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The role of occupational safety in road works: Implementation of preliminary risk analysis in the execution of asphalt resurfacing

O papel da segurança do trabalho em obras rodoviárias: Implementação da análise preliminar de riscos na execução de recapeamento asfáltico

El papel de la seguridad laboral en las obras viarias: Aplicación del análisis preliminar de riesgos en la ejecución de repavimentaciones asfálticas

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Abstract
The aim of this research is to present, through the application of a risk analysis technique, a mapping of dangerous occurrences, the causes and consequences of the risks to which highway construction workers are exposed, as well as to recommend appropriate control measures for the case study investigated. A photographic survey was carried out on a critical stretch of road resurfacing work located on Avenida Dona Otília, in the São Pedro district of Manaus/AM. The Preliminary Risk Analysis (APR) technique was used to draw up a qualitative and quantitative opinion of each function included in the construction work process, with the aim of diagnosing the risks and finding improvements in the working conditions at each position, with a view to the well-being and protection of workers' lives. However, the survey indicated a higher incidence of physical risks, especially in the role of paver operator. It is therefore necessary to introduce an accident prevention policy, training workers to recognize potentially dangerous situations before accidents or near misses occur, and to keep records of both. Another important measure is to check the condition of EPI and implement equipment control sheets. The risk of being run over was observed in all functions, and it is important that there is adequate signage for employees on the road, the works and the maximum speed allowed on these stretches.
Keywords: Risks; Asphalt paving; Road works.

Resumo
Esta pesquisa tem como objetivo apresentar, por meio da aplicação de uma técnica de análise de risco, um mapeamento das ocorrências perigosas, as causas e consequências dos riscos a que estão expostos os trabalhadores da construção de obras em rodovias, bem como recomendar medidas de controle adequadas para o estudo de caso

investigado. Foi realizado um levantamento fotográfico em um trecho crítico da obra de recapeamento rodoviário localizado na Avenida Dona Otília, no bairro São Pedro, em Manaus/AM. Utilizou-se a técnica de Análise Preliminar de Risco (APR) para elaborar um parecer qualitativo e quantitativo de cada função inserida no processo de execução da obra, com o intuito de diagnosticar os riscos e encontrar melhorias nas condições de trabalho em cada posto, visando o bem-estar e a proteção da vida dos trabalhadores. Contudo, o levantamento indicou uma maior incidência de riscos físicos, principalmente na função de operador de vibroacabadora. Dessa forma, é necessário introduzir uma política de prevenção de acidentes, treinando os trabalhadores para reconhecerem situações potencialmente perigosas antes de ocorrerem acidentes ou quase acidentes, e manter registros de ambos. Outra medida importante é a verificação da condição dos EPIs e a implementação de fichas de controle destes equipamentos. O risco de atropelamento foi observado em todas as funções, sendo importante a existência de sinalização adequada para os colaboradores na pista, as obras e a velocidade máxima permitida nesses trechos.
Palavras-chave: Riscos; Pavimentação asfáltica; Obras rodoviárias.

Resumen
El objetivo de esta investigación es presentar, mediante la aplicación de una técnica de análisis de riesgos, una cartografía de los sucesos peligrosos, las causas y las consecuencias de los riesgos a los que están expuestos los trabajadores de la construcción de carreteras, así como recomendar medidas de control adecuadas para el caso de estudio investigado. Se llevó a cabo un estudio fotográfico en un tramo crítico de obras de repavimentación de carreteras situado en la Avenida Dona Otília, en el barrio de São Pedro, en Manaus/AM. Se utilizó la técnica de Análisis Preliminar de Riesgos (APR) para elaborar un dictamen cualitativo y cuantitativo de cada función involucrada en el proceso de la obra, con el objetivo de diagnosticar los riesgos y encontrar mejoras en las condiciones de trabajo en cada puesto, con vistas al bienestar y a la protección de la vida de los trabajadores. Sin embargo, la encuesta mostró una mayor incidencia de riesgos físicos, especialmente en la función de operador de pavimentadora. Por lo tanto, es necesario introducir una política de prevención de accidentes, formando a los trabajadores para que reconozcan las situaciones potencialmente peligrosas antes de que se produzcan accidentes o casi accidentes, y llevar un registro de ambos. Otra medida importante es comprobar el estado de los EPI y aplicar fichas de control de los equipos. El riesgo de atropello se observó en todas las funciones, por lo que es importante que exista una señalización adecuada para los trabajadores sobre la carretera, las obras y la velocidad máxima permitida en estos tramos.
Palabras clave: Riesgos; Pavimentación asfáltica; Obras viales.

1. Introduction

Safety at work is of great relevance in the construction industry, especially in road works due to the traffic on the road, making the road a disputed space between the machines needed for repair, SUVs and trucks at high speed, the displacement of materials and minimum infrastructure for the work, and men to perform the work on the stretch (Nascimento, et al., 2021; Santos, et al., 2022; Souza Nascimento, et al., 2023). In these cases, the strongest work safety resource is signage, which if well designed, contributes to the comfort and safety of both the road users and the workers on the stretch.

This scenario, associated with the constant exposure to risk situations resulting from the absence or weakness of preventive practices, has resulted in compromised health of workers in this sector and the occurrence of a high number of accidents, where occupational safety is one of the great challenges in civil construction (Souza Nascimento et al., 2021). Therefore, in any activity it is necessary to evaluate the risks to which workers are exposed through probability and consequence analysis. This analysis can be carried out by applying various techniques, specific to each situation and which can be complemented with others to achieve greater efficiency (Zwirtes, et al., 2022).

One of the most used techniques is called Preliminary Risk Analysis (APR), which aims to identify hazards and risk analysis that consists in pointing out dangerous events, causes and consequences, and foundation control measures. Generally, the technique is performed in the preliminary stages of the project, but can be applied in units already in operation, allowing a review of existing safety aspects.

This research aims to apply the APR technique in each function of the execution process of the resurfacing work of a critical stretch located on Avenida Dona Otilia, in the neighborhood of São Pedro in Manaus/AM, in order to diagnose risks and propose improvements in working conditions in each position, meeting the legislation and proposing adjustments for the

safety and comfort of the worker. Subsequently, this research is segmented into three sub-items. The first one contextualizes the bibliographical survey, followed by a brief exposition about the field mapping "in loco". Finally, the third section explains the analysis of other examples that stimulate the understanding of the respective subject.

2. The Role of Occupational Safety in Road Works

Roads are the most used roads in Brazil, reaching 62.7% of the national preference (Ilos, 2023). Due to the intense flow of traffic, they are always in need of maintenance and expansion, which are usually carried out by stretches.

According to Bernucci et al., (2022), pavements used on highways are multi-layer structures that need to be resistant to weathering and the loads of circulating vehicles, present impermeability, flexibility, stability, resistance to fire, skidding, and thermal cracking. To this end, there are regulatory standards for construction and renovation, both with regard to the stages of paving and signaling.

The DNIT (National Department of Transport Infrastructure), provides standards and manuals for works on highways, as well as the DER (Department of Highways), provides to technicians in the area the Manual of Road Signaling, which contains information, concepts and descriptions of techniques to guide the development of signage correctly for each case in order to avoid accidents. Both are presented in the form of legislation, including part of the CTB (Brazilian Traffic Code), established by Law No. 9.503, of September 23, 1997.

Bastos (2009), prepared a case study from the survey of the general aspects of the signaling of works on a highway in Uberlândia/MG, based on the requirements of NRs (Regulatory Standard), and the CTB (Brazilian Traffic Code). Analyzing occupational safety, it can conclude that, when employed, it is exposed in a timid, deficient and incomplete way. Other similar studies pointed out the weak participation of risk management, indicating that this sector is deficient and in need of greater attention in the area of civil construction.

2.1 Importance of risk identification

When it comes to risk identification there are three words that are fundamental to guarantee success in the implementation of any technique: recognize, evaluate, and control. Baccarini (2000) defines risk identification simply and directly as "the process of determining what might happen, why, and how.

It is known the importance of knowledge about the risks present within a system, whatever it may be, so that it is possible to identify and correct the deviations before failure occurs, reducing the probability of human error (Morano, 2006).

The task of analyzing the hazards in a workplace or system can be daunting. However, without an effective study, potential hazards may not be discovered before resulting in injuries and losses. The cost of an accident is often greater than the cost of the analysis that could have prevented it from happening, further compromising the progress and quality of the construction. There are many ways to assess the potential hazards of a process or job site, and each approach has strengths and weaknesses (Florero, 2016).

According to Kerzner (2013), the first step in the identification of risks is the detection of potential risk areas, and through the effectiveness of this identification, management efficiency is obtained. The failure in risk management or the non-application of management techniques result in accidents, which directly affect the system, either through damages to the machine or to the worker, or in financial losses.

2.2 Preliminary risk analysis technique

To ensure efficiency in the work performed, in any branch of activity, it is necessary to previously identify the risks present in each function. Good risk management avoids failures that would result in accidents, which directly affect the system

as a whole, whether with financial, human resources, or machinery losses. The risk analysis techniques are divided into qualitative and quantitative, which can be subdivided into probabilistic and deterministic (Melo, et al., 2006). The best technique to use varies with each situation, and both analyze the chances of occurrence and existing consequences (Cassoli, 2006; Zwirtes, et al., 2022).

According to Reginato et al., (2015), the analyses developed in the Brazilian civil construction sector make greater use of qualitative risk analysis tools, which are those that are based on the evaluation and combination of their probability of occurrence with their consequences, for example: Checklist; Preliminary Risk Analysis (APR); Hazard and Operability Study (HAZOP); Failure Modes and Effects Analysis (FMEA); Historical Event Analysis; Fault Tree Analysis (FTA); among others (Brown, 1998). There are many ways to assess the potential hazards of a process or workplace, and each approach has strengths and weaknesses. For example, Occupational Risk Analysis (ART), which has a focus on the workforce, is particularly effective in protecting workers because it considers each of the tasks that a professional must perform (Cassoli, 2006).

Veronezi e Catai (2014) defines the Preliminary Risk Analysis (APR) as a technique of hazard identification and risk analysis that consists in pointing out hazardous events, causes and consequences, in addition to establishing control measures. This technique is usually performed in the preliminary stages of the project, but can be applied in units already in operation, allowing, in this case, a review of existing safety aspects. The APR is a widely used technique due to its low cost, but it is important to note that its efficiency increases if it is complemented with another more detailed analysis technique, such as Fault-Tree Analysis (FTA) or Failure Mode and Effect Analysis (FMEA).

To apply the chosen technique, a checklist was drawn up, a photographic survey of the working conditions of each worker, the identification of the functions and then the respective hazards, a survey of the protective equipment used, and the elaboration of possible preventive measures and improvements in worker comfort and well-being.

3. Methodology

A qualitative study was conducted where its procedure followed the following path: it sought to follow the indispensable methods and techniques that could answer the proposed objective, thus based on an "in loco" case study. With an approach characterized as quantitative, with its purpose in analyzing the preliminary risks caused by the lack of work safety in the execution of asphalt resurfacing.

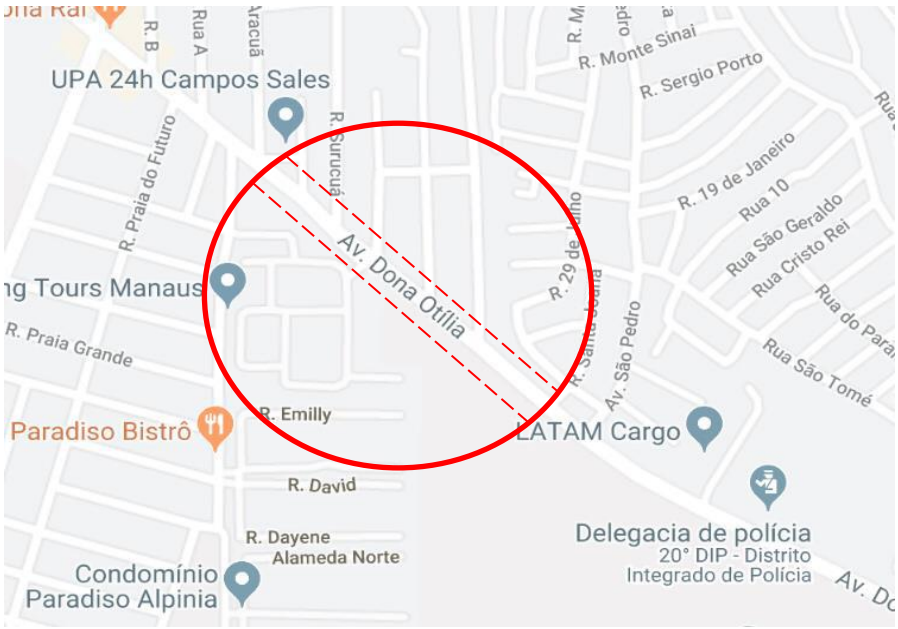
Subsequently, this research is segmented into three sub-items. The first contextualizes the bibliographical survey, followed by a brief exposition on the "in loco" field mapping. Finally, the third section explains the analysis of the results, as well as other examples that stimulate the understanding of the respective subject.

The study was conducted in a company in the business of asphalt paving, which is contracted to provide maintenance on the highways of Manaus. The monitored work was the execution of the resurfacing of the critical stretch located on Avenida Dona Otilia, in the neighborhood of São Pedro, where the removal of the damaged asphalt and the entire process of forming layers of new asphalt cover was performed (Figure 1).

The photographic records were taken in February 2022, with the work already in the asphalt application phase. The stretch is a Class IV-B single lane highway in the City of Manaus. Due to its geographical location and functionality, it is considered a link road that reaches an approximate length of 57 km.

The workers are male, with an average age of 33 years old, and work 8 hours a day, with a rotation of functions, since each team works on a specific stage of the layers, with specific functions, with the exception of the workers.

Figure 1 - Location.



Source: Google Earth (2022).

3.1 Implementation of preliminary risk analysis (APR)

According to Silva et al., (2018), APR consists of a study to be conducted during the design or development phase of a project, in order to determine the risks that may be present during the operational stage. This technique can also be used as a review tool, periodically evaluating process risks that may not have been previously raised (Nagata, et al., 2018), or due to the occurrence of unforeseen processes.

The development of the APR itself is performed through the registration of a form for each activity, which must present the identified hazards, their causes, their detection mode, their potential effects, their frequency categories, severity and risks of their consequences, the corrective/preventive measures, and the identifier of the accident scenario (Alves, et al., 2014). The model form used is exemplified in Table 1, which should be filled out as described below.

Table 1 - APR Completion Form.

Activity:						
Danger	Cause	Consequence	Category			Recommendations
			Freq.	Sev.	Risks	

Source: Adapted from Aguiar (2011).

- 1st column – **Danger:** accidental events that have the potential to cause harm to the facility, operators, the public, or the environment.
- 2nd column – **Causes:** can involve as many intrinsic equipment failures, as well as human error in operation and maintenance.
- 3rd column – **Consequences:** are the possible harmful effects of each identified danger.
- 4th column – **Frequency:** the frequency classes provide an expected qualitative indication of occurrence for each of the identified scenarios and are presented in Table 2.

Table 2 - APR Scenario Frequency Categories.

Category		Description
A	Extremely remote	Extremely improbable to occur during the lifetime of the installation.
B	Remote	It should not occur during the lifetime of the installation.
C	Improbable	Probable to occur during the lifetime of the operation.
D	Probable	Expected to occur up to once during the lifetime of the operation.
E	Frequent	Expected to occur several times during the lifetime of the operation.

Source: Adapted from Alves et al., (2014).

- 5th column – **Severity:** these are the categories that provide a qualitative indication of the degree of severity of the consequences of each of the identified scenarios and are presented in Table 3.

Table 3 - Severity Category.

Category		Description
I	Negligible	The exposure will not result in a major consequence to the worker, nor will it produce functional damage or injury, or contribute a risk to the employee in the performance of his or her duties.
II	Marginal or borderline	The exposure will affect the worker to some extent, but without involving major damage or injury, and can be compensated for or controlled adequately.
III	Critique	The exposure will affect the worker causing injury, substantial harm, or will result in an unacceptable risk requiring immediate corrective action.
IV	Catastrophic	Exposure will produce severe consequence to the employee, resulting in their total productive disability, injury, or death. It is characterized by urgency in priority, and elimination when identified.

Source: Adapted from DEFENSE – MIL-STD-882E (2012).

- 6th column – **Risks:** Combining the frequency categories with the severity categories, we obtain the Risk Matrix, presented in Table 4, which provides a qualitative indication of the risk level for each scenario identified in the analysis. Where: (1) – Negligible; (2) – Minor; (3) – Moderate; (4) – Serious; (5) – Critical.

Table 4 - Risk Classification Matrix.

Severity \ Frequency	A	B	C	D	E
IV	(2)	(3)	(4)	(5)	(5)
III	(1)	(2)	(3)	(4)	(5)
II	(1)	(1)	(2)	(3)	(4)
I	(1)	(1)	(1)	(2)	(3)

Source: Adapted from Eletronuclear (2014).

- 7th column – **Recommendations:** contains the measures that should be taken, mitigate the frequency or severity of the accident or any observations pertinent to the accident scenario under study (Eletronuclear, 2014).

3.2 Pneumatic roller compactor operator

The pneumatic roller operator is responsible for compacting the materials used in the subgrade, subbase, base and aggregates used in the asphalt layer. The work environment of this function is the equipment cabin, consisting of a seat,

steering and a lever, and, depending on the equipment, a cover (Figure 2 illustrates this environment). The equipment produces 87.7 dB, exposing the worker to physical risk, for example.

Figure 2 - Pneumatic Road Roller.

Source: Authors (2023).

3.3 Pneumatic roller compactor assistant

The function of the auxiliary is to keep the tires clean, since the asphalt mass tends to adhere to the tire rubber, decreasing its compaction efficiency, and can damage it if not removed while it is hot. The auxiliary works in the application of vegetable oil with the backpack pump during the operation of the roller (Figure 3).

Figure 3 - Assistant performing his task.

Source: Authors (2023).

3.4 Asphalt paver operator

The paver table has the function of receiving the load of asphalt mix from the supply truck and spreading the material through the vibrating table, producing a smooth and homogeneous surface. The operator has the function of keeping the flames lit to ensure the ideal temperature for the application of the asphalt mix as shown in Figure 4.

Figure 4 - Asphalt Paver Operator.

Source: Authors (2023).

3.5 Servants

The servant's is the position that has the largest number of workers. Their function is to help level the road grade, clean the site before applying bituminous material, unload the aggregate from the truck using shovels, and manually correct the poured aggregate. As this function does not have a machine, the operator does not have a specific work environment, i.e., he remains on the track during the execution of all services, helping the operators and being exposed to sound pressure levels of 87.7 dB. The working day is 44 hours per week and the equipment handled are: rakes, brooms, shovels and buckets (Figure 5).

Figure 5 - The laborers distributing and leveling the asphalt mix.

Source: Authors (2023).

It was observed that this function is exposed to considerable risks of concern, such as being run over, since the worker remains on the road during various stages of the work, exposed to the traffic of trucks and cars; and the chemical risk due to contact with the bituminous product, as shown in Figure 6.

Figure 6 - Car driving alongside the workers who are working on the stretch.

Source: Authors (2023).

4. Results and Discussion

The risks found in each function were put into charts, presenting the identified risks, the causative agents, the sources, the means of propagation, exposure time, the consequences, the frequency of occurrence, the individual and collective protection equipment needed to reduce the risks, and the measures needed to improve the working conditions at each position.

In the survey carried out "in loco", the following activities were found to be performed by workers on the stretch of road studied: compactor tire roller operator, compactor tire roller assistant, vibrofinisher operator, and laborers.

After filling out the tables applying the APR methodology at each workstation, it is possible to proceed with the elaboration of the Risk Matrix, which allows for a simplified visualization of the risks, based on severity versus frequency, and a color scheme that indicates the type of risk to which the worker is exposed.

4.1 Pneumatic roller compactor operator

During the monitoring, it was observed that the activity involves several risks in the function of operator of tire roller compactor, which were identified and classified as environmental risks (physical and biological) observed in Table 5, ergonomic (Table 6) and accident (Table 7). Then, using the APR technique, it was possible to identify the determination of the risk category in each of these hazards and the recommendations indicated for each group. Among them is the risk of vibration (physical), often caused by unbalance of the machine.

According to Estupinãn (2011), the vibrations generated by these machines are of low amplitude and the sound pressure level in many cases may be enough to not be able to identify the vibrations generated by the presence of defects, requiring preventive maintenance and if necessary, corrective.

Table 5 - APR implementation resulting in physical and biological risks.

Number of workers: 1							
Danger		Cause	Consequences	Category			Recommendations
				F	S	R	
PHYSICISTS	Impact Noise	Sound pressure level	Partial hearing loss; tinnitus	D	III	4	Use of EPIs (adequate ear protection), EPCs (physical barrier). Administrative measures: change of function, removal.
			Nausea; dizziness	D	I	2	
			Cephalea	E	I	3	
			Deafness	C	IV	4	
	Vibration	Machine movement	Partial hearing loss; tinnitus	C	III	3	
			Nausea; dizziness	C	II	2	
			Cephalea	E	II	4	
			Deafness	C	IV	4	
BIOLOGICALS	Contamination	Contact: fungi and bacteria; insect bites (virus)	Contagious Diseases	E	II	4	Use of EPIs (long boots, long pants, long sleeve shirt); keeping the workplace organized and clean; training on personal hygiene and not sharing EPIs, cups, and cutlery.
	Poisoning	Contact with poisonous animals (e.g. snakes, scorpions)	Poisoning, injury, wounding	C	III	3	

Source: Authors (2023).

Table 6 - APR implementation resulting in ergonomic risks.

Number of workers: 1							
Danger	Cause	Consequences	Category			Recommendations
			F	S	R	
ERGONOMIC	Improper posture	Fatigue, back pain	E	II	4	Ergonomic study, training, stretching and rest breaks, relaying, change of position, walking; change of function and/or layoffs.
	Repetitive movements	Fatigue, back and limb pain	E	II	4	

Source: Authors (2023).

Table 7 - APR implementation resulting in accident risks.

Number of workers: 1							
Danger	Cause	Consequences	Category			Recommendations
			F	S	R	
ACCIDENTS	Hit by a car	Heavy machinery moving in the same place	Dislocation, abrasions, fractures, trauma and death	C	IV	4	Organized, signaled, isolated, and clean work area; conduct inspection and maintain a safe distance between workers to avoid hitting them with tools; use the appropriate EPIs for the activity; when there is a possibility of electrical cables the location must be properly monitored; keep away from moving vehicles and equipment; conduct training periodically.

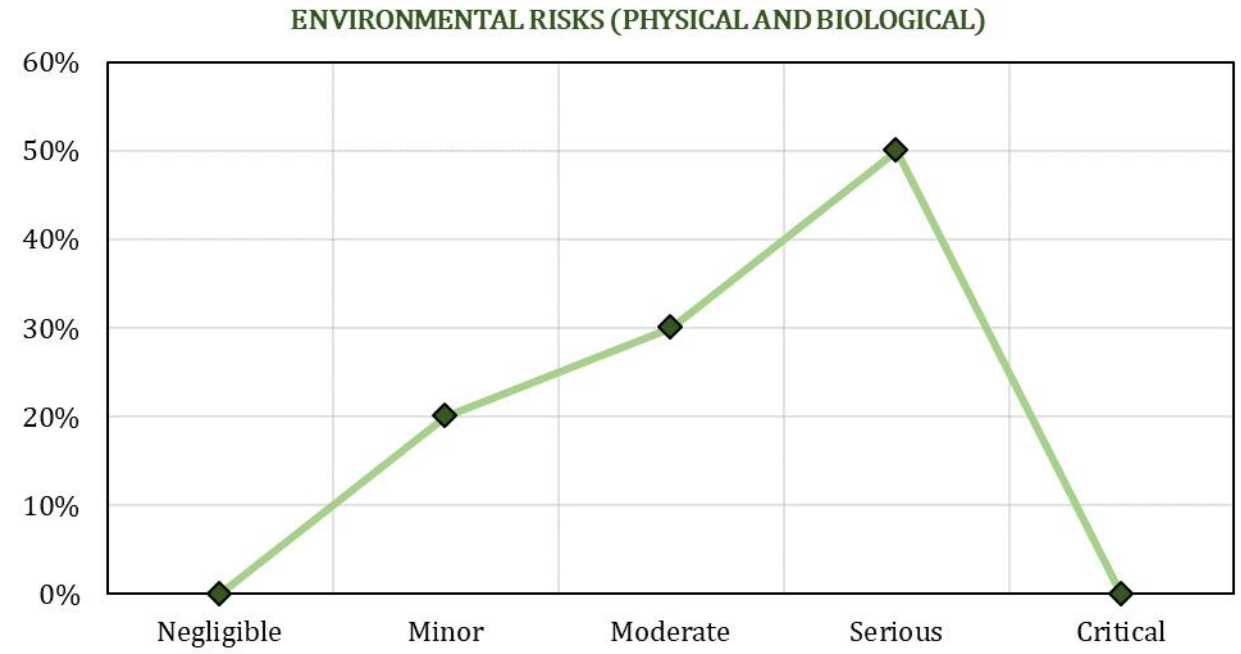
Source: Authors (2023).

The high level of decibels emitted by the equipment caused the sound pressure level to be classified as high risk, because it may cause, over time, deafness to the operator. The vibration caused by the equipment reaches the operator's body completely, and may cause problems in the spinal column, being a high risk.

As for environmental risks (physical and biological), according to the risk classification matrix (Table 5), 20% were classified in risk category (2) - Minor; 30%, in risk category (3) - Moderate; and 50% in risk category (4) - Serious (Figure 7).

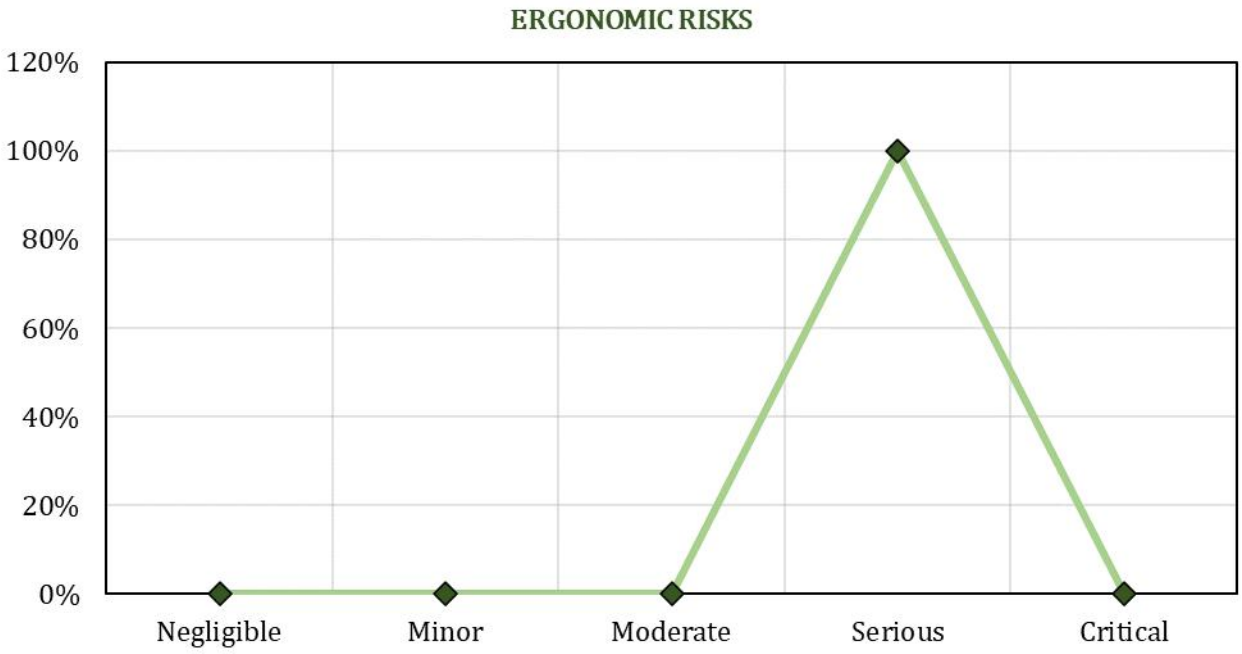
Regarding ergonomic risks (Table 6), they were all classified as category (4) - Serious (Figure 8). Finally, regarding the risks of accidents (Table 7), they were all classified as category (4) - Serious (Figure 9).

Figure 7 - Matrix of physical and biological risks classification.



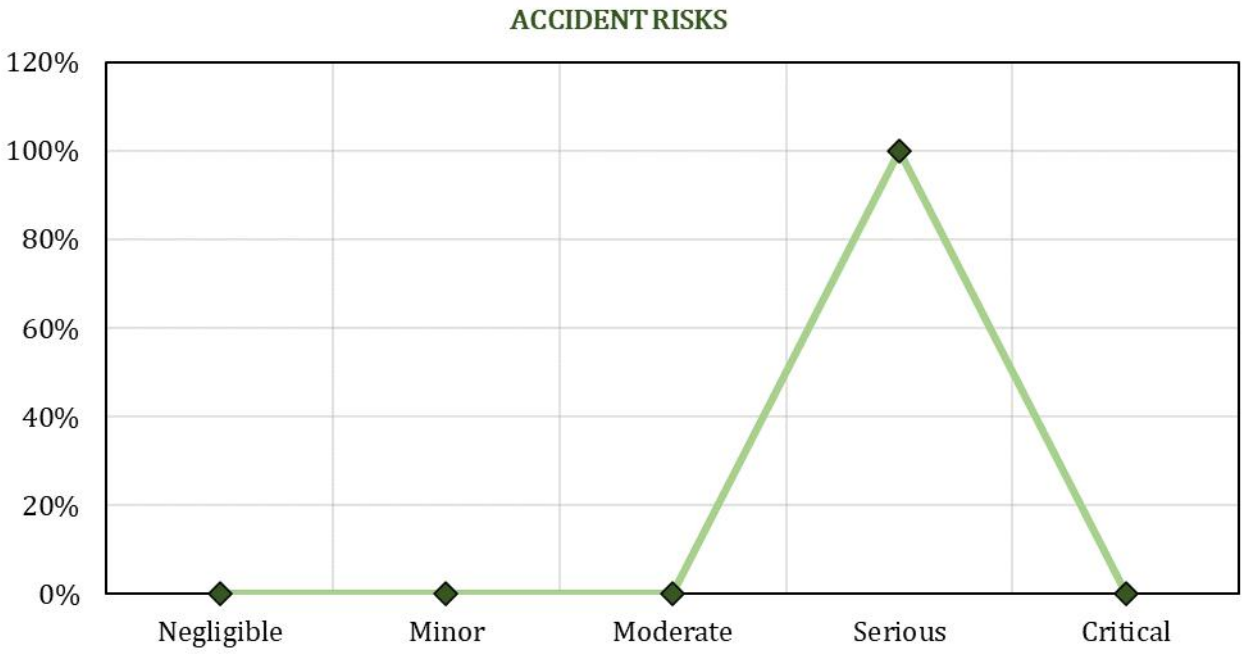
Source: Authors (2023).

Figure 8 - Matrix of the ergonomic risk classification.



Source: Authors (2023).

Figure 9 - Matrix of the accident risk classification.



Source: Authors (2023).

4.2 Pneumatic roller compactor assistant

With the implementation of the Preliminary Risk Analysis for the function of tire roller assistant, the categories above 3 (three) stand out, that is, there is need for intervention and the application of preventive measures (Tables 8; 9 and 10).

Table 8 - APR implementation resulting in physical and biological risks.

Number of workers: 2							
Danger		Cause	Consequences	Category			Recommendations
				F	S	R	
PHYSICISTS	Impact Noise	Sound pressure level	Partial hearing loss; tinnitus	D	III	4	Use of EPIs (adequate ear protection), EPCs (physical barrier). Administrative measures: change of function, removal.
			Nausea; dizziness	D	I	2	
			Cephalea	E	I	3	
			Deafness	C	IV	4	
	Vibration	Machine movement	Partial hearing loss; tinnitus	C	III	3	
			Nausea; dizziness	C	II	2	
			Cephalea	E	II	4	
			Deafness	C	IV	4	
BIOLOGICALS	Contamination	Contact: fungi and bacteria; insect bites (virus)	Contagious Diseases	E	II	4	Use of EPIs (long boots, long pants, long sleeve shirt); keeping the workplace organized and clean; training on personal hygiene and not sharing EPIs, cups, and cutlery.
	Poisoning	Contact with poisonous animals (e.g. snakes, scorpions)	Poisoning, injury, wounding	C	III	3	

Source: Authors (2023).

Table 9 - APR implementation resulting in ergonomic risks.

Number of workers: 2						
Danger	**Cause**	**Consequences**	**Category**			**Recommendations**
			F	**S**	**R**	
ERGONOMIC	Improper posture	Fatigue, back pain	E	II	4	Ergonomic study, training, stretching and rest breaks, relaying, change of position, walking; change of function and/or layoffs.
	Repetitive movements	Fatigue, back and limb pain	E	II	4	

Source: Authors (2023).

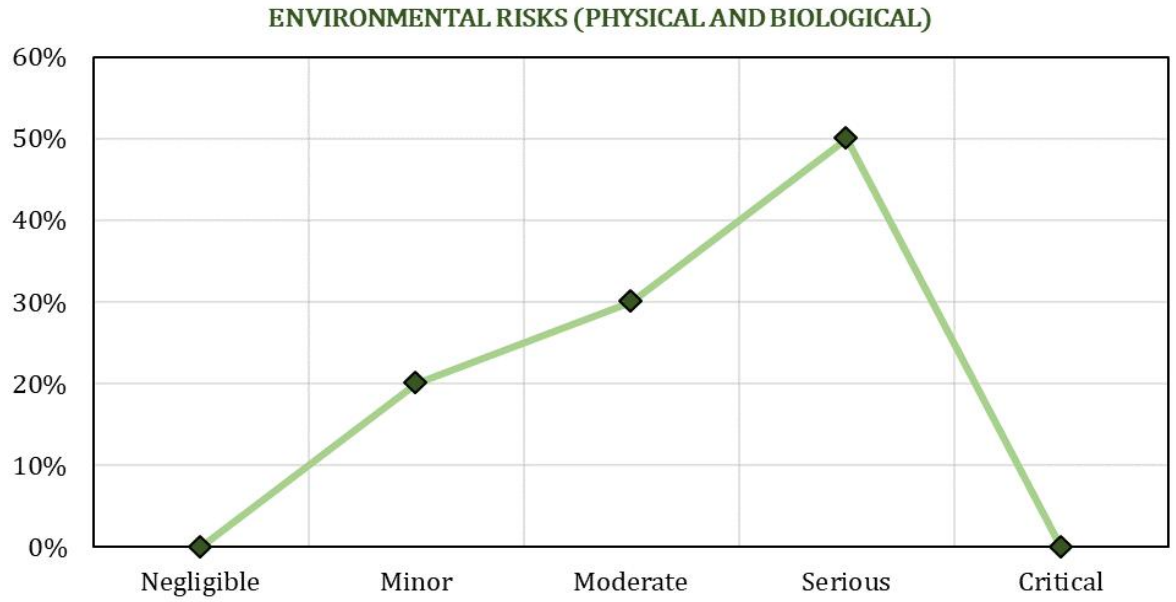
Table 10 - APR implementation resulting in accident risks.

Number of workers: 2							
Danger		**Cause**	**Consequences**	**Category**			**Recommendations**
				F	**S**	**R**	
ACCIDENTS	Hit by a car	Heavy machinery moving in the same place	Dislocation, abrasions, fractures, trauma and death	C	IV	4	Organized, signaled, isolated, and clean work area; conduct inspection and maintain a safe distance between workers to avoid hitting them with tools; use the appropriate EPIs for the activity; when there is a possibility of electrical cables the location must be properly monitored; keep away from moving vehicles and equipment; conduct training periodically.

Source: Authors (2023).

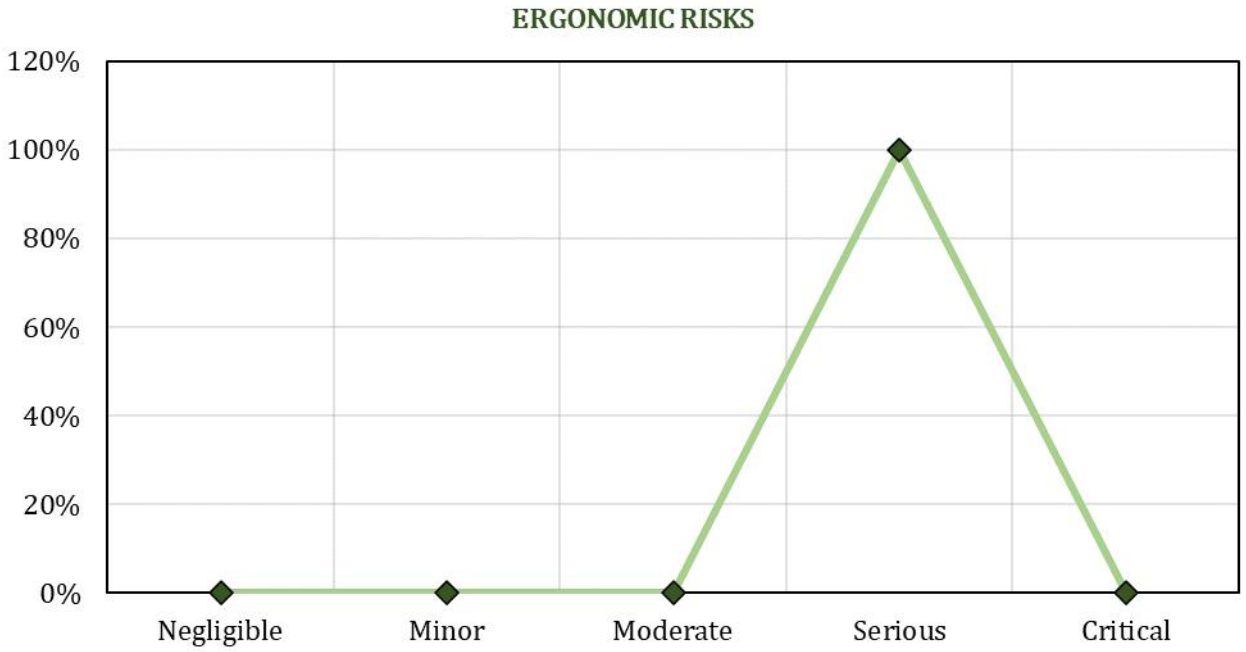
As for environmental risks (physical and biological), according to the risk classification matrix (Table 8), 20% were classified in risk category (2) - Minor; 30%, in risk category (3) - Moderate; and 50% in risk category (4) - Serious (Figure 10). Regarding ergonomic risks (Table 9), they were all classified as category (4) - Serious (Figure 11). Finally, regarding the risks of accidents (Table 10), they were all classified as category (4) - Serious (Figure 12).

Figure 10 - Matrix of physical and biological risks classification.



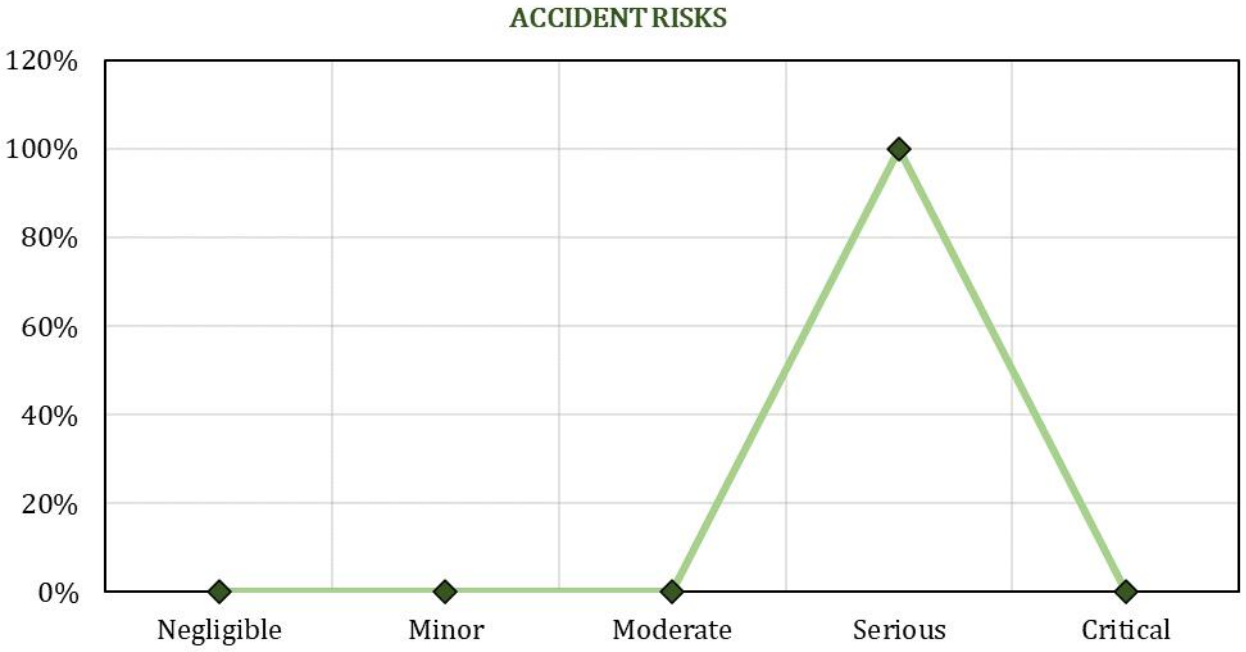
Source: Authors (2023).

Figure 11 - Matrix of the ergonomic risk classification.



Source: Authors (2023).

Figure 12 - Matrix of the accident risk classification.



Source: Authors (2023).

4.3 Asphalt paver operator

Among the risks raised in Table 11, the sound pressure level produced by the machine is 84.7 dB, a value informed by the manufacturer. This particular equipment has the risk of crushing due to the presence of moving and rotating parts that can hit the worker if these are not protected (Table 12).

Table 11 - APR implementation resulting in physical and chemical risks.

Number of workers: 1							
Danger		**Cause**	**Consequences**	**Category**			**Recommendations**
				F	**S**	**R**	
PHYSICISTS	Impact Noise	Sound pressure level	Partial hearing loss; tinnitus	D	III	4	Use of EPIs (adequate ear protection), EPCs (physical barrier). Administrative measures: change of function, removal.
			Nausea; dizziness	D	I	2	
			Cephalea	E	I	3	
			Deafness	C	IV	4	
	Vibration	Machine movement	Partial hearing loss; tinnitus	C	III	3	
			Nausea; dizziness	C	II	2	
			Cephalea	E	II	4	
			Deafness	C	IV	4	
CHEMICALS	Intoxication	GLP Bottle	Inhalation of nitrous gases	E	II	4	Use of EPIs (long boots, long pants, long sleeve shirt); keeping the workplace organized and clean; training on personal hygiene and not sharing EPIs, cups, and cutlery.
	Asphalt Emulsion	Exposure to hydrocarbon vapors	Burns	E	II	4	

Source: Authors (2023).

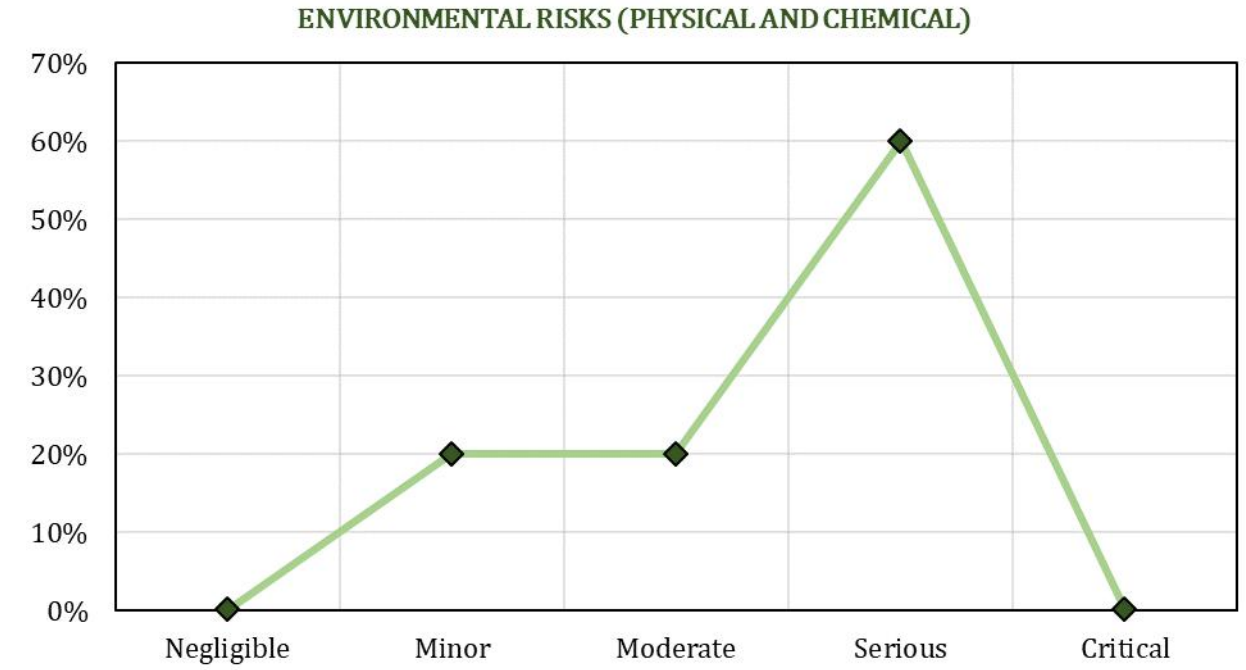
Table 12 - APR implementation resulting in accident risks.

Number of workers: 1							
Danger		**Cause**	**Consequences**	**Category**			**Recommendations**
				F	**S**	**R**	
ACCIDENTS	Hit by a car	Heavy machinery moving in the same place	Dislocation, abrasions, fractures, trauma and death	C	IV	4	Organized, signaled, isolated, and clean work area; conduct inspection and maintain a safe distance between workers to avoid hitting them with tools; use the appropriate EPIs for the activity; when there is a possibility of electrical cables the location must be properly monitored; keep away from moving vehicles and equipment; conduct training periodically.

Source: Authors (2023).

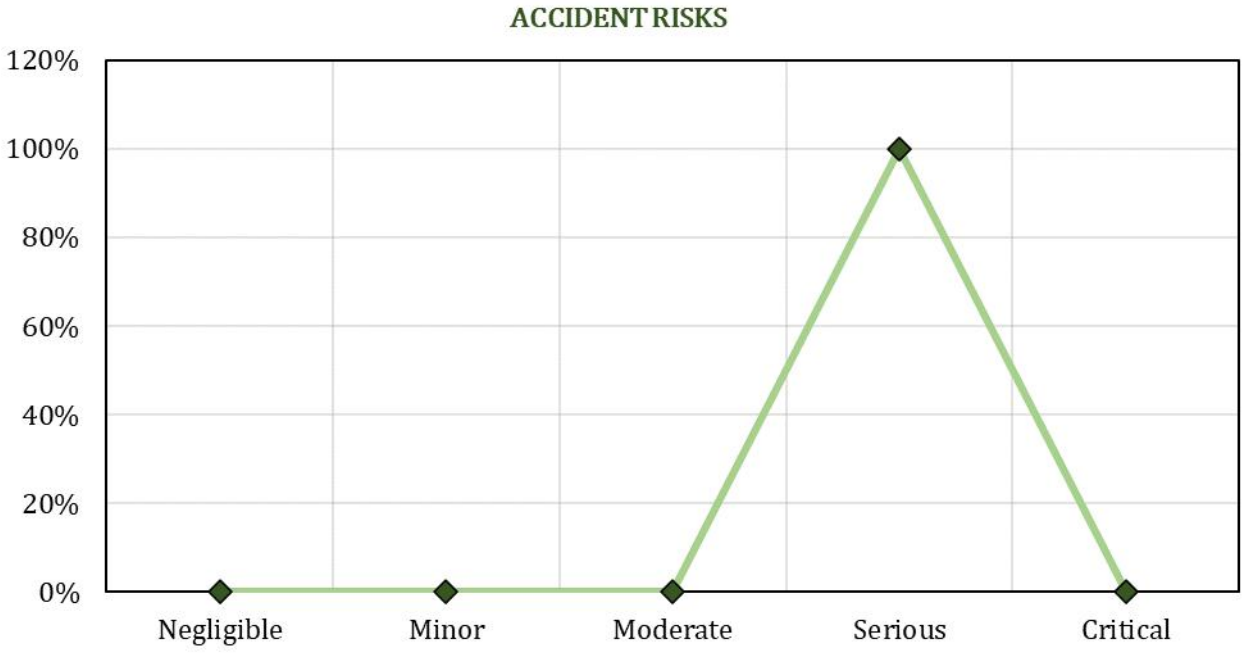
As for environmental risks (physical and chemical), according to the risk classification matrix (Table 11), 20% were classified in risk category (2) - Minor; 20%, in risk category (3) - Moderate; and 60% in risk category (4) - Serious (Figure 13). With regard to accident risks (Table 12), they were all classified as category (4) - Serious (Figure 14).

Figure 13 - Matrix of physical and chemical risks classification.



Source: Authors (2023).

Figure 14 - Matrix of the accident risk classification.



Source: Authors (2023).

4.4 Servants

The servant's service is extremely important during the execution of the asphalt resurfacing work, because any undesirable interference can cause problems that make the process more time consuming and laborious. To prepare the analysis, it was observed during the on-site monitoring in which situations and moments this service was necessary.

Much of this work is done manually and, because it is an open-air activity, there are several risks to which the workers

are exposed. Thus, the care with their health and safety must be carefully observed, in order to avoid damage to health and safety. The analysis of environmental risks (physical, chemical and biological) is presented in Table 13; and of the accident risks, in Table 14.

Table 13 - APR implementation resulting in physical, chemical and biological risks.

Number of workers: 10							
Danger		Cause	Consequences	Category			Recommendations
				F	S	R	
PHYSICISTS	Impact Noise	Sound pressure level	Partial hearing loss; tinnitus	D	III	4	Use of EPIs (adequate ear protection), EPCs (physical barrier). Administrative measures: change of function, removal.
			Nausea; dizziness	D	I	2	
			Cephalea	E	I	3	
			Deafness	C	IV	4	
	Vibration	Machine movement	Partial hearing loss; tinnitus	C	III	3	
			Nausea; dizziness	C	II	2	
			Cephalea	E	II	4	
			Deafness	C	IV	4	
CHEMICALS	Intoxication	GLP Bottle	Inhalation of nitrous gases	E	II	4	Use of EPIs (long boots, long pants, long sleeve shirt); keeping the workplace organized and clean; training on personal hygiene and not sharing EPIs, cups, and cutlery.
	Asphalt Emulsion	Exposure to hydrocarbon vapors	Burns	E	II	4	
BIOLOGICALS	Contamination	Contact: fungi and bacteria; insect bites (virus)	Contagious Diseases	E	II	4	Use of EPIs (long boots, long pants, long sleeve shirt); keeping the workplace organized and clean; training on personal hygiene and not sharing EPIs, cups, and cutlery.
	Poisoning	Contact with poisonous animals (e.g. snakes, scorpions)	Poisoning, injury, wounding	C	III	3	

Source: Authors (2023).

Table 14 - APR implementation resulting in accident risks.

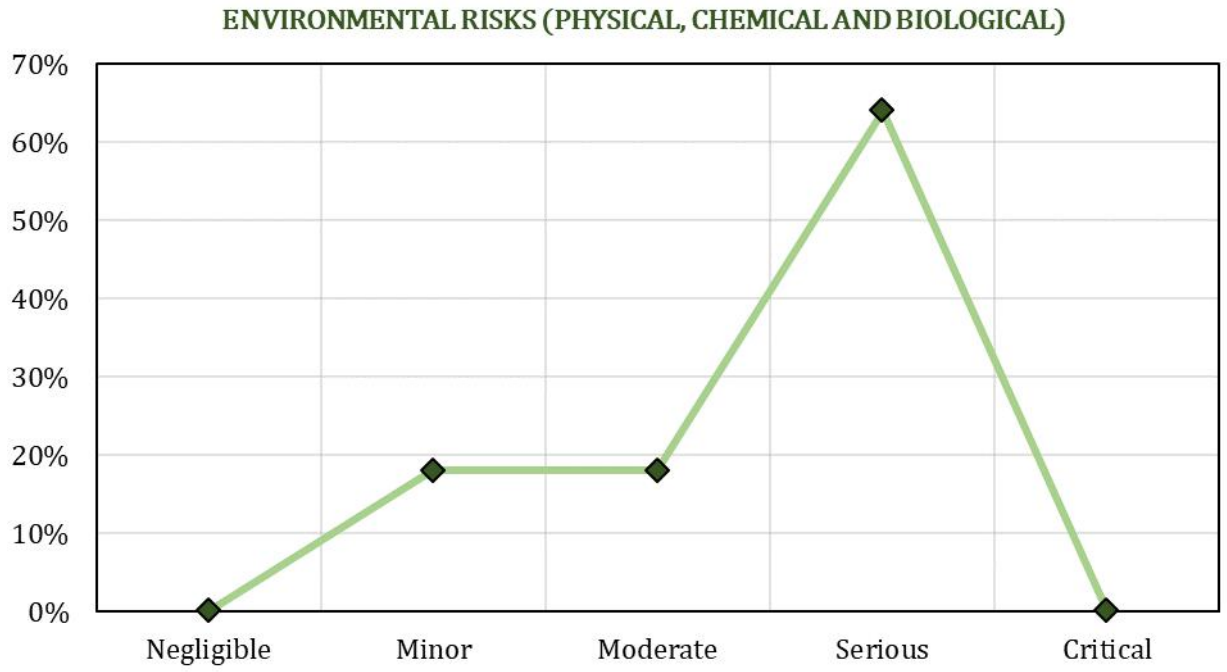
Number of workers: 10							
Danger		Cause	Consequences	Category			Recommendations
				F	S	R	
ACCIDENTS	Hit by a car	Heavy machinery moving in the same place	Dislocation, abrasions, fractures, trauma and death	C	IV	4	Organized, signaled, isolated, and clean work area; conduct inspection and maintain a safe distance between workers to avoid hitting them with tools; use the appropriate EPIs for the activity; when there is a possibility of electrical cables the location must be properly monitored; keep away from moving vehicles and equipment; conduct training periodically.

Source: Authors (2023).

As for environmental risks (physical, chemical and biological), according to the risk classification matrix (Table 13), 18% were classified in risk category (2) - Minor; 18%, in risk category (3) - Moderate; and 64% in risk category (4) - Serious (Figure 15).

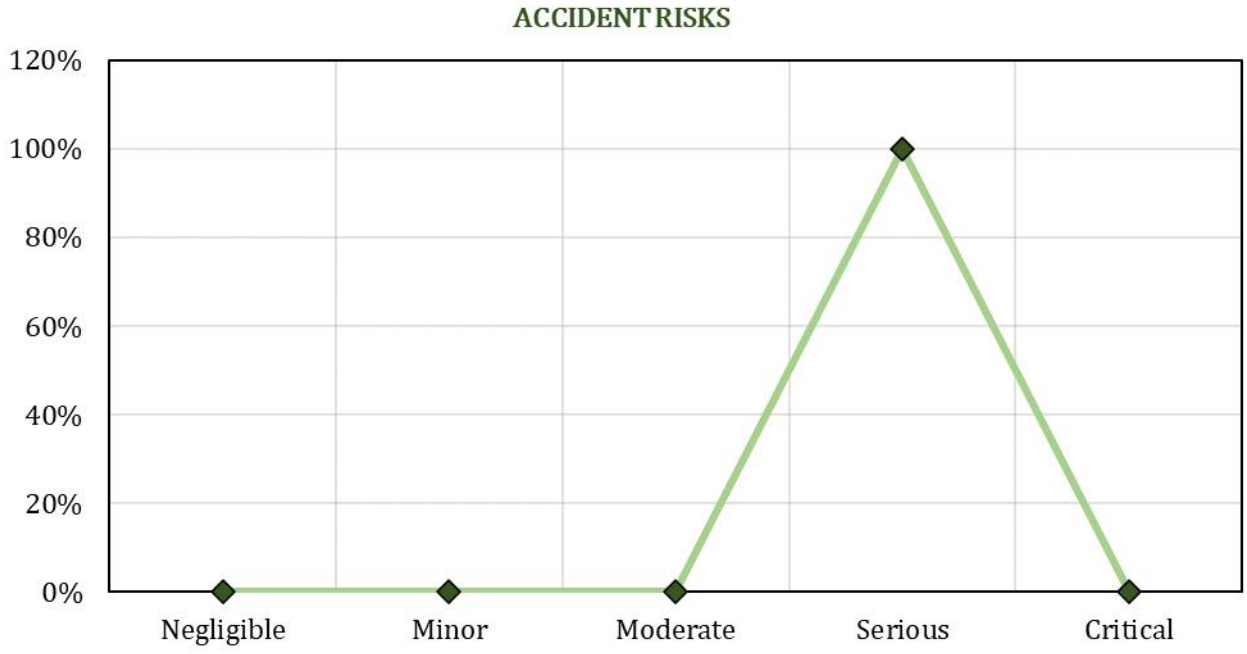
With regard to accident risks (Table 14), they were all classified as category (4) - Serious (Figure 16).

Figure 15 - Matrix of physical, chemical and biological risk classification.



Source: Authors (2023).

Figure 16 - Matrix of the accident risk classification.



Source: Authors (2023).

Therefore, regarding the environmental risks, taking into account the four workstations analyzed, 55% were classified as category (4) risks; 26% in category (3); and only 19% in category (2). Ergonomic risks resulted in 100% in category (4). Regarding accident risks, when considering all the activities analyzed, 100% presented category (4). The risks framed in categories (5) and (4) require immediate care, in order to neutralize them or reduce the chances of occurrence of these factors. Those classified as category (3) should be observed and neutralized with the implementation of recommended corrective

and/or preventive measures. The minor risk category (2) does not require the adoption of intensive measures, however, in order to ensure the health and safety of workers, the recommendations presented for each activity must be followed.

5. Final Considerations

We conclude that road works are of paramount importance for the development of the Brazilian economy. However, several factors make the sector still present a high number of work accidents. The lack of instruction of workers is one of the factors that leads to this high rate of accidents. Therefore, the implementation of techniques that establish safety measures is of great relevance to change this scenario. In many cases, the measures that lead to the neutralization/elimination of these risks or the minimization of their consequences are of simple solution.

It was observed that the Preliminary Risk Analysis is a tool of easy implementation and relatively low cost, which, when correctly applied, allows an overview of the hazards involved in certain activities, enabling the identification of risks with the greatest impact on the health and safety of workers. This methodology presents itself as a viable alternative in the risk management of road execution and expansion activities.

Among the processes analyzed during the asphalt resurfacing stage, the most recurrent risk level was (4) - Serious, present in 62% of the hazards found, followed by (3) - Moderate, presented in 22% of the hazards. The risk level (2) - Minor was present in 16% of the hazards identified. In this context, we can see the importance of an effective control of the activities regarding the health and safety of the workers in the sector.

It was noted that the previous development of the analysis allows that, in the next enterprises, a greater planning of the activities, processes, and risk stages occurs, a standardization of the tasks and attributions of responsibilities, and a system of identification and control of the nonconformities.

Finally, for an effective use of the results of this research, the company that executes this type of infrastructure work should go beyond the content of the current legislation, seeking better health and safety conditions for its workers and thus improve its results.

5.1 Suggestions for future research

During the preparation of this study, some possibilities for continuing the research were identified, including:

- Implementing other analysis models, such as Ergonomic Occupational Analysis (AET), to identify the risks at each workstation in the execution process and;
- Check other possible workplaces to implement these occupational safety techniques.

References

Aguiar, L. A. (2011). Metodologias de análise de riscos APP & HAZOP. *Digital journal*, 95 (1), 1-30. http://static.sapucaia.ifsul.edu.br/

Alves, A. S. et al. (2014). Diagnóstico das condições de trabalho em serraria, Uruará, Pará, Brazil. *Enciclopédia Biosfera*, 2 (19), 2879-2888. http://www.conhecer.org.br/

ABEDA - Associação Brasileira das Empresas Distribuidoras de Asfalto (2001). *Resolução No. 19, de 11 de julho de 2001*. https://www.abeda.org.br/

Associação Brasileira de Normas Técnicas (2014). NBR 14725-4: Produtos químicos - Informações sobre segurança, saúde e meio ambiente Parte 4: Ficha de informações de segurança de produtos químicos (FISPQ). *Brazilian standard*. https://ww3.icb.usp.br/

Baccarini, D. (2000). Risk Management Australian Style - theory vs. practice. *Paper presented at Project Management Institute Annual Seminars & Symposium*, 1 (20), 1-16. https://www.pmi.org/

Bastos, B. (2009). *Segurança no Trabalho e Prevenção de Acidentes*. Editora Atlas S.A.

Bernucci, L. B. et al. (2022). *Pavimentação Asfáltica: Formação Básica para Engenheiros*. (2nd ed.), ABEDA e Petrobras.

Cassoli, L. M. (2006). Acidente ocupacional com material biológico: adesão ao seguimento ambulatorial segundo as características do acidente e do acidentado. São Paulo, Brazil: *Dissertação de Mestrado em Ciências da Faculdade de Medicina da Universidade de São Paulo*. https://www.teses.usp.br/

Reginato, J. C. L. et al. (2015). Análise preliminar de risco em uma obra rodoviária de mobilidade urbana na região metropolitana de Curitiba. *Revista SODEBRAS*, 10 (118), 10-15. http://repositorio.utfpr.edu.br/

Estupinãn, E. A. (2011). Análise de vibração aplicada em máquinas rotativas de baixa velocidade. *Mundo Mecânico*. https://www.mundomecanico.com.br/

ILOS. (2023). Você sabe o quanto as rodovias podem ajudar ou prejudicar a economia? *Instituto de Logística e Supply Chain*. https://ilos.com.br/

Kerzner, H. R. (2013). *Project Management: a systems approach to planning, scheduling, and controlling*. 11th Edition. New Jersey, United States: John Wiley & Sons.

Morano, C. A. R. (2006). Aplicação das técnicas de identificação de risco em projetos de E & P. Niterói, Brazil: *Monografia de Pós-Graduação - MBA em Engenharia Econômica e Financeira da Universidade Federal Fluminense*. doi:10.22409/engevista.v8i2.198

MSR. (2006). Manual de Sinalizacão Rodoviária. São Paulo, Brazil: *Departamento de Estradas de Rodagem do Estado de São Paulo*.

Nascimento, J. W. S. et al. (2021). Functional evaluation of pathologies in flexible pavement. Revista Científica Multidisciplinar Núcleo do Conhecimento, 6 (6), 110-129. 10.32749/nucleodoconhecimento.com.br/civil-engineering/flexiblepavement

Norma Regulamentadora. (2021). NR6: Equipamentos de Proteção Individual – EPI. Brasília, Brazil: *Ministério do Trabalho e Emprego*.

Nascimento, J. W. S. et al. (2021). NR16: Atividades e Operações Perigosas. Brasília, Brazil: *Ministério do Trabalho e Emprego*.

Nascimento, J. W. S. et al. (2021). NR9: Programas de Prevenção de Riscos Ambientais. Brasília, Brazil: *Ministério do Trabalho e Emprego*.

Nagata, F. Y. et al. (2018). Caracterização dos níveis de ruído ocupacional em uma indústria de base florestal. *XXXIX Encontro nacional de engenharia de produção*. https://www.abepro.org.br/

Florero, N. S. (2014). Aplicação da análise preliminar de riscos nos processos da fabricação de mistura asfáltica a quente. Curitiba, Brazil: *Trabalho de Conclusão de Curso de Especialização da Universidade Tecnológica Federal do Paraná*.

Santos, J. L. et al. (2022). Asphalt resurfacing: analysis in a critical segment in the city of Manaus. *Brazilian Journal of Development*, 8 (5), 10580-10595. doi:10.34117/bjdv8n5-5400

Silva, A. V. et al. (2018). Aplicação da análise preliminar de riscos (APR) em açougues da cidade de Imperatriz/MA. *Brazilian Journal of Production Engineering*, 4 (1), 196-209. http://periodicos.ufes.br/BJPE/

Souza Nascimento, J. W. et al. (2023). The effect of using recycling techniques on asphalt pavements. *Brazilian Journal of Development*, 9 (7), 22354-22367. doi:10.34117/bjdv9n7-0098

Souza Nascimento, J. W., Santos, S. G. M., & Sampaio, A. T. (2021). Variação dos riscos ergonômicos no ambiente de trabalho em um canteiro de obras. *23rd Congresso Nacional de Engenharia de Segurança do Trabalho*, 1(1), 138-141. https://www.anest.org.br/

Melo, L. H. C. et al. (2006). Análise Preliminar de Risco na pavimentação asfáltica tipo TSD. *Faculdade de arquitetura, Engenharia e tecnologia da UFMT*. https://baixardoc.com/

Veronezi, C. T. P., & Catai, R. E. (2014). Análise preliminar de risco na manutenção predial de uma instituição federal de ensino superior. *Revista Engenharia e Construção Civil*, 1 (1), 48-62. https://periodicos.utfpr.edu.br/

Zwirtes, G. L. et al. (2022). Práticas de aprendizagem em ergonomia e segurança do trabalho - AET E APR em laboratório de anatomia animal. *Anais da SIEF*, 1 (1), 1-13. 10.29327/170181.2022-8

Zwirtes, G. L. et al. (2022). Análise preliminar de risco e análise ergonômica do trabalho em laboratório de anatomia animal. *XXVIII Congresso Nacional de Estudantes de Engenharia Mecânica*, 1(1), 1-8. https://eventos.abcm.org.br/