

Analysis of work accidents and occupational diseases in tunnelling as a support for risk management

Análisis de los accidentes laborales y enfermedades ocupacionales en tunelización como soporte para la gestión de riesgos

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Abstract

This article is a contribution to close the scientific gap due to the lack of statistical data on accidents at work and occupational diseases in tunnelling. The characterization of the most typical events, understanding the cause of their occurrence, is of great importance for their prevention and for determining the existing hazards. This will allow the events analysis to gain more space as a tool for risk analysis, through the already established added value of learning from past events and mistakes. Thus, it is possible to study in due time potential causes of harmful events that may occur. With these advantages, companies can improve their risk assessments and control their costs. This article analyses statistically, using Eurostat variables, the most typical accidents at work and occupational diseases in tunnelling in Portugal, comparing them with other types of construction, using the same indicators. It starts by presenting an overview of accidents at work and occupational diseases in tunnelling worldwide, describing their impact. Afterwards, it presents statistical data from the Portuguese construction and tunnelling sectors, using the data from 150 accidents at work and 42 cases of occupational diseases in tunnelling to compare with construction, showing why tunnelling is so specific.

Keywords: Accidents; prevention; diseases; tunneling; Portugal

Resumen

Este artículo es una contribución para cerrar la brecha científica debida a la falta de datos estadísticos sobre accidentes laborales y enfermedades ocupacionales en la construcción de túneles. La caracterización de los acontecimientos más típicos tiene gran importancia para determinar los peligros existentes, permitiendo que el análisis de los eventos trascienda como una herramienta para el análisis de los riesgos, a través del valor agregado de aprender de los eventos pasados. Así, es factible estudiar las posibles causas de los eventos perjudiciales que pueden ocurrir. Con estas ventajas, las empresas pueden mejorar sus evaluaciones de riesgo y controlar sus costos. En este artículo se analizan estadísticamente, los accidentes laborales y las enfermedades ocupacionales más comunes en Portugal, utilizando las variables de Eurostat, y comparándolos con los de la construcción en general, utilizando los mismos indicadores. Se presenta una visión general de los accidentes y enfermedades laborales en túneles de todo el mundo; se analizan datos estadísticos (portugueses) de la construcción y tunelización, utilizando los datos de 150 accidentes de trabajo y 42 casos de enfermedades ocupacionales en túneles para compararlos con los de la construcción, mostrando por qué tunelización es tan específico. Así, se hace una relevante contribución técnico-científica para comprender las causas de los accidentes laborales y enfermedades ocupacionales.

Palabras clave: Accidentes; prevención; enfermedades; túneles; Portugal

1. Introduction

1.1 Overview

Tunnelling (TUNLG) is a part of the construction sector and it is a specific area in which there have been considerable financial investments (Tender and Couto, 2016a) and which has been increasing in volume (Ritter et al., 2013) and importance for the development of cities (Delmastro et al., 2016). Construction (CONST) has a range of risks already reasonably known, such as: exposure to loud noises, vibrations, dust, hazardous chemicals and biological substances, risk of slipping and stumbling, falling to a lower level, being run-over/hit by vehicles, being crushed, being hit by falling objects, and risks associated with handling heavy loads and hand-held tools. It is clear to see that these risks are all present in TUNLG. However, adding to those, TUNLG presents a set of specificities increasing its complexity (Tender and Couto, 2016a), mainly in terms of geotechnical unpredictability, interaction with both rock and soft materials, and a whole set of specific characteristics (e.g. hazardous gases, working in confined spaces, high temperatures, and working under pressure and humidity conditions). Of course, the presence of these risks can increase the likelihood of Accidents at Work (AW) and Occupational Diseases (OD).

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The present paper will take into account the differences between the two main tunnelling methods (Tender and Couto, 2016a): CEM - Conventional Excavation Method, and TBM - Tunnel Boring Machine Excavation Method while exploring human health and safety risks.

For several years, tunneling has been prone to fatal AW (Tender and Couto, 2017). (Table 1) shows some figures of fatal accidents in tunneling.

Table 1. Fatal accidents/Kilometer

Name	Fatal accidents/km
Seikan	0.4
Channel Tunnel	0.056
Crossrail	0.024

As can be seen by the Channel Tunnel's fatal accident rate, there has been a positive trend in the number of fatal accidents, as a result of the efforts made to improve workers' health and safety conditions.

1.2 The importance of AW and OD

In business terms, AW and OD can have a very negative impact on the companies involved:

- *Compliance with deadlines:* The occurrence of a serious or fatal AW usually causes an interruption of works in one of the work fronts and may, in more serious cases, have an impact on the overall execution time. The suspension of works may be short, lasting a few hours, or long, pending the gathering of all the data necessary for the investigation. While accidents may not have been considered one of the major causes for delays, when they do occur they can "be decisive for the progress of the works, even compromising, in some cases, the success of the project" (Couto, 2007).

- *Related costs:* The abovementioned interruption of works involves high economic implications (Hermanus, 2007) with consequent direct or indirect costs (López-Alonso et al., 2015), such as loss of productivity and yield, low morale, compensation for damages, and time spent in the analysis of the AW, which can have relevant costs which will certainly affect, through a reduction of the company's profit margins, its competitiveness. In addition, it will be less likely that the company will become a preferred supplier, namely for Project Owners where prevention is in the forefront of concerns (Tender, 2018). Due to its impact, this theme will certainly raise the company's decision-makers interest, and therefore it should always be included in the analysis of safety and health subjects (Shannon et al., 1999).

Currently, risk management emerges as an effective procedure that has gradually been involved in decision making processes (Mahdevari et al., 2014) and thus constitutes the cornerstone of occupational safety and health management (Carvalho, 2013). To ensure proper risk management, the obvious first step is a reliable identification of hazards (Badri et al., 2013). This step can be considered as the most critical of the whole process, insofar as an unidentified hazard is an hazard which is not assessed and therefore becomes an uncontrolled one (Carvalho, 2013). If this process is not complete and consistent, it will not be possible to recover from errors in later phases, and risk management will assume a false structure (Ceyhan, 2012). The characterization of the most typical events, understanding the cause of their occurrence or appearance, is of great importance for their prevention (Hola and Szóstak, 2014) and for determining the existing hazards. This will allow the accident analysis to "gain more space as a tool for the prevention of accidents" (Reis, 2007), through the already established added value of learning from



mistakes (Azevedo, 2010). Thus, it is possible to study in due time potential causes of harmful events (Pirsaheb et al., 2015). With these advantages, companies can make the most of their decisions and control their costs (Hale et al., 2007).

The bibliographic research revealed a lack of statistical data available on AW and OD in TNLG (Tender and Couto, 2016b). Even the ITA, with its Working Group "Safety and Health at Works", has never compiled any statistics on the frequency or nature of AW or OD (Lamont, 2016). Institutionally, it is found that the regulatory authorities of each country have compiled statistical data on the CONST sector but seldom distinguish different types of construction, such as TUNLG (Lamont, 2011). The research questions this paper tries to answer are:

Q1 - What is the typical type of AW and OD (the one that happens most frequently or more likely to appear) corresponding to the most frequent AW and OD in TNLG? Based on this definition, it will be possible to identify the themes where the priorities should be focused, so that they are scrutinized in greater detail.

Q2 - Are the characteristics of occurrence of AW and appearance of OD in TUNLG similar to those of the construction sector in general?

So, this study has a great practical significance, which is always needed in this type of research (Shannon et al., 1999), with its objective to fill the important gap in knowledge regarding AW and OD, both for the specificity of details for TUNLG and for the comparison with the CONST sector in Portugal, assisting in this way the scientific, technical and inspective community in improving risk characterization and management.

2. Methodology

The methodology used here intends to be as rigorous as possible, so as to be able to present truly effective crucial questions, which can be useful to direct increasingly effective preventive measures (Shannon et al., 1999).

Following it is described the research methodology options in terms of accidents at work and occupational diseases.

2.1 Accidents at work

The investigation now presented was carried out through the analysis of several variables that allow not only to characterize the victim of the AW/OD but also to describe the causes and harmful consequences of the latter.

There are several methodologies for AW analysis, depending on the desired objectives and degree of depth. In the present case, the goal was to use a method that allows the circumstances and the primary causes of an AW to be characterized as objectively as possible. The methodology chosen for the AW analysis analysed the variables described in the European Statistics on Accidents at Work (ESAW) given that they correspond to a methodology accepted at a European level and widely used. The variables chosen for analysis were: occupation, time, place, specific physical activity; deviation; material agent; contact; type of injury, part of body injured, number of days lost. This ensured it was possible to characterize the accident minimally, both in terms of characterization of the victim and in terms of characterization of the situation that led to the AW.

Since the variables in the ESAW "Occupation" and "Place" were not fully suitable for this study, answer choices better suited to the objectives pursued were created. Since there were changes made to the answer choices to the Eurostat variables, it was necessary to validate this new structure of answers. For that end, the Delphi method, which is a technique for group decision-making, was employed in order to ensure an agreement of the 15 experts, with more than 5 years of experience on the field, about the validity of the new answer choices (Zio and Pacinelli, 2011). The survey was conducted in two rounds. The survey was considered closed when all the experts fully agreed and accepted the proposed contents.

Regarding the process to obtain data on AW in Portugal, the authors used the data given by the Governmental Office for Strategy and Planning (GEP). The data in this study, obtained between January and March of 2016, were taken from a seriation, provided by GEP, of the AW in CONST (general) and in class "024-underground" during 2013 (at the time the data were obtained for this study, those were the most updated data GEP had). Given that the GEP did not have data for 2014 and 2015 and in order to assess whether those years followed the trends of the GEP data for 2013, a gathering of information was carried out with project owners and contractors of this type of works (EMP) over the AW occurred in those years. The companies chosen were the two most respected at national level (in terms of work owner and of contractor). The information was received by the authors via e-mail, in the form of maps containing the characterization data of AW. A total of 150 AW between 2012 and 2015 were analysed.



For those cases where no statistical data were found regarding the possibilities of responses to variables, they will not be presented (n.a.).

2.2 Occupational diseases

As for OD, the methodology used will also be the one Eurostat proposes, in this case, based on the European Occupational Diseases Statistics (EODS). The variables studied by the EODS were: country, age, sex, occupation, economic activity of employer, diagnosis, severity, exposure-cause, exposure-material agent, year for first recognition, severity of disease for the first recognition. For this study, the variables chosen were "Occupation" and "Diagnosis", because they are the ones that allow to characterize minimally the setting of appearance of OD.

The information source of the OD data analysed was the Social Security Institute (through its department responsible for producing and certifying private sector occupational disease statistics) which provided detailed information on 1615 OD certified between 2000 and 2015 in the CONST sector and on 42 OD certified between 2001 and 2015 in TUNLG.

3. Results

This chapter intends to present the results obtained regarding the statistical data of AW (Table 2) and OD (Table 3)x\). For each variable, the results of the information obtained from the GEP and from the companies (in the case of AW) and from ISS (in the case of OD) will be presented.

The compilation of data presented in this study was carried out in two strands: one for CONST, the other for TUNLG, aiming at achieving the intended comparison between the two activities.

Acknowledging a study's limitations and their impact in its conclusions is a part of the service the authors offer their readers (Shannon et al., 1999). Therefore, the authors would like to note the following limitations to the present study:

- This study only analysed accidents leading to lost days, which means that, since there are also accidents that do not lead to lost days, some situations still remain unanalysed.

- This study is restricted to the reality of the authors' country (Portugal). This means that it should be replicated in other countries and the respective results should be compared.

- Even though the authors did address information requests to several companies, only two of them have replied– fortunately, they are the two biggest companies of the field in Portugal.

3.1 Accidents at work

The typification of accidents at work is shown below.



Table 2. The typification of accidents at work is shown below

	CONSTRUCTION	TUNNELLING	
		GEP	EMP
Occupation of the victim	n.a.	n.a.	"Handlers/operators/drivers" (27.4%), "Miner" (13.6%), and "Formwork carpenter" (13.6%)
Time	n.a.	since the answer choices were changed, there are no GEP data available for this analysis	"From 10am to 12pm" (22.7%) and "From 2pm to 5pm" (22.7%).
Place where the AW occurred	n.a.	n.a.	"Formwork and concreting area" (22.9%), "Between the excavation face and the undercut for the sidewalls foundations" (12.1%), "Excavation face" (10.6%)
Specific physical activity	"Work with hand-held tools" (31.7%), "Carrying by hand" (24.6%)	"Work with hand-held tools" (39.3%), "Movement" (20.2%), "Handling objects" (14.3%)	"Handling objects" (39.4%), "Movement" (16.7%) and "Work with hand-held tools" (16.6%)
Deviation leading to the AW	"Body movement under or with physical stress (internal injury)" (26.6%), "Loss of control (total or partial) of machine or equipment" (20.8%), "Slipping or stumbling with fall of person to a lower level", "Slipping or stumbling on the same level" (20.7%).	"Body movement under or with physical stress (internal injury)" / "Body movement without physical stress (external injury)" (35.7%) and "Slipping or stumbling with fall" (33.3%), both of which together account for a significant proportion of the totality (69.0%)	"Body movement under or with physical stress (internal injury)" / "Body movement without physical stress (external injury)" (31.8%), "Slipping or stumbling with fall" (22.7%)
Material agent of contact - mode of injury	"Objects, machine or vehicle components, debris, dust, incandescent particles, concrete" (38.0%)	"Objects, machine or vehicle components, debris, dust, incandescent particles, concrete" (14.3%)	"Objects, machine or vehicle components, debris, dust, incandescent particles, concrete" (31.8%)
Type of injury	"Wounds and superficial injuries" (50.6%), "Dislocations, sprains and strains" (22.5%)	"Wounds and superficial injuries" (59.5%), "Dislocations, sprains and strains" (19.0%)	"Wounds and superficial injuries" (40.9%) and "Bone fractures" (18.2%)
Part of body injured	"Upper Extremities" (31.7%) and "Lower Extremities" (23.9%)	"Lower Extremities" (33.3%) and "Upper Extremities" (31.0%)	"Upper Extremities" (45.5%) and "Lower Extremities" (25.8%)
Number of lost days	"7 to 13 days" (17.5%) and "30 to 90 days" (16.9%), with an average of 26.1 days.	n.a.	"30 to 90 days" (42.7%) and "90 to 180 days" (16.7%), with an average of 60.8 days



3.2 Occupational diseases

The typification of occupational diseases is shown below.

Table 3. The typification of occupational diseases is shown below

	CONSTRUCTION	TUNNELLING (ISS)
Occupation of the victim	n.a.	"Miners" (47.6%), followed by "Waterproofing operator" (21.4%) and "Formwork carpenter" (11.9%)
Diagnosis	"Hearing disorders" (34.1%), "Musculoskeletal problems" (28.0%) and "Respiratory/pulmonary disorders" (25.9%).	"Respiratory/pulmonary disorders" (45.2%) and "Hearing disorders" (26.2%)

4. Discussion of results

4.1.1 Occupation of the victim

The main occupation affected is "Handlers/operators/drivers", which can be explained by the specificity of the construction process, which makes massive use of operators and drivers - for drilling, removal of muck or concreting, in the case of CEM, or for transport of materials and equipment (namely using rail vehicles), in the case of TBM. The second most affected occupation is "Miner". This can be explained, especially in the case of CEM, by the high exposure to risks associated with people being near the excavation front, such as the fall of blocks from the excavation face or run-overs. The occupation of "Formwork carpenter", the third most affected by AW and predominant with CEM, can be explained by the fact these workers are using, and in permanent contact with, very heavy temporary structures, fixed and mobile, asymmetrical in shape and with sharp edges - namely formwork moulds for final lining (both for the construction of the shoes and for the execution of a full cross-section).

4.1.2 Time

Although no GEP data have been obtained, in CONST there is a tendency for the greatest number of AW to occur in the periods "From 10am to 12pm" and "From 12pm to 2pm" (Reis, 2007).

From the above, it can be concluded that, in TUNLG, the period in which more AW occur is the period traditionally considered as supplementary or nocturnal (between 5pm and 8pm and between 8pm and 8am). This can be justified with the fact that working in shifts or in overtime hours, which are traditional ways of organizing work in TUNLG (namely the former), may have implications for the normal responsiveness of the human body and, therefore, may increase the likelihood of AW occurring in that timeframe (Ling et al., 2009).

4.1.3 Place where the AW occurred

Since there are no data for "CONST" and "TUNLG" there is no way to compare. The place where most AW occur, "Formwork and concreting area", can be explained by the fact that there is a large gathering of workers in certain areas, to perform the final lining of the tunnel (Tender and Couto, 2016b), both in CEM (use of heavy machinery for waterproofing, installing reinforcements and formwork/concreting), and in TBM (installing prefabricated segments). This simultaneous presence of a large number of equipment and workers in the same place contributes to the occurrence of AW (Tender and Couto, 2016a). Kikkawa's studies (Kikkawa, 2015) are in agreement with these percentages as to the place where most AW occur, indicating that most AW occur in the places where final lining is under way: 46.0% in the case of CEM, 50.6% in the case of TBM.

4.1.4 Specific physical activity

Since the data obtained from GEP and from EMP are different, all of these three activities with the most AW will be addressed here.

The high percentage of AW in TUNLG with "Work with hand-held tools" can be explained by the use of tools for the installation of stabilization devices (in CEM) and prefabricated parts (in TBM), as well as for the maintenance and repair of equipment, which means that workers usually spend a lot of time working with hand-held tools. The AW occurring during "Handling objects" can be explained by the high number of objects that are



handled in both methods: stabilization devices, blocks, rolls of waterproofing systems, rails for reinforcement and formwork panels, in the case of CEM, and prefabricated segments, in the case of TBM. In both cases there are also objects that can be pieces of equipment or components of electrical, compressed air, water or ventilation infrastructures. The AW occurred in "Movement" can be attributed to run-overs by mobile equipment (vehicles) or falls from height or on the same level. It should be noted that the relevance of this activity as a cause of AW, referred to by the International Tunnelling Association (International Tunnelling Association-Working Group 5, 2008), has also been highlighted in the transalpine experience, in which a great part of the AW occurred during movement and transport (Vogel and Kunz-Vondracek, 2013). In CONST, the second cause is "Carrying by hand", which has a low percentage of AW in TUNLG. This can be explained by the almost non-existent carrying by hand of parts or materials in TUNLG (usually, they are carried by multipurpose loaders or other machinery).

4.1.5 Deviation leading to the AW

The data obtained via GEP and via EMP are identical.

The data show that "Body movement under or with physical stress (internal injury)" is the most prevailing in CONST and TUNLG. The figure of "Body movement under or with physical stress (internal injury)" is explained by the need to handle/come into contact with equipment, tools or objects, and the body is subjected to physical stress during those activities. Relevant for this deviation are works near the excavation face (in the case of CEM), where blocks falling from the crown are one of the major causes of AW, adding to the vast amount of heavy machinery (Tender et al., 2015) required, which leads to the risk of run-overs (Mahdevari et al., 2014). Also relevant is the transport of material to the work place (in the case of TBM). It should also be noted that there is a risk of sprayed concrete fragments falling down (Tender et al., 2015). The percentage of "Body movement without physical stress (external injury)" can be explained by people coming into contact with objects, equipment, tools, ground, etc., leading to external injuries, such as cuts, lacerations, enucleations, haematomas, burns, etc.. "Slipping or stumbling with fall", in the case of falls to a lower level, can be explained with people falling down while using temporary working platforms for final linings (waterproofing, reinforcement and concreting), in the case of CEM, and during the assembly, disassembly and positioning of the tunnel boring machine, in the case of the TBM. "Slipping or stumbling with fall" on the same level is a common cause of AW (Tender and Couto, 2016a) and it can happen due to the irregularity of the ground, in the case of CEM, and during walking along the tunnel boring machine, in the case of TBM. Also, the manual handling of loads can obstruct visibility and worsen this situation (Tender and Couto, 2016a).

4.1.6 Material agent of contact - mode of injury

In this variable, there is a similarity in the responses between "CONST" and "TUNLG". "Objects, machine or vehicle components, debris, dust, incandescent particles, concrete" encompasses a large variety of elements, many of them particularly present in tunnelling, such as rock blocks (Tender and Couto, 2016a), debris from blasting operations, sprayed concrete, etc. However, since it is a mix of elements, individual analysis is difficult to achieve. It should also be noted that "Equipment - portable or mobile" has been identified as one of the major causes of AW (Waris et al., 2014) by run-overs (Tender and Couto, 2016a), namely involving trucks for the transport of muck, loader shovels and conveyor belts (Groves et al., 2007), corroborating the relevant experience of the transalpine tunnels that most accidents in TUNLG are related to traffic and transport (Vogel and Kunz-Vondracek, 2013).

4.1.7 Type of injury

The main cause, with a high percentage, is "Wounds and superficial injuries". "Wounds and superficial injuries" may be explained by the amount of objects and materials this type of works requires to be handled by hand. As for the second cause, GEP and EMP data are different, so both causes will be analysed. The "Dislocations, sprains and strains" can be related to fall of person on the same level, which has been identified as one of the main deviations. "Bone fractures" can be explained by contact with very big objects, such as stabilization devices and parts of formwork moulds (in the case of CEM) or prefabricated segments (in the case of TBM).

4.1.8 Part of body injured

Though the data obtained from GEP and EMP were different, they are restricted to two parts of the body, and it is worthy of notice the high percentage represented by both parts of the body in TUNLG.

The fact that one of the parts of the body most injured is "Lower Extremities", more prone to be injured during slipping or falling, can be connected to objects falling, e.g. blocks, or to strains due to uneven ground, namely in CEM. As for "Upper Extremities", these figures can be explained by the high amount of work with hand-held tools (usually with heavy tools, such as bars for scaling and crowbars (Groves et al., 2007)) or by contact with rolling material or prefabricated segments. Also, the high amount of loads handled, both in CEM (e.g. when it comes to stabilization devices), and in TBM (e.g. handling parts of the TBM during its assembly and disassembly, or



prefabricated segments during their positioning and assembly) means there is a high tendency to have contact with hands, arms, legs and feet, whether due to falls or to other types of contact.

4.1.9 Number of lost days

It is clear that "TUNLG" presents an average of days lost much higher than construction. This fact can be justified by a seeming greater severity of "Wounds and superficial injuries" (haematoma, lacerations or open wounds) that results in a high number of days lost.

4.2 Occupational diseases

4.2.1 Occupation of the victim

Miners are often close to the excavation face, where there is breathable dust (Tender and Couto, 2016a), which is often composed of rock with a high level of silica. They are also exposed to fumes from the use of explosives, particles of dust from sprayed concrete, oil mists (for example, for protecting the surface of concrete spray robots), and exhaust gases, which are all present in the confined space of the excavation face. As for "Waterproofing operator", they are likely to be exposed to a greater number of physical stress situations, with musculoskeletal consequences, and to chemicals, namely in the form of vapours, e.g. from products to heat the waterproofing lining. As for "Formwork carpenters", there is a high exposure to cement and formwork release agents.

4.2.2 Diagnosis

"TUNLG" does not present the same characteristics as "CONST". While in CONST "Hearing disorders" and "Musculoskeletal problems" are at the top, in TUNLG the first place goes to "Respiratory/pulmonary disorders", followed by "Hearing disorders". Together, the two main diagnosis in TUNLG reach the significant percentage of 71.4%.

Within the respiratory/pulmonary disorders, it is important to distinguish the disorders affecting the airways from the ones affecting the lungs. As for the inflammation of the airways, it has been shown that the exposure to particles and gases from diesel combustion products (from heavy machinery, in CEM, and locomotives, in TBM) (Tender and Couto, 2016b) and from the blasting of explosives (in the case of CEM), namely ANFO-based explosives, (Tender et al., 2015) is frequently associated to the onset or worsening of asthma and chronic bronchitis (Oliver and Miracle-McMahill, 2006). On the other hand, dust from the cement used in the sprayed concrete can contribute to worsening asthma conditions, which translates into a reduction of the lung function of operators of concrete spray robots (Bakke et al., 2001). The oils used to protect the machinery against concrete splatters and build-up or to clean the formwork moulds, due to their composition, can also give rise to airways problems (Bakke and Ulvestad, 2015), namely asthma. As for pneumoco-nioses, caused by the deposition of dust particles in the lung, it is important to distinguish the ones caused by deposition of silica dust from the rock mass, a more typical situation in this type of work (Tender et al., 2015), from the ones caused by the deposition of as-bestos particles, a less typical situation. To be noted that silicosis is the oldest and more serious occupational disease known. The occupations most affected by dust and gases are borers and boring machine workers (Bakke et al., 2001), and it should be noted that the risks of exposure to the above agents affect those working nearby, but also those working in places where fumes, vapours or particles pass through.

5. Conclusions

The results presented here stemmed from a careful analysis of the information retrieved from GEP and from companies. The statistical data obtained are now a source of information available to anyone who wants to use information on AW or OD to improve risk analysis. It was possible to get objective and quantified answers to the research questions:

The typical AW occurs with mobile equipment operators between 5pm and 8am, in formwork and concreting area, while working with hand-held tools, causing body movement under physical stress caused by machine components, debris or concrete, with wound or superficial injuries in arms, hands, legs or feet with a total of 60.8 lost days.

The typical OD occurs in front excavation miners by respiratory/pulmonary disorders.

Additionally it can be concluded that there are marked differences, relative to some of the variables studied, between the CONST sector and TUNLG.



This study improves risk analysis tools in TUNLG and should serve as a starting point for a more extensive international study, with a larger AW and OD sample, enabling the most accurate identification of the tasks with the greatest potential for harm and requiring the most urgent intervention.

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