Sugar Cane Production Processes (Case Study: X Sugar Cane Factory – West Java)”, focuses on analyzing the production risks of sugar cane production processes and how to mitigate them. It talks about how most risks come from the sugar supply processes such as milling, evaporation, and cogeneration (Suripto, 2018). It also discusses how these risks can be mitigated by managing the processes more effectively. This shows how it is important to include possible solutions to the potential problems that a risk analysis paper might expose.

As previously mentioned in the above paragraphs, very few Ecuadorian companies are dedicated to the production of ammunition and the assembly of firearms. There are even fewer risk assessments and case studies that have been written about these companies. They operate in an industry that contains major risks to its workers but lacks representation due to the lower number of companies. One article that thoroughly discusses this topic is "La Seguridad en el Almacenamiento de Municiones y Explosivos en el Ecuador" (Security of the Storage of Ammunition and Explosives in Ecuador). Similar to this paper, it was written as an analysis of Ecuadorian companies. Furthermore, it was also written about Ecuadorian companies that operate in the munitions and explosives sector. It explores previous disastrous events that have occurred at these companies over many years (Salazar, 2012). Most of these incidents involved dangerous explosions, which are common consequences of accidents in the munitions sector and often pose serious risks to all persons involved. Apart from mentioning the explosions, the article also highlights the projects and programs that were initiated to prevent events like those from ever happening again in the future. These programs were established to end unwanted detonations of explosive materials or munitions. It discusses the risks that arise from various sources such as natural, societal, psychological, and technological causes.

One more type of article that was researched to improve the content of this paper is an article that investigates multiple methods to accomplish a risk analysis. "Critical analysis of risk assessment methods applied to construction works" is a paper that mentions an extensive list of risk analysis methodologies. It describes each method and narrows its focus down to just 4 main methods that were selected based on their affinity to the construction industry (Carpio, 2017). While the construction industry is a little different than the munitions and explosives industry, it still lays the groundwork for what this paper hopes to achieve.

5. METHODOLOGY

Risk analysis may be carried out effectively with a variety of different methods. The methods used may vary based on the requirements of each industry and the risks related to them. The company studied in this paper does not have existing sources with the data required by the desired methods. Hence, in this analysis, the main factors of analysis were carried out through detailed in-person interviews with factory management and technicians, gathering company background data from the Human Resources and Safety departments, and establishing processes through technical diagramming, to satisfy the requirements for the present work.

The study was carried out during daytime shifts from 7:30 am to 3:30 pm from Monday to Friday to identify the tasks done by 7 workers, their frequency, and their duration. Based on these factors, the ANACT, RNUR, NTP 330, and FINE methods were selected for the present analysis. Each methodology fits the operating procedures of the company and supports the proposed objectives.

5.1 ANACT

The method of the Agence Nationale pour l' amélioration des Conditions de Travail (ANACT) is a large-scale risk analysis method intended for use by larger companies that export their product to an international market. This analysis technique solely deals with qualitative data and relies on a classification system based on a scale with three categories (Gonzales 2014). These categories are labeled as bad, regular, or good. This technique is somewhat different from the rest, but it ultimately achieves the same goal (Nogareda, 2000). This method is based upon the idea that the highest experts on safety within a facility are the workers employed there, no matter their position. Because of this, its data is based on a series of tables provided by the method (Nogareda, 2000) (Tables 1, 2, and 3).

This method works well at evaluating very low risks and very extreme risks. However, it is not as good at identifying and classifying risks falling in the middle of the spectrum. It leaves out a large set of data that could be beneficial for risk analysis. This sets it apart from the rest by allowing it to analyze both extreme ends of the spectrum, but the tradeoff is costly (Nogareda, 2000). In conclusion, the ANACT method is useful when trying to classify extreme risks, but does not stand well on its own and should be paired with other methods that complement its shortcomings.

5.2 RNUR

The Régie Nationale Des Usines Renault Methodology (RNUR) is a risk analysis method that grades various parameters based on their score against three safety factors. This allows it to identify the most at-risk areas. It is primarily applied to production chains. The goal is to improve personal and workplace safety. It is an effective technique that can be used to identify a large scale of risks ranging from normal risks to major catastrophes (Carpio, 2017). While it is typically a useful tool, it falters when used to detect very minor risks. It is a method that detects major risks.

The RNUR method uses qualitative results to determine if the desired outcome is satisfactory through a table that ranks the actual conditions of the factory. According to this scale, 1 is the most satisfactory, and 5 is the most dangerous (Carpio, 2017). It gathers, measures, and rates all the possible variables of a workplace. This is very useful because other methods can sometimes miss areas that they are not testing. This method tests the workplace. This may miss very minor details, but when used correctly it can be very beneficial as it pinpoints risk areas and gives results in an easy-to-understand form (VASILIU, 2013).

5.3 NTP 330

The National Institute of Safety and Hygiene at work (INSHT) has proposed and developed a risk analysis method known as NTP 330. This method allows the ranking of existing risks based on their magnitude (Espinheira, 2020). Instead of using specific values, this method uses 4 generalized levels to make its application much simpler and more practical (Belloví, 1993). It considers the probability, deficiency, and exposure levels of each identified risk. It uses those parameters to develop a risk matrix for analysis, which can be easy to read and allows the results to be clearly displayed. These can be used to determine which risks need immediate solutions and must be prioritized (Belloví, 1993).

5.4 FINE

The Fine Technique is a way to mathematically calculate risk from quantitative data. It is a broad method that can be used in many areas. It rates the significance of a risk on a scale of very high, high, remarkable, possible, and acceptable. It is useful for detecting small to normal risks but should be reconsidered when applied to extreme risks (Carpio, 2017). It provides a beneficial economic analysis that can be used to determine justifiability.

This technique uses a formula that determines the significance of a risk based on its level of danger. The formula has a few parameters it considers; The first parameter is a probability factor, which is the likelihood of the event under investigation. The second parameter is the possible consequences of an event. The third parameter is an exposure factor. Those factors are all considered and output the final risk significance score (Carpio, 2017). Overall, it is a complex method, but can be used to identify details that other tests might miss.

The presented methods work together efficiently by addressing the problem from different angles and prioritizing the most critical needs (Bessa, 2015).

6. IMPLEMENTATION OF THE METHODS

6.1 Company background

Santa Bárbara EP is a company located in Sangolquí, Ecuador, that began operation in 1978. Currently, it has 72 workers divided into two sections. The first section is the administrative department, where 21 people work. The second section corresponds to the manufacturing operations with 51 workers. This study focuses on the 2nd section, the manufacturing plant, where the company has 3 main areas: guns, ammunition, and metal structures (See Figure 1).

The company operates in an area of 13,400 square meters. This study will focus on the ammunition department. The reception, assembly, quality control, and packaging of the ammunition can be seen in Figure 2.

To better understand how the company operates, the general process of the company is presented in Figure 3. This describes the general process of the production of the ammunition. It starts with the quality control of the raw materials and ends with the packaging of the finished products.

Specifically, the area operates under two different production lines. The first one is done automatically through the assembly machine, and the second is carried out manually by the workers, who compress the gunpowder into each bullet casing. The criteria used by the operators on whether to choose a production line depends mainly on the quantity required to produce. If the required number of bullets is under 100,000 units, the manual line is used.

6.2 Products

The ammunition department oversees the production of two types of ammunition. These types are divided into lethal and non-lethal ammunition. For the lethal munitions, they produce three different types of ammo: 5.56 mm, 7.62 mm, and 9 mm. Meanwhile, the non-lethal products include ammunition of calibers 12-gauge, 16-gauge, and 20-gauge. The ammunition department uses only one machine to produce the three different calibers of ammunition in both the lethal and non-lethal divisions. They have made this possible through the different combinations of tooling in the main machine. The setting for each type of ammo that will be produced is adapted accordingly. That means they import the raw materials needed from different countries such as Colombia, in the exact quantities needed in order to minimize the risk from the storage of dangerous materials (OSHA, 2017).

6.3 Production process

The production process has an initial quality inspection of the received materials in order to review the status of the materials that will be used during manufacturing. If it does not meet the standards, the material is rejected and sent back. High quality is sought to be achieved because their main market is providing ammunition to public forces such as the National Police and the Army. They also provide a smaller quantity to athletes in sports that use ammunition.

6.4 Automatic process

The automatic process starts with the operator of the first machine loading the gunpowder and all other raw materials into the machine. The raw materials consist of gunpowder, the casing, the bullet, and the primer. Then the machine assembles all the parts automatically, and the product is collected in a box (See Figure 4). Next, the box with the product is transported to the quality control machine, which weighs each bullet while an operator performs a visual inspection of the product. Next, the bullets pass through a process where a serial number for identification is printed. Finally, 2 more operators pack the bullets in small boxes of 25 units each (See Figure 5).

6.5 Manual process

The manual process follows the same steps described for the automatic procedure with a difference in the first machine. To replace this machine, an operator manually adds the gunpowder to the body of the ammunition. Then they compress it into the finished product (See Figure 6).

6.6 ANACT methodology

To apply this method, first, an interdependence analysis was run to identify the relationship that exists between the different areas that are part of ammunition production. According to the ANACT Method, 3 different types of relationships are established. D1 represents an immediate or short material dependence, D2 represents a medium or long material dependence, and D3 represents a simultaneous task (NTP 2010) (See Table 1).

Accordingly, a balance of the status of working conditions was held to analyze the weak and strong points of the working area. The first graph shows the global evaluation of each of the indicators, while the second one illustrates the profile of this situation (See Tables 2 and 3). Hence, the results of this chart show two factors classified as 'bad'; The identified 'bad' factors are the conservation and breakdown of the working tools. Also, there are four factors classified as 'regular', which can be improved. These factors are Material handling conditions, the adaptation of the tools to work, duration of the series of task distributions, and compatibility with the tools of quality level.

Therefore, an identification of the actual situation and facilities of the area was executed to identify and justify the factors representing bad and regular classifications that must be improved.

6.6.1 General conditions overview and descriptions:

The whole ammunition worksite presents broken windows and a worn-out floor with small holes in it. The chairs and wooden tables are old and worn out. According to the workers, the temperature levels are typically uncomfortable and are elevated when the machinery is in operation. The tools and materials used are not well organized. The chemicals used do not have appropriate labeling. Obsolete machines are still in the factory, taking up space, which could be used for productive activities. The 'danger' labels on the floor are not visible and are worn out (See Figures 7, 8, and 9).

Machine one workstation: This area presents narrow spaces for walking. The machine used was designed for one type of ammunition, but through the years it has been adapted to produce other ammo types. There are objects obstructing the walkway. Also, the tools and materials are not well organized (See Figures 10 and 11).

Quality control workstation: This area's floor is worn-out, some chairs where the workers spend hours working are not ergonomic, and some are broken. The operator in this station does many repetitive movements each time which should be considered as a health risk factor (See Figure 12).

Packaging workstation: The chair in this station is not appropriate for the work being done. The table is broken. The danger label on the floor is not visible. The machine being used has not been calibrated in recent years. In the walkway, there are some boxes and materials laying down. The work is repetitive and requires a high level of attention for a long period of time (See Figure 13).

6.7 RNUR methodology

To evaluate each workstation, the RNUR method was applied in the Machine one, quality control, and packaging areas. An adaptation of the RNUR method was used to carry out the analysis for each area. Hence, the factors considered in this analysis were A, B, C, and D, which correspond to safety and ergonomics. This evaluation is rated with a score between one and five, which classifies 3 as the normal level. Thus, the variables that achieve a score of 4, are factors that should be improved (NTP 176) (See Table 4).

As explained before, only four factors were considered with the 5 to 19 criteria that were established. In this way, psychological and social factors were not considered but could be addressed in further studies.

In the first workstation, specifically in machine one, the criteria that have a score greater than or equal to 4, should be improved as soon as possible. This area reached a score of 4 in security, sound environment, job appearance, and level of attention. These factors were considered high due to the loud sound that the ammunition machine produces, the worn-out tools that lack a maintenance program, and the high level of attention that is required to verify that all the bullets are assembled correctly (See Table 5).

In the second area, the quality control area, the factors that displayed a score equal to or greater than 4 are sound environment, mental operations, and level of attention. This is due to the visual inspection that the workers need to perform in this area. This is vital to decide if the bullet passes the quality control check or needs to be reprocessed (See Table 6).

For the packaging area, the factors with a score equal to or greater than 4 were environmental noise, artificial lighting, job appearance, working posture, maintenance posture, and level of attention. This can be explained by the bad chair conditions that workers use and the postures they must hold for long periods of time (See Table 7).

From these observations, Figure 14 shows the total score per workstation obtained in each area. Even though all three of them produced similar scores, machine one and the packaging area are the areas with the highest scores. Hence, further analysis of frequency and severity has been done to evaluate each risk and build a risk matrix.

6.8 NTP 330

For this method the probability and consequence to determine the significance level was first calculated (Silva, 2019). To start developing the risk matrix, the probability of the damage occurring used the following criteria:

- High probability: damage will always or almost always occur
- Medium probability: damage will occur some of the time
- Low probability: damage will rarely occur

To quantify these criteria, the Probability level table was established, where the scores range from 2 to 40 and classify the risk from low to very high (See Table 8).

To determine the final score, it is mandatory to record the deficiency and exposure levels. For the deficiency level, the table classifies the values from 0 to 10, from acceptable to very deficient (See Table 9). For the exposure level, the values go from 1 to 4 to indicate if the exposure is sporadic or continued (See Table 10). For simplicity, these variables will be shortened to their respective abbreviations, such as PL for probability level.

To determine PL we need to calculate:

$$PL = DL * EL$$

where:

$$DL = Deficiency\ level$$

$$EL = Exposure\ level$$

To continue with the development of this matrix, the consequence level is calculated by scores ranging from 10 to 100. It deduces if the consequence will harm the workers in a certain magnitude. If not, they will be considered small injuries (See Table 11).

Lastly, the risk level (RL) is calculated as:

$$RL = PL * CL$$

Where:

$$PL = Probability\ level$$

$$CL = Consequence\ level$$

To be able to interpret this obtained value, the intervention level table is used where a level of I means that the risk represents an urgent correction needed. A level of IV represents a more relaxed scenario where further analysis is required (See Table 12).

Once the risks are classified by intervention level, an economic analysis was held to determine if the improvements are worth it (See Tables 13, 14, and 15).

To better understand each of the matrices developed for each area, a Pareto chart was made to identify the risk factors representing the necessary intervention level.

For the machine one area, following the rule of 80-20, the risk factors that need a high intervention are entrapment by or between objects, entrapment by the return of machines or vehicles, noise, fires, explosions, workstation dimensions, exposure to gasses and vapors, and exposure to harmful or toxic substances. Based on these results, the company monitors these factors closely to keep labor injuries to a minimum (See Figure 15).

For the quality control area, the main factors considered are repetitive movements, mental load, noise, entrapment by or between objects, entrapment by the return of machines or vehicles, and workstation dimensions. The solutions presented are driven by these main factors (See Figure 16).

Finally, for the packaging area, the risk factors are mainly repetitive movements, workstation dimensions, and psychological load (See Figure 17).

Considering the priority of each of the factors identified, the control activities proposal was developed according to ISO 45001:2018 (Constantine, 2018). This means the following stages were followed respectively: elimination, substitution, engineering controls, administrative controls, and personal protective equipment. In this section, the proposals cover most of the steps. An administrative plan will be presented later in this paper.

- **Machine one area:** The workers need to have proper auditive protection. Further evaluation of the noise levels must be conducted. For the entrapment risk, the workers need to implement a daily checklist of PPE revisions to avoid torn fabric. The use of a mask must be incorporated to avoid inhaling toxic substances through the mouth or nose.
- **Quality control area:** The personnel must rotate tasks and implement active breaks for the workers. An ergonomic and correct layout of the workstation needs to be provided. Also, the workers need to be wearing steel-toe boots due to the danger posed by ammunition falling on their feet.
- **Packaging area:** For this area, a task rotation must be done regularly. The proper usage of PPE and reusable auditive protection needs to be implemented.

- **General workplace:** Window repairs need to be carried out. Also, the floor needs to be fixed to avoid tripping hazards. New ‘danger’ ribbons, machine labels, and labels for chemicals and workspaces should be implemented (See Table 16).

6.9 FINE methodology

To understand and quantify how valuable and necessary the suggested improvements are for this company, the FINE method considers the consequence level, exposure level, and probability level. These elements were used to calculate and determine the risk level. Once this value has been obtained for each identified risk, the method requires two more variables that can be quantified through the degree of correction and its correction cost.

A total of 13 problem categories were identified, and from those, a total of 20 possible solutions or improvements were subject to the FINE method. Some examples of the identified problems are entrapment by or between objects, explosions, and exposure to harmful or toxic substances. The consequence level, exposure level, and probability level were determined for each problem category. Then, these levels were multiplied together to find the risk level of each problem.

Following the analysis of the problems, next, the possible solutions were analyzed. Some of the solutions to the mentioned problems are the use of steel-toe boots, ventilation, gloves, and safety goggles. For each solution, the degree of correction and the correction cost was found by researching online sources and retailers to find the price of implementing the solutions. The total cost was found by multiplying the unit price by the number of required units (See Table 17). This total price was then analyzed to determine the degree of correction and the correction cost. These problems, solutions, and prices can all be found below.

The next step in the FINE method is to evaluate each improvement via the following equation:

$$J = \frac{Risk\ Level}{Correction\ cost\ *\ Degree\ of\ correction}$$

Therefore, the value obtained is classified into three different categories that indicate whether the improvement should be considered justifiable or not justifiable. Based on that conclusion, if the result lands in the first rank, the investment is not justified. If it falls in the second rank, the investment is somewhat justified. Lastly, if the result is in the third rank, or in other words, if the justifiability is greater than 10, then the investment is completely justified as shown below:

$$0 < J < 10$$

$$10 < J < 20$$

$$J > 10$$

The improvements that were suggested are all in the third rank and thus are justifiedm as seen in Table 18. Consequently, the improvements are then applied by the company.

6.10 Culture of safety

In order to analyze the culture of safety that the company currently has, an evaluation of safety culture was distributed and filled out by the workers whose tasks are done in the ammunition area. This evaluation covers seven important topics with a variety of questions. It has been adapted from an original method presented by the department of HSE in the government of the United Kingdom. (Hse Uk, 2020).

In the evaluation, the workers responded to a set of questions covering management commitment, communication, employee involvement, training/information, motivation, compliance with procedures, and learning organization. These questions provide insight into their perception of the safety culture within their work area.

The results obtained from this evaluation show that there is an existing culture of safety, but it is minimal. To be proficient, the safety culture must be grown and cultivated (ACHE, 2017). A Pareto chart was created by analyzing the number of responses answered with “Totally Disagree”. This Pareto Chart shows that 8 main questions needed to be prioritized (Powell, 2015). The concerns posed by these 8 questions could be mainly addressed through actions that the administrative team could relatively easily take (See Figure 18). Based on the survey results, some recommended improvements have been listed below.

7. IMPROVEMENT PROPOSALS

Based on the findings listed above, to encourage and reinforce a health and safety culture, which is defined as the product of individual and group perceptions, attitudes, and behavior toward the commitment of a company in health and safety management (ACSNI, 1993), a series of corrective activities were selected and proposed to the company (Ndedi, 2017). These proposals are selected to increase the workers' responsibility for occupational health and safety (Sukadarin, 2012).

There are three key elements of safety culture. They are rules and practices to effectively control hazards, a positive attitude towards control procedures, and the ability to learn from accidents and performance indicators (Hse Uk, 2020). To develop the recommendations for the company, the following concepts intend to encourage and develop the safety culture maturity model in a way that will increase consistency and engage all the staff to fight complacency (Hse Uk, 2020).

7.1 Weekly safety talk by each employee

Developing a conscious safety culture depends not only on the company's managers but on all the workers as well. With that notion in mind, a method has been presented to the company as an activity that schedules one weekly safety talk given by a randomly selected employee. This proposed solution would allow one employee to choose any topic related to safety in the workplace and share a brief presentation with all the workers. The estimated time for each presentation is around 30 minutes, and it should initiate a conversation between all the staff members. Accordingly, the objective of randomly choosing an employee is to ensure that everyone is accountable for safety and expresses their concerns from different points of view.

7.2 Safety cards

Each member of the working team is responsible for encouraging safety in their daily work. A safety card plan has been developed because of this collective responsibility. The dynamic of this activity consists of filling out a small set of questions. The questions will allow the team members to understand what safety issues their co-workers might have seen. If any of the staff members observe an activity that is not considered safe, they will fill out a safety card with the following categories:

1. Area observed:
2. Date:
3. Activities observed:
4. Feedback given:
5. Stop work takes place:
6. Attachments:
7. Number of people at risk:
8. Type of risk:
    - Body position (bending, lifting, pushing, pulling, overreaching, overexerting)
    - Conditions (access, signs, explosion hazard, housekeeping standards, slips, trips, noise, temperature, work at heights)
    - Environmental (chemical storage, waste management, spill preparedness)

- Procedures (proper tool and equipment use, training, proper PPE use)

Hence, the worker describes the activity. The main point of this is to provide feedback and the solution that the worker used. They could also assign the activity to another person in that area. At the end of the month, the manager should establish the total number of cards that each worker should do as a goal. As an incentive, the manager will give a prize to any employee that reaches that goal. That will serve as a motivational way to increase safety in the area.

7.3 Stop work policy

Once the safety cards are understood and implemented in the ammunition area, it is important to define the stop work policy. This policy specifically authorizes each worker, supplier, manager, and every other member of the workforce to stop any activity that is being done in an unsafe manner. It is important to explain this policy to everyone so that when someone applies it, the worker that is forced to stop does not feel offended. The person applying the stop work policy must be sure to apply properly and politely so that no one will be upset by it.

7.4 Self-safety checklist before starting daily activities

This checklist is intended to be done every day by every employee before starting any activity. Every worker will carry out an individual evaluation of their own personal safety at work. The questions proposed are:

Do I have all the necessary PPE equipment?

Is my workplace clean and organized?

Are the equipment and tools that I will use in good condition?

Am I competent to perform the task?

Have obstructions been cleared from my workspace?

Do I know the correct procedures to safely perform my duties?

It is suggested that the company add more questions over time that may be adapted as the company changes.

7.5 The Five S (5’s)

The 5’s started with the Toyota production system in the mid 20 century and has been adapted to many different types of industries (Hse Uk, 2020). For this company, it is proposed that they should adapt the sort, set in order, shine, standardize, and sustain components of this method to better fit their company. This will develop a safer work environment and reduce risk.

7.6 Safety scoreboard

This common practice done by most companies is a useful tool to keep track of workplace safety because it encourages workers and allows a visual representation of their performance. Also, it helps to communicate the main message, which is to work in a safe environment and let them know they are working in a safe space.

7.7 Calibration and maintenance of equipment and tools

The workers deserve a workplace where they can work safely and perform their best knowing that they will go back home healthy. One important component of safety is to ensure that the workers are following the established procedures and using adequate tools and equipment. In this way, the company should create a schedule to calibrate and give maintenance to all the equipment and tools used in order to ensure they are certified and in good condition to work. This can be done through different suppliers that will provide a certificate and have a record of the times and next due dates.

7.8 EPP delivery format

Finally, the company needs to implement an EPP delivery format that may allow them to keep a record of the EPP delivered and be sure to provide the workers with the correct equipment according to specific times needed. This format should include the name of the worker, their ID, the delivery date, the quantity delivered, and the description of the items. Also, once it has been obtained, the worker signs a form that ensures their understanding of the importance and responsibility of wearing it.

7.9 Implementation

To train and inform the workers about all of the planned improvements that will be implemented, a training course has been provided to the ammunition area employees. This was done so that everyone will have access to the knowledge required for the future implementation of said improvements and also to greatly aid the development of a culture of safety (Smith, 2009).

8. CONCLUSIONS

- In conclusion, the fusion of the 4 methodologies used, ANACT, RNUR, NTP 330, and FINE, was vital to the risk analysis because it allowed beginning with a basic understanding and then proceeding to determine the risks that require more attention. This was crucial because it defined the scope of the problem and allowed the initiation of a solution.
- As a whole, all 4 of the methods collaborated well together and combined to analyze the general situation. They complimented each other nicely because they also provided insight into specific areas, such as an economic analysis of the solutions.
- NTP 330 was essential to identify the most critical risk. That was one of the primary outputs of that method, and it provided a very useful analysis to define the intervention levels.
- FINE was useful to determine if a solution was cost-effective and justifiable for the company because it was critical to promoting solutions that were economically achievable with the company's assets.

- Overall, while all 3 areas do require some attention, at the current time, the data from this assessment has identified Machine 1 as the area that needs the most immediate correction.
- There is not a significant pre-existing culture of safety within the company, so training must be provided to ensure the safety of each and every worker and cultivate a safety culture.
- From the results of the questionnaire, the main issues identified were that workers are uncomfortable with the current safety situation and do not feel supported by their managers when addressing these concerns.
- This study is meaningful because it will benefit the industry by increasing risk awareness and improving safety conditions within a company. These benefits will be seen throughout the company by all employees.

9. RECOMMENDATIONS

- Conduct a deeper workstation study that would allow for more ergonomic factors to be analyzed and corrected.
- Implement Lean tools, such as 5's, to create a sense of organization and cleanliness in each individual workstation.
- Evaluate the workers' perception of safety culture. This would be beneficial because it would allow an analysis to become more catered to its respective facility of study.
- Study risks that were not classified as a priority. While they might not be a priority now, there is always a chance that they could develop into a much larger issue in the future if not properly managed.

10. LIMITATIONS & NEXT STEPS

- The first major limitation was time. This was by far the largest limitation to the overall success of this risk analysis. During the beginning stages of research, there was a temporary halt to the factory's production. This delay was caused by a shortage of necessary raw materials. Because of this halt in production, the factory was unable to be properly analyzed for some time.

- The other main limitation was funding. This limitation made it difficult to determine which solutions were viable under the limited economic situation.
- For the next steps, run a more in-depth risk analysis of the remaining areas of the company so that all employees are made aware of the situation.

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12. ANNEX

11.1 Tables

Table 1. Interdependence analysis of the ammunition area

Areas	Raw material reception	Assembly machine	Quality control	Serial number printing	Packaging
Raw material reception		D1	D2	D2	D2
Assembly machine	D1		D1	D2	D2
Quality control	D2	D1		D3	D3
Serial number printing	D2	D2	D3		D1
Packaging	D2	D2	D3	D1	

Table 2. Balance of the status of working conditions

Elemental evaluation of the actual situation						
Date: 19/10/2022	**Evaluator: Ana Albiño**	**Observed area: Ammunition area**				
		Evaluation				
Indicators	**Variables(Questions)**	**Good**	**Regular**	**Bad**	**Strengths**	**Weakness**
Worked material	Material characteristics	Good	Indifferent	Bad	Good quality control process	
	Handling conditions	Good	Indifferent	Bad	Cotton gloves used	
Adequacy of work tools	Conservation	Good	Regular	Bad		Worn-out by usage
	Adaptation to work	Good	Regular	Bad		Several tools adapted to other tasks
	Breakdowns	Never	Sometimes	Usually		Lack of maintenance program
Task distribution	Division of tasks	Good	Regular	Bad	Achieve daily goals	
	Duration of the series	Good	Regular	Bad		High work hours
	Operator action	Hard	Weak	Null	A lot of attention required	
Job Feasibility	Regarding the concept of the product	It helps	Null	Hinders	Good product	
	Regarding the operating method	It helps	Neutro	Hinders	Good method	
Required quality level	Material compatibility	Good	Media	Difficult	Quality material	
	Compatibility with tools	Good	Media	Difficult		Tools/machines can improve
	Organization Compatibility	Good	Media	Difficult	Good processes	
Social utility and prestige of the product	Sensitivity to social utility	Yes	-	No	Few factories in the country	
	Sensitivity to prestige	Yes	-	No	Well known company	
	Value judgment Division of tasks	Positive	Indifferent	Negative	Achieves quality standars	

Table 3. Profile balance of the status of working conditions

Elemental evaluation of the actual situation				
Date: 19/10/2022	**Evaluator: Ana Albiño**	**Observed area: Ammunition area**		
Indicators	**Variables(Questions)**	**Evaluation**		
		Good	**Regular**	**Bad**
Worked material	Material characteristics	●		
	Handling conditions		●	
Adequacy of work tools	Conservation			●
	Adaptation to work		●	
	Breakdowns			●
Task distribution	Division of tasks	●		
	Duration of the series		●	
	Operator action	●		
Job Feasibility	Regarding the concept of the product	●		
	Regarding the operating method	●		
Required quality level	Material compatibility	●		
	Compatibility with tools		●	
	Organization Compatibility	●		
Social utility and prestige of the product	Sensitivity to social utility	●		
	Sensitivity to prestige	●		
	Value judgment Division of tasks	●		

Table 4. Measurement scale for the RNUR method

Level	Meaning
5	Very dangerous. Improve quickly
4	Dangerous in the long term
3	Acceptable
2	Satisfactory
1	Very satisfactory

Table 5. RNUR method for the machine one workstation

		Criteria	Level	Work Area: Machine 1	
Safety Factor		**A**	**5**	Security	4
Ergonomic Factors	**Physical environment**	**B**	**6**	Thermal environment	3
			7	Sound environment	5
			8	Artificial lighting	3
			9	Vibrations	3
			10	Environmental hygiene	3
			11	Job appearance	4
	Physical load	**C**	**12**	Main Posture	3
			13	Most unfavorable posture	2
			14	Work effort	3
			15	Working posture	3
			16	Maintenance effort	3
			17	Maintenance posture	3
	Mental load	**D**	**18**	Mental operations	3
			19	Level of attention	4

Table 6. RNUR method for the quality control workstation

		Criteria	Level	Work Area: Quality control	
Safety Factor		**A**	**5**	Security	3
Ergonomic Factors	**Physical environment**	**B**	**6**	Thermal environment	3
			7	Sound environment	4
			8	Artificial lighting	3
			9	Vibrations	3
			10	Environmental hygiene	3
			11	Job appearance	3
	Physical load	**C**	**12**	Main Posture	3
			13	Most unfavorable posture	3
			14	Work effort	3
			15	Working posture	3
			16	Maintenance effort	3
			17	Maintenance posture	3
	Mental load	**D**	**18**	Mental operations	4
			19	Level of attention	4

Table 7. RNUR method for the packaging workstation

		Criteria	Level	Work Area: Packaging	
Safety Factor		A	5	Security	3
Ergonomic Factors	Physical environment	B	6	Thermal environment	3
			7	Sound environment	4
			8	Artificial lighting	4
			9	Vibrations	3
			10	Environmental hygiene	3
			11	Job appearance	4
	Physical load	C	12	Main Posture	3
			13	Most unfavorable posture	2
			14	Work effort	3
			15	Working posture	4
			16	Maintenance effort	2
			17	Maintenance posture	4
	Mental load	D	18	Mental operations	3
			19	Level of attention	4

Table 8. Probability Levels

Probability level	PL	Meaning
Very high	Between 40-24	Poor condition with continued exposure, or very poor with frequent exposure. Normally the materialization of the risk occurs frequently.
High	Between 20-10	Poor condition with frequent or occasional exposure, or very poor condition with occasional or sporadic exposure. The materialization of the risk is likely to happen several times in the work life cycle.
Medium	Between 8-6	Poor situation with sporadic exposure, or situation that can be improved with continuous or frequent exposure. It is possible that the damage will happen sometime.
Low	Between 4-2	Improvable situation with occasional or sporadic exposure. The risk is not expected to materialize, although it may be conceivable.

Table 9. Deficiency Levels

Deficiency level	DL	Meaning
Very deficient (VD)	10	Significant risk factors have been detected that determine the generation of failures as very possible. The set of existing preventive measures regarding risk is ineffective.
Deficient (D)	6	Some significant risk factor has been detected that needs to be corrected. The effectiveness of the set of existing preventive measures is significantly reduced.
Improvable (IM)	2	Minor risk factors have been detected. The effectiveness of the set of existing preventive measures with respect to the risk is not appreciably reduced.
Acceptable (A)	-	No notable anomaly has been detected. The risk is controlled. It is not valued.

Table 10. Exposure Levels

Exposition level	EL	Meaning
Continued (EC)	4	Continuously. Several times in your working day with the extended time.
Frequent (EF)	3	Several times in your working day, even with short times.
Occasional (EO)	2	Sometime during your working day and with a short period of time.
Sporadic (ES)	1	The exposure situation occurs eventually.

Table 11. Consequence Levels

Consequence level	CL	Personal injury	Material damage
Fatal or catastrophic	100	1 or more dead	Total destruction of the system (difficult to renew it)
Very serious	60	Serious injuries that may be irreparable	Partial destruction of the system (complex and expensive repair)
Serious	25	Injuries with temporary work disability	Process shutdown required to perform repair
Mild	10	Small injuries that do not require hospitalization	Repairable without the need to stop the process

Table 12. Intervention Levels

Intervention level	RL	Meaning
I	4000-600	Critical situation. urgent correction.
II	500-150	Correct and adopt control measures.
III	120-40	Improve if possible. It would be convenient to justify the intervention and its profitability.
IV	20	Do not invest, unless even more precise analysis justifies it.

Table 13. NTP 330 Matrix for Machine 1

Risk analysis							Risk evaluation NTP 330							Risk control
Process	Work station	Activities	Source	Task	Risk factor	Risk/Effect	Deficiency level	exposure level	probability level	PL interpretation	Consequence level	LR Risk level		Control activities according to ISO 45001:2018
			Falling objects in handling	Improper markings		Concussion,broken bones, disorientation	6	3	18	High	10	180	II	Engineering Controls: Install signs PPE Controls: Provide PPE Helmets
			Falls of people to the same level	Obstacles in the way		Injuries, bruises, broken bones, sprains	6	2	12	High	25	300	II	Engineering Controls: Install signs Mark Walkways
			Stepped on objects	Obstacles in the way		Sprains	6	2	12	High	10	120	III	Engineering Controls: Install signs Mark Walkways PPE Controls: Provide PPE Boots
			Collision with moving objects	Obstacles in the way	Mechanical	Injuries, bruises, broken bones, sprains	6	1	6	Medium	25	150	II	Engineering Controls: Install signs Mark Walkways PPE Controls: Provide PPE Boots
			Blows/cuts by objects tools	Not wearing PPE		Not use of appropiate PPE	2	1	2	Low	10	20	IV	PPE Controls: Provide PPE gloves
			Entrapment by or between objects	Not following the procedures		Soffocation	6	4	24	Very High	60	1440	I	Administrative Controls: Provide Operational Trainings
		e machine.	Entrapment by return of machines or vehicles	Not following the procedures		Injuries, bruises, broken bones, sprains	6	4	24	Very High	60	1440	I	Administrative Controls: Provide Operational Trainings

Assembling of ammunition	Ammunition machine one	er is checking the overhead mirros to ensure the materials are travelling properly while the other worker is monitoring how they are exiting the machine.	Entrapment by return of machines or vehicles	Not following the procedures		Injuries, bruises, broken bones, sprains	6	4	24	Very High	60	1440	I	Administrative Controls: Provide Operational Trainings
			Fires	Storage of gunpowder	Physical	Injuries, bruises, broken bones, sprains	6	3	18	High	60	1080	I	Engineering Controls: Provide fire extinguishers Administrative Controls: Provide Operational Trainings
			Explosions	Storage of gunpowder		Shrapenel punctures	6	3	18	High	60	1080	I	Administrative Controls: Provide Operational Trainings PPE Controls: Provide PPE Clothing
			Thermal stress	Improper ventilation, overheating of machines		Dehydration,exhausti on	2	3	6	Medium	10	60	III	Engineering Controls: Install Insulation Install Ventilation Administrative Control: Require Breaks
			Indirect electrical contacts, short circuits	Not wearing PPE		Burns, electrocution, injuries	2	2	4	Low	25	100	III	PPE Controls: Provide Electrical Resistant PPEs
			Noise	Not wearing PPE		Hearing loss, irritability, headaches, tension	6	4	24	Very High	60	1440	I	PPE Controls: Provide PPE Ear Plugs Administrative Controls: Require Breaks

Assem	Ammu	The first worker lift the casing and the gunpowder into a top oriented feeder then as they pass throug the machine, one worker is ch												Require Breaks
			Illumination	Improper illumination		Irritability, headaches, tension	2	2	4	Low	25	100	III	Engineering Controls: Install more lighting Administrative Controls: Require Breaks
			Exposure to gases and vapors	Not wearing PPE	Chemical	Respiratory problems, eye or skin irritation	6	3	18	High	25	450	II	PPE Controls: Provide PPE masks Provide PPE Clothing
			Exposure to harmful or toxic substances	Not wearing PPE		Respiratory problems, eye or skin irritation	6	3	18	High	25	450	II	PPE Controls: Provide PPE masks Provide PPE Clothing
			Contacts with caustic and/or corrosive substances	Not wearing PPE		Respiratory problems, eye or skin irritation	6	3	18	High	25	450	II	PPE Controls: Provide PPE masks Provide PPE Clothing
			Work station dimensions	Improper layout distribution	Ergonomic	Musculoskeletal problems	6	3	18	High	60	1080	I	Engineering Controls: Provide New Workstations Administrative Controls: Require Breaks
			Physicial overload or overexertion	Lack of proper materials		Musculoskeletal problems	2	3	6	Medium	25	150	II	Administrative Controls: Limit Daily Lifting Require Breaks PPE Controls: Provide PPE Lifting Equipment
			Forced postures	Improper furniture		Musculoskeletal problems	6	2	12	High	25	300	II	Engineering Controls: Provide New Chairs Administrative Controls: Require Breaks
														Engineering
			Acoustic discomfort	Machine sounds loudly		Musculoskeletal problems	6	2	12	High	25	300	II	Engineering Controls: Install Sound Dampers PPE Controls: Provide PPE Earplugs
			Thermal discomfort	Machines are overheating		Dehydration,exhaustion	2	2	4	Low	10	40	III	Engineering Controls: Install Insulation Install Ventilation Administrative Control: Require Breaks
			Light discomfort	Improper illumination		Irritability, headaches, tension	2	2	4	Low	10	40	III	Engineering Controls: Install New Lighting Administrative Controls: Require Breaks

Table 14. NTP 330 Matrix for Quality Control

Risk analysis							Risk evaluation NTP 330							Risk control
Process	Work station	Activities	Source	Task	Risk factor	Risk/Effect	Deficiency level	exposure level	probability level	PL interpretation	Consequence level	LR Risk level		Control activities according to ISO 45001:2018
		ptable weights. While this is happening, a worker is doing a visual inspection of the bullets.	Falling objects due to collapse or collapse	Improper markings	Mechanical	Concussion, broken bones, desorientation	2	2	4	Low	10	40	III	Engineering Controls: Install signs PPE Controls: Provide PPE Helmets
			Falling objects in handling	Obstacles in the way		Injuries, bruises, broken bones, sprains	2	2	4	Low	10	40	III	Engineering Controls: Mark Paths Administrative Controls: Provide Handling Trainings
			Entrapment by or between objects	Not following the procedures		Injuries, bruises, broken bones, sprains	6	3	18	High	25	450	II	Administrative Controls: Provide Operational Trainings
			Entrapment by return of machines or vehicles	Not following the procedures		Injuries, bruises, broken bones, sprains	6	3	18	High	25	450	II	Administrative Controls: Provide Operational Trainings
			Explosions	Storage of gunpowder	Physical	Shrapenel punctures	6	2	12	High	25	300	II	Administrative Controls: Provide Operational Trainings PPE Controls: Provide PPE Clothing
			Thermal stress	Machines overheating		Soffocation	2	2	4	Low	25	100	III	Engineering Controls: Install Insulation Install Ventilation Administrative Control: Require Breaks
			Noise	Loud machine sounds		Hearing loss, irritability, headaches, tension	6	4	24	Very High	25	600	I	PPE Controls: Provide PPE Ear Plugs Administrative Controls: Require Breaks

Quality control	Weight quality control machine	Initially, as bullets are travelling through the process, the machine will simultaneously print serial numbers and and ensure accepta	Illumination	Improper illumination		Irritability, headaches, tension	2	3	6	Medium	10	60	III	Engineering Controls: Install more lighting Administrative Controls: Require Breaks
			Exposure to gases and vapors	Not wearing PPE	Chemical	Respiratory problems, eye or skin irritation	2	2	4	Low	10	40	III	PPE Controls: Provide PPE masks Provide PPE Clothing
			Work station dimensions	Improper furniture	Ergonomic	Musculoskeletal problems	6	3	18	High	25	450	II	Engineering Controls: Provide New Workstations Administrative Controls: Require Breaks
			Forced postures	Improper furniture		Musculoskeletal problems	6	3	18	High	25	450	II	Engineering Controls: Provide New Chairs Administrative Controls: Require Breaks
			Repetitive movements	Improper furniture		Musculoskeletal problems	10	3	30	Very High	60	1800	I	Administrative Controls: Require Breaks
			Acoustic discomfort	Machines are very loud		Irritability, headaches, tension	6	2	12	High	25	300	II	Engineering Controls: Install Sound Dampers PPE Controls: Provide PPE Earplugs
			Thermal discomfort	Machines overheating		Irritability, headaches, tension	2	2	4	Low	25	100	III	Engineering Controls: Install Insulation Install Ventilation Administrative Control: Require Breaks
			Light discomfort	Improper illumination		Irritability, headaches, tension	2	3	6	Medium	25	150	II	Engineering Controls: Install New Lighting Administrative Controls: Require Breaks
			Mind load	Decide if a bullet is correct or not	Psychosocial	Irritability, headaches, tension	6	3	18	Very High	60	1080	I	Administrative Controls: Require Breaks

Table 15. NTP 330 for Packaging

Risk analysis							Risk evaluation NTP 330							Risk control
Process	Work station	Activities	Source	Task	Risk factor	Risk/Effect	Deficiency level	exposure level	probability level	PL interpretation	Consequence level	LR Risk level		Control activities according to ISO 45001:2018
Packaging	Manually packaging	Bullets leave the quality control machine and are then transported to a worker who is waiting to package bullets in groups of 25.	Falling objects in handling	Improper markings	Mechanical	Concussion ,broken bones, desorientation	2	3	6	Medium	10	60	III	Engineering Controls: Mark Paths Administrative Controls: Provide Handling Trainings
			Stepped on objects	Obstacles in the way		Injuries, bruises, broken bones, sprains	2	1	2	Low	10	20	IV	Engineering Controls: Install signs Mark Walkways PPE Controls: Provide PPE Boots
			Fires	Not following the procedures	Physical	Shrapenel punctures	2	2	4	Low	10	40	III	Engineering Controls: Provide fire extinguishers Administrative Controls: Provide Operational Trainings
			Explosions	Not following the procedures		Shrapenel punctures	2	2	4	Low	10	40	III	Administrative Controls: Provide Operational Trainings PPE Controls: Provide PPE Clothing
			Thermal stress	Machines overheating		Soffocation	6	2	12	High	25	300	II	Engineering Controls: Install Insulation Install Ventilation Administrative Control: Require Breaks
			Noise	Machines are very loud		Irritability, headaches, tension	2	2	4	Low	25	100	III	PPE Controls: Provide PPE Ear Plugs Administrative Controls: Require Breaks
			Illumination	Improper illumination		Irritability, headaches, tension	6	4	24	Very High	10	240	II	Engineering Controls: Install more lighting Administrative Controls: Require Breaks
			Exposure to gases and vapors	Not wearing PPE	Chemical	Respiratory problems, eye or skin irritation	2	2	4	Low	10	40	III	PPE Controls: Provide PPE masks Provide PPE Clothing
			Work station dimensions	Improper furniture	Ergonomic	Musculoskeletal problems	6	4	24	Very High	25	600	I	Engineering Controls: Provide New Workstations Administrative Controls: Require Breaks
			Forced postures	Improper furniture		Musculoskeletal problems	6	4	24	Very High	10	240	II	Engineering Controls: Provide New Chairs Administrative Controls: Require Breaks
			Repetitive movements	Improper furniture		Musculoskeletal problems	10	4	40	Very High	60	2400	I	Administrative Controls: Require Breaks
			Acoustic discomfort	Machines are very loud		Irritability, headaches, tension	6	2	12	High	10	120	II	Engineering Controls: Install Sound Dampers PPE Controls: Provide PPE Earplugs
			Light discomfort	Improper illumination		Irritability, headaches, tension	2	3	6	Medium	10	60	III	Engineering Controls: Install New Lighting Administrative Controls: Require Breaks
			Mind load	Pack a bullet and check it it is fine	Psychosocial	Irritability, headaches, tension	6	3	18	Low	25	450	II	Administrative Controls: Require Breaks

Table 16. Risk Factor Totals

Risk Factors	Level I	Level II	Level III	Level IV	Sum	Percentage
Mechanical	2	5	4	2	13	24.07%
Physical	5	2	8	0	15	27.78%
Chemical	0	3	3	0	6	11.11%
Biological	0	0	0	0	0	0.00%
Ergonomic	6	8	4	0	18	33.33%
Psychological	2	0	0	0	2	3.70%
Subtotal	15	18	19	2	54	
Estimation	27.78%	33.33%	35.19%	3.70%		100.00

Table 17. Solution Costs

Problem	Solution	Unit Cost	# of Units	Total Cost
Noise	Safety Ear Muffs	$37.24	7	$260.68
Entrapment by or Between Objects	Steel Toe Boots	$36.23	7	$253.61
Entrapment by or Between Objects	Hard Hats / Helmets	$25.85	7	$180.95
Entrapment by the Return of Machines or Vehicles	Danger Ribbons	$9.88	3	$29.64
Tripping	Repair Floors	$99.29	per m^3 (130)	$12,907.70
Entrapment by or Between Objects	Labels	$2	25	$50.00
Workstation Dimensions	Ergonomic Tables	$200	9	$1,800.00
Illumination	Repair Windows	$31.19	per m^2 (70)	$2,183.30
Fires	Fire Extinguishers	$70	3	$210.00
Explosions	Dust Vacuums	$159.99	1	$159.99
Explosions	Ventilation	$13.83	2	$27.66
Explosions	Machinery Maintainence	$2,000	1	$2,000.00
Exposure to Gasses and Vapors	Safety Masks	$34.14	7	$238.98
Exposure to Harmful or Toxic Substances	Protective Overalls	$26	7	$182.00
Exposure to Harmful or Toxic Substances	Gloves	$20.28	7	$141.96
Exposure to Harmful or Toxic Substances	Safety Goggles	$7.04	7	$49.28
Electrocution	Repair Outlets	$9.80	25	$245.00
Electrocution	Label Outlet Voltages	$2	25	$50.00
Forced Positions	Ergonomic Chairs	$87	7	$609.00
Standing Work	Anti-Fatigue Mat	$30	9	$269.91

Table 18. FINE Calculations

Consequence Degree	Exposition Degree	Probability Degree	C*E*P	Correction Cost	Correction Degree	Justifiability	Justified	Price Source
15	6	6	540	2	2	135	yes	Degso, 2022
25	10	2	500	2	3	83.33333333	yes	Degso, 2022
25	10	2	500	2	3	83.33333333	yes	Degso, 2022
25	10	2	500	0.5	3	333.3333333	yes	Degso, 2022
15	10	3	450	4	2	56.25	yes	generadordeprecios, 2022
15	10	6	900	1	2	450	yes	mercadolibre, 2022
5	10	3	150	3	1	50	yes	economicpartners, 2022
15	10	2	300	3	2	50	yes	generadordeprecios, 2022
50	6	2	600	2	2	150	yes	uline, 2022
100	6	2	1200	2	3	200	yes	pycca, 2022
100	6	2	1200	0.5	3	800	yes	generadordeprecios, 2022
100	6	2	1200	3	3	133.3333333	yes	tecniprecision, 2022
25	6	2	300	2	2	75	yes	Degso, 2022
25	6	2	300	2	2	75	yes	lacasadeoverolecuador, 2022
25	6	2	300	2	2	75	yes	Degso, 2022
25	6	2	300	0.5	2	300	yes	Degso, 2022
15	3	2	90	2	3	15	yes	ebay, 2022
15	3	1	45	1	2	22.5	yes	mercadolibre, 2022
15	10	6	900	2	2	225	yes	sillasmodulares, 2022
15	10	6	900	2	3	150	yes	amazon, 2022

11.2 Figures

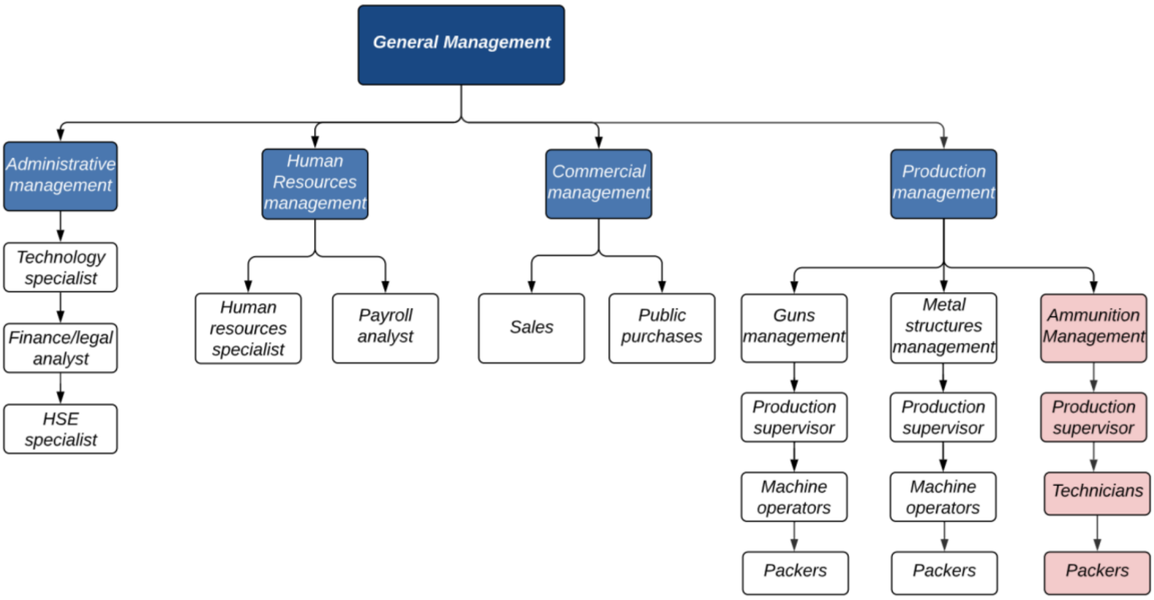

Figure 1. Organization chart of “Santa Bárbara EP”

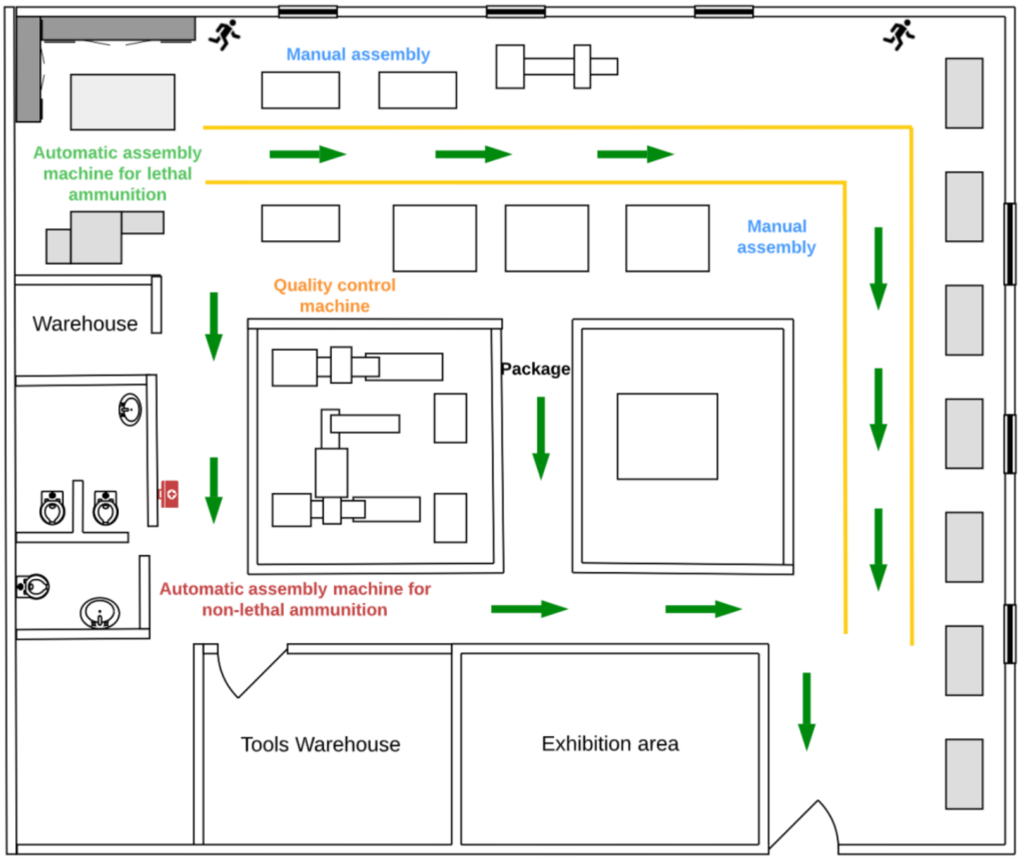

Figure 2. Ammunition Production Floor

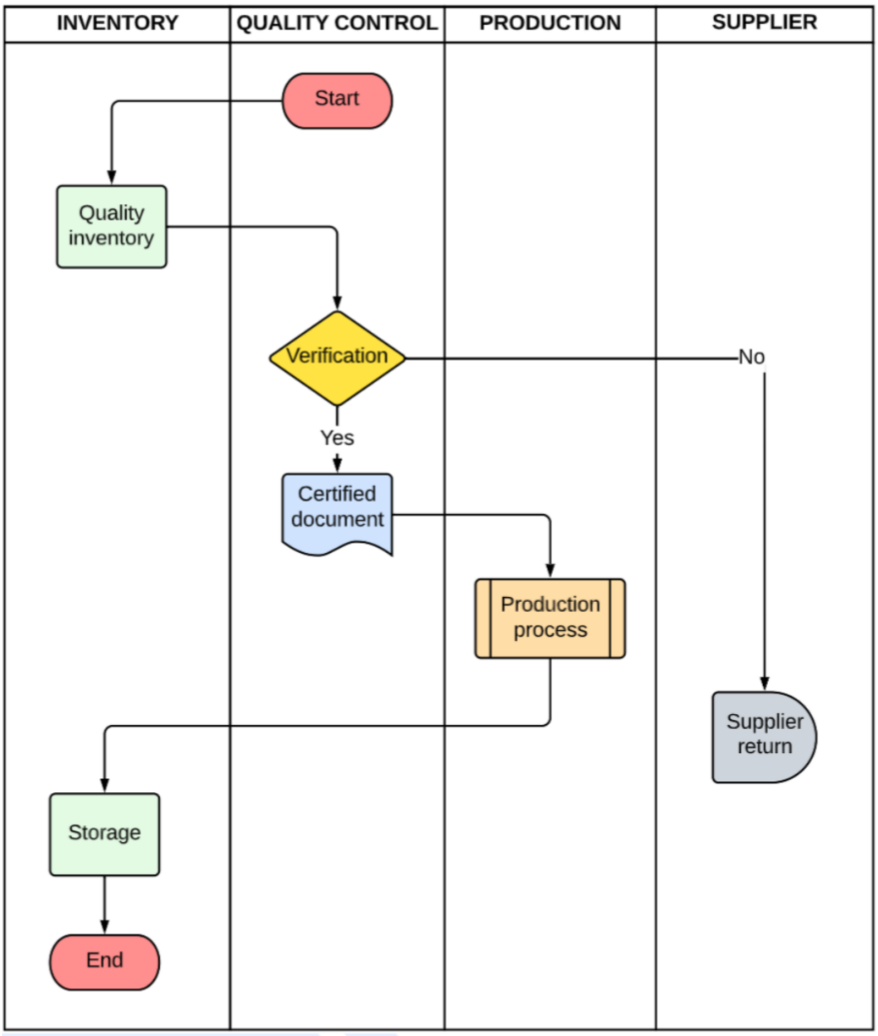

Figure 3. General production process

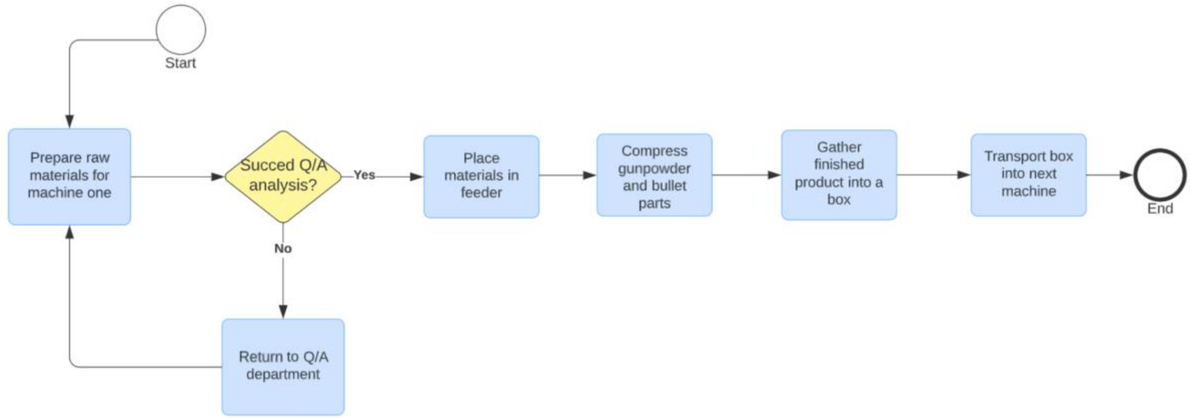

Figure 4. Automatic production process of Machine 1

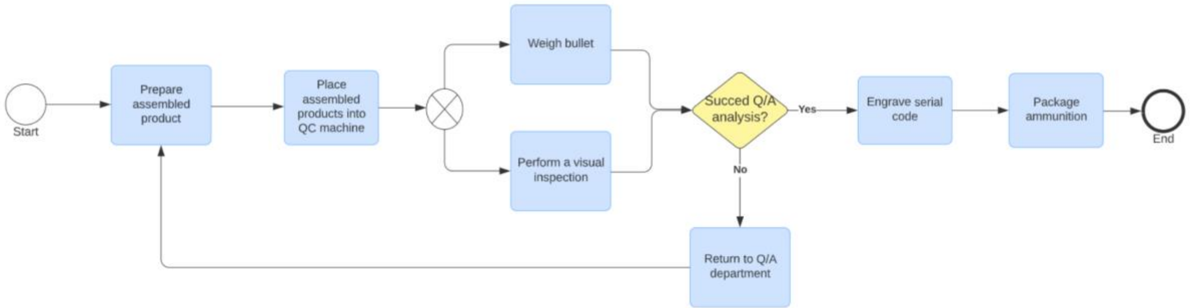

Figure 5. Quality control process of automatic and manual assembly

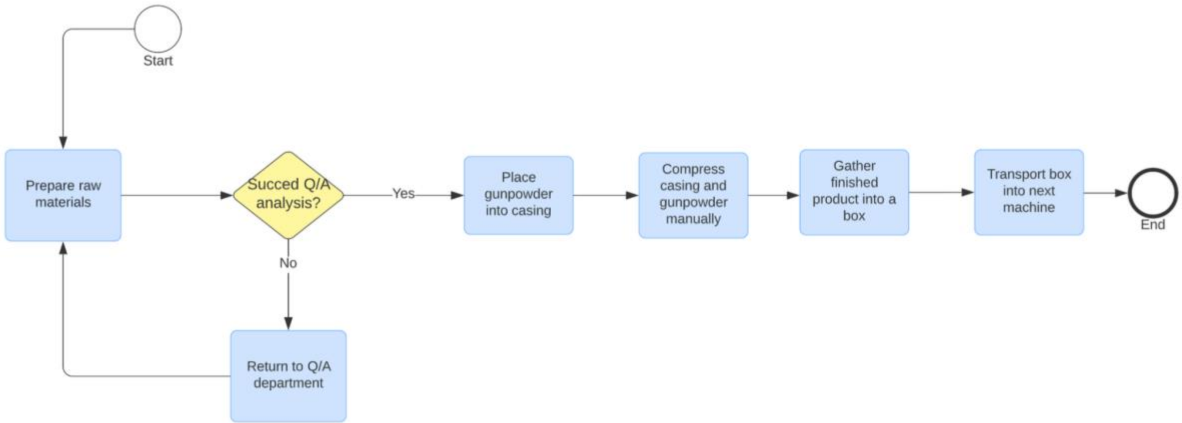

Figure 6. Manual production process of the ammunition assembly

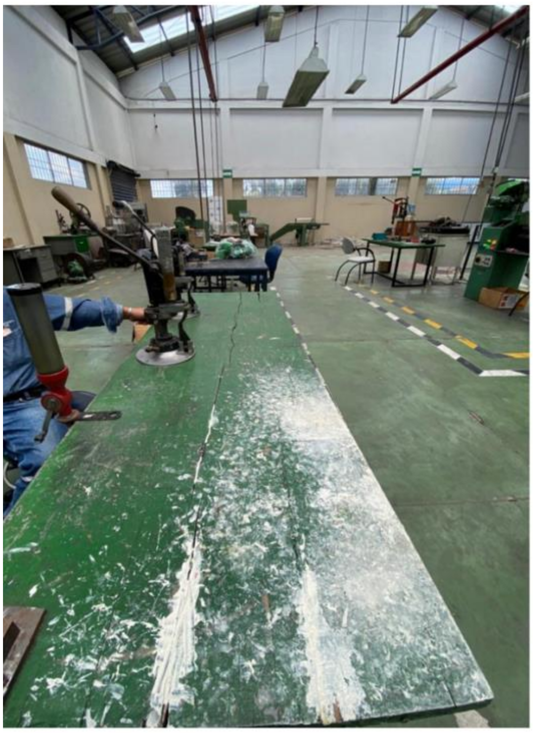

Figure 7. Status of the tables

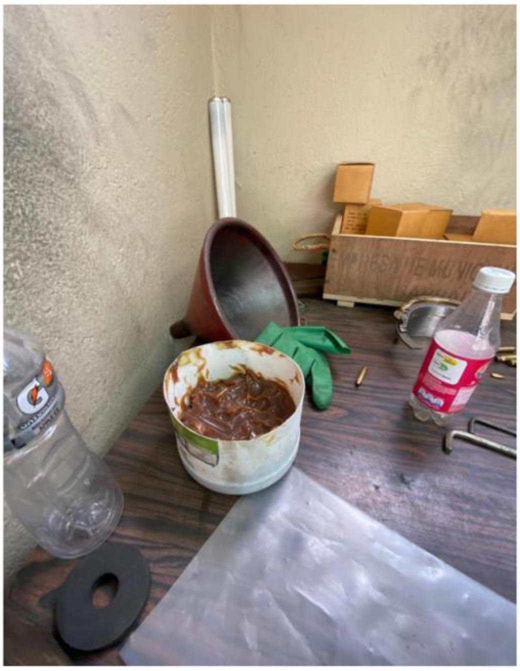

Figure 8. Status of Tools

Figure 9. Status of the floor

Figure 10. Status of the chairs

Figure 11. Objects in the walkway

Figure 12. Damaged Electrical system

Figure 13. Status of Electrical Outlets

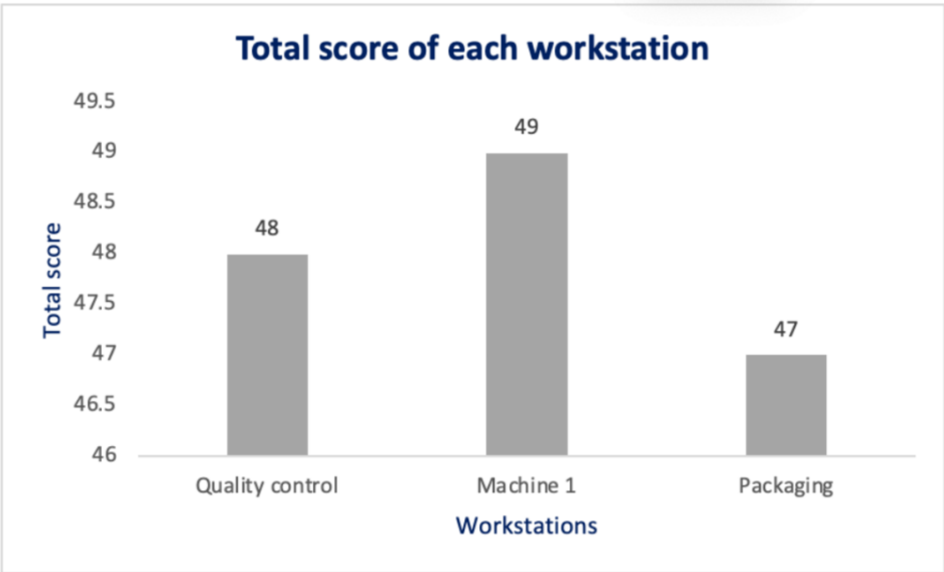

Figure 14. Total score of each workstation

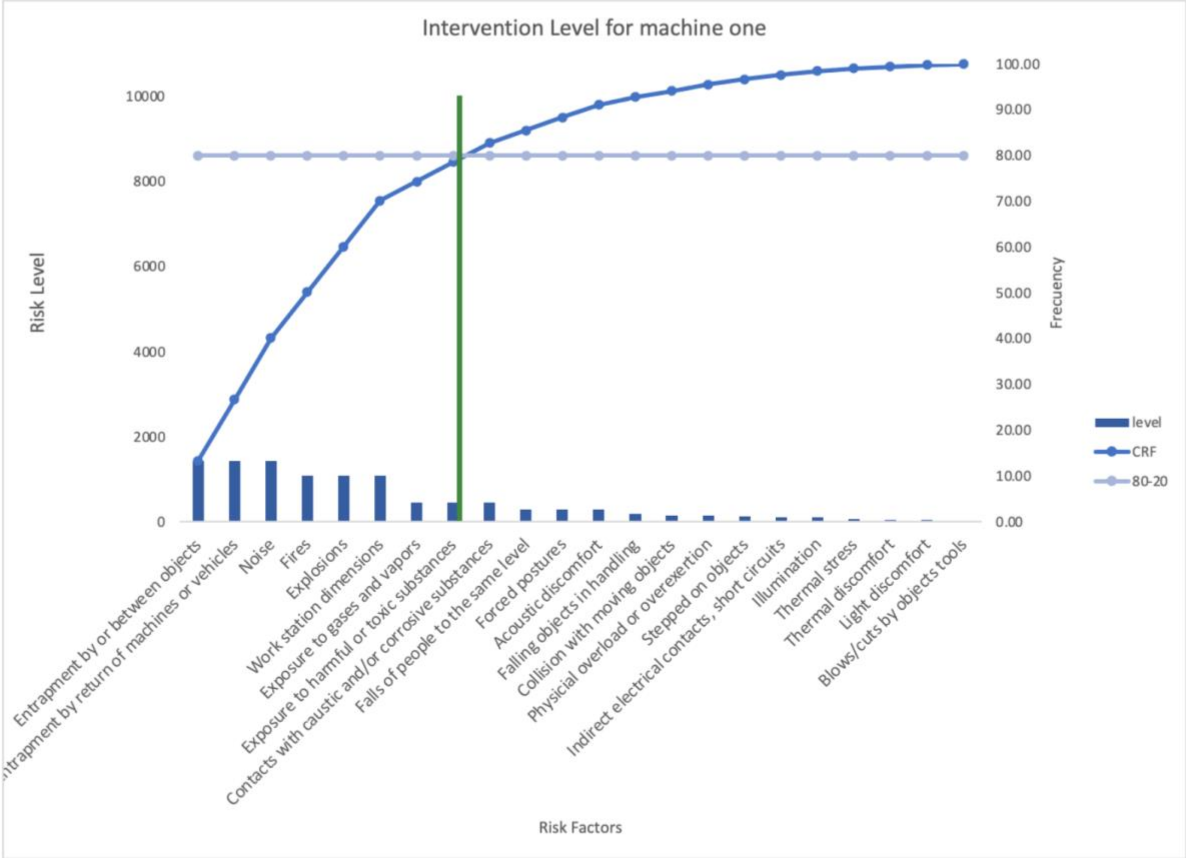

Figure 15. Intervention Level for Machine 1 Pareto Chart

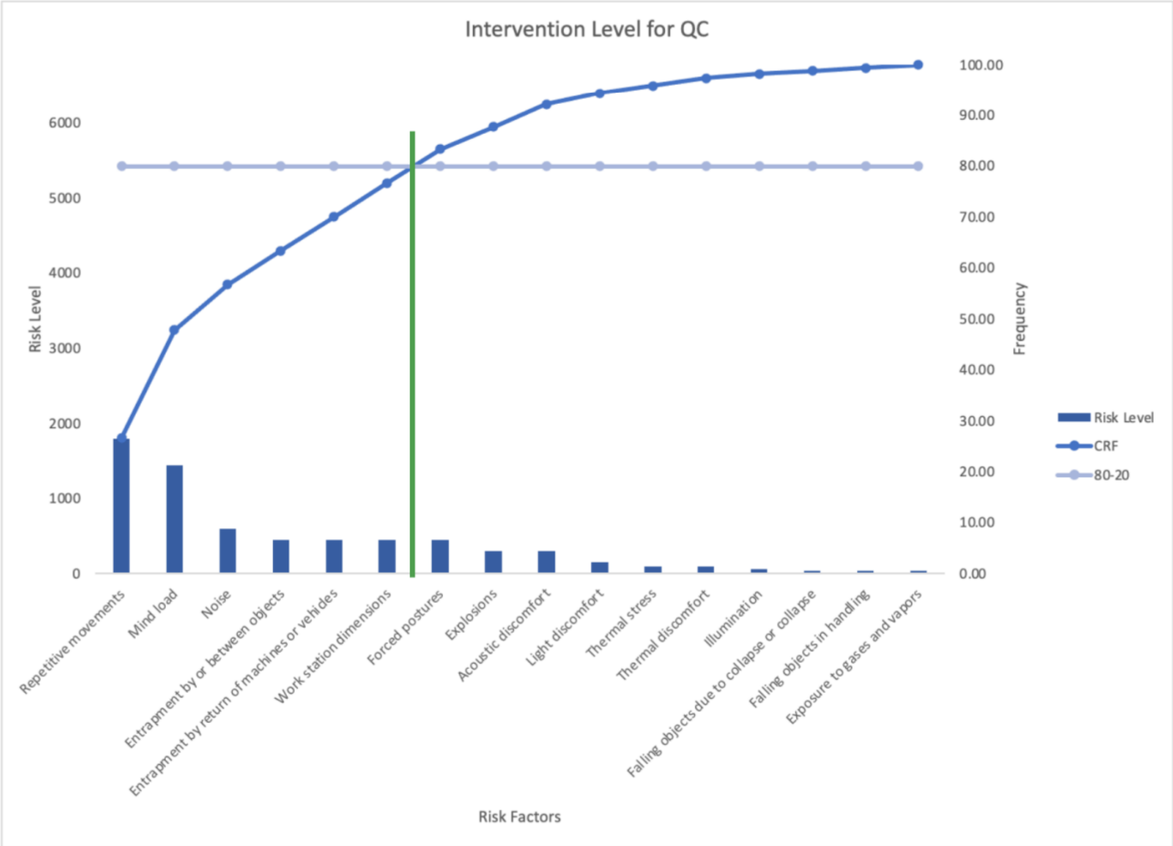

Figure 16. Intervention Level for Quality Control Pareto Chart

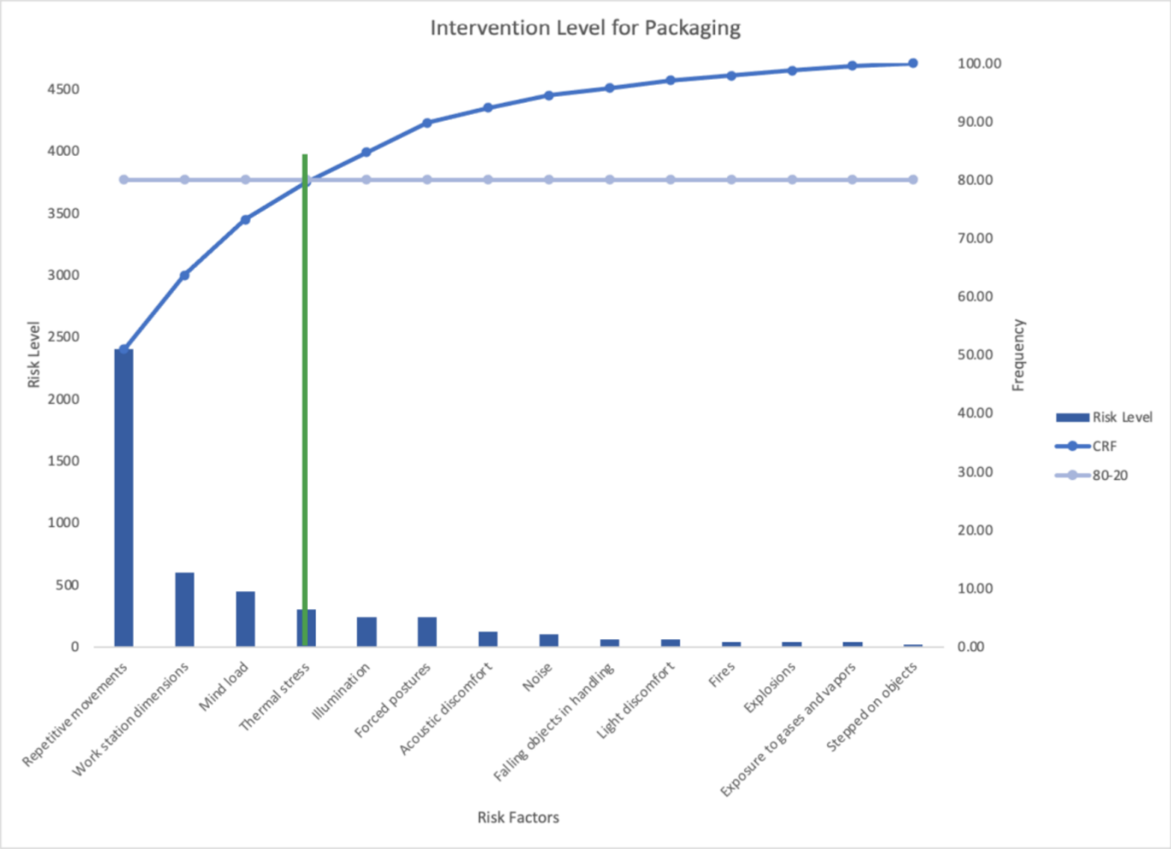

Figure 17. Intervention Level for Packaging Pareto Chart

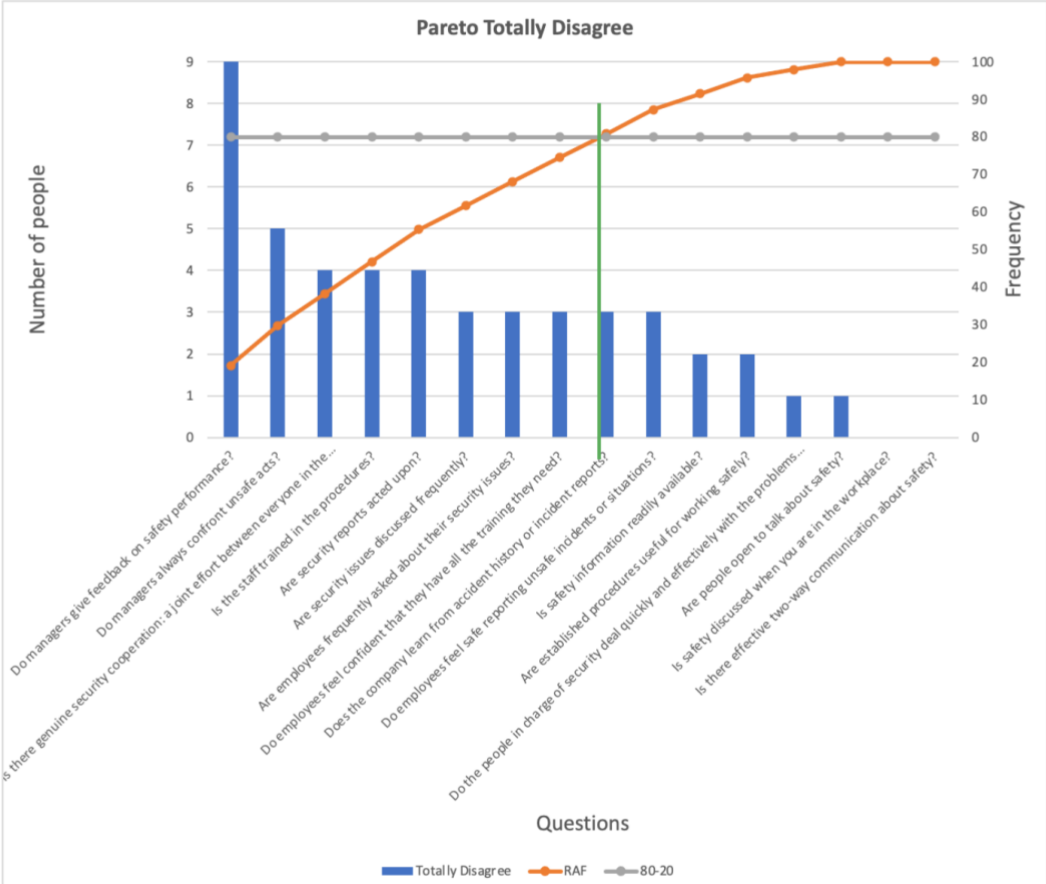

Figure 18. Culture of Safety Evaluation Results