Accidents at work: an insight into logistics operations

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Abstract: The logistics industry ensures the delivery and storage of goods and materials around the world, covering both the distribution and the warehousing sectors of every industry. The injury rate of the logistics industry is notable and above the average compared to other industries. The high accident rate of the logistics industry is partly due to the significant weight and size of some of the items handled and the vehicles and equipment required to handle them. Also, logistics entails workers moving between different work areas or sites during the day, each of which have many different safety measures, procedures, and approaches to risk management. This paper introduces a structured analysis of occupational accidents that occurred during logistics operations. The investigation includes more than 900 fatal and serious accidents that occurred in Italy between 2002 and 2016, involving workers from the logistics industry. The findings show that the contact of the injured worker with moving objects or vehicles, the variation of movement of the vehicle or transport system, and the falling of objects from above were the most common types of accidents that occurred in logistics. Industrial trucks were the most frequent risk factors that triggered the investigated events. Material handling was the activity that the injured workers were usually performing when the accidents occurred. The leading apparent causes of accidents were the voluntary adoption of an improper procedure, e.g. the bypass of a risk control measure, and the misplacement of the worker. The lack of training appears to be the leading root cause of the investigated events.

Keywords: logistics; occupational accidents; root causes analysis; occupational health and safety.

I. INTRODUCTION

This paper proposes a structured analysis of work accidents that occurred in Italy in the last decades, during logistics operations. The logistics industry reports high injury rates, which are above the average compared to other industries. In 2016, logistics was the number two most dangerous industry in the EU-27, with 625 fatal accidents, and second only to construction, which registered 705 fatal events (Eurostat, 2020). These statistics are partially due to the significant weight and size of some of the items that workers must handle, and the vehicles and equipment adopted, i.e. logistics systems need large spaces and infrastructures to store the goods, and heavy equipment for material handling, such as industrial trucks, forklifts and towing tractors (Suh, 2021). Also, psychosocial risk factors, such as the time pressure or the excessive load of work, violence or the perceived threat of violence and harassment or intimidation, and the stress associated with the possibility of losing a job in the near time, increase the risks associated with logistics activities (Sadłowska-Wrzesińska and Mościcka-Teske, 2016). Finally, logistics operations require the workers to move between different areas or sites during the day, each of which entails different safety procedures and practices. The logistics industry ensures the delivery and storage of goods and materials around the world, covering both the distribution and the warehousing sectors of every industry. During the COVID-19 pandemic, the logistics industry faced strong efforts to mitigate the effects of the supply chains disruptions affecting the production systems all over the world (Meyer, Walter and Seuring, 2021). Logistics companies had to find new and unpredicted ways to ensure the resilience of logistics operations and to face the uncertainties and the new risks triggered by the pandemic (Caballini, Ghiara and Persico, 2022). While other industries suffered from the effects of this unpredictable event, logistics operators have experienced a boom year. Some leader companies grew by five percent during the pandemic, thanks to the incomes from the growing e-commerce activity. The business-to-consumer parcel shipment industry was the main driver of such rapid growth. The COVID-19 lockdown restrictions have enhanced the marked shift from the stationary trade of consumers to e-commerce shipping models, which is creating new opportunities for logistics and third-party logistics providers (Chasdi, 2021).

The Health and Safety Executive of the UK government reveals that before the COVID-19 lockdown, the rate of self-reported non-fatal injury to workers in Great Britain showed a downtrend. The rate for the 2020/21 period, which includes the years affected by the coronavirus pandemic, was not statistically significantly different

from the previous period. Around 2.1% of UK workers in the transportation and storage industry sustained a workplace injury. This rate is statistically significantly higher than that for workers across all UK industries (1.8%). Conversely, the number of fatal injuries in 2020/21 (10) is in comparison with the annual average number of fatalities for the 2016/21 period (13). However, the fatal injury rate for transportation and storage in the same 5-year period (0.85 per 100,000 workers) is around twice the rate for all UK industries (0.42 per 100,000 workers) (Health and Safety Executive, 2021). These data confirm that logistics operations expose the workers to occupational risk factors, increasing the probability of fatal and non-fatal accidents in this industry. Furthermore, the recent COVID-19 pandemic enhanced the critical factors affecting the health and safety conditions of workers during logistics operations. Hence, understanding the causes and the dynamics of occupational accidents in this industry is important to ensure the effectiveness of the safety procedures and the risk management policies for logistics operations.

The study in this paper supports the ongoing research on the design of modern manufacturing systems, to investigate and understand workers' reasonably foreseeable behaviors and to provide directions for occupational accident prevention. Previous studies focused on the dynamics of occupational accidents that occurred in metalwork, manufacturing, and during maintenance interventions (Botti *et al.*, 2020, 2021; Botti, Melloni and Oliva, 2021, 2022). The analysis of the occupational accidents by risk factors revealed strong analogies between metal production and manufacturing, i.e. the most frequent risk factors for occupational accidents were the use of fixed machinery, followed by the use of fixed material transport equipment and the use of industrial trucks. The adoption of an improper procedure was the leading apparent cause of accidents that occurred in metal production and during manufacturing operations that involved the use of fixed machinery. An example is a case of a worker who bypassed the two-hand control and activated the machinery with the pedal. The bypass of the machinery safety barrier, i.e. the two-hand control, cost the worker the arm amputation. The solution suggested in the reports for preventing such improper procedure is the application of an additional barrier between the risk factor, i.e. the fixed machinery, and the worker. This solution may result in higher complexity for the task accomplishment. Though, an additional barrier would encourage further improper behaviors, with no impact on their root causes. Consequently, the focus of accident prevention strategies should be more on the causes of accidents rather than on their effects, i.e. workers' improper behaviors. Hence, the research questions behind this study are "Is it possible to understand the causes of the occupational accidents that occur during logistics operations?" and, if so, "Is it possible to design ad-hoc preventive strategies that can address such causes?". Section II in this paper describes the methodology adopted in this research to analyze the occupational accidents that occurred in the Italian logistics industry. The aim was to understand the risk factors and the common dynamics of occupational accidents that occurred during logistics operations. The results are described in Section III. Finally, Section IV and Section V discuss the findings of this research, providing suggestions and directions for future research on occupational health and safety during logistics operations.

II. Materials and Method

The investigation in this paper includes the analysis of more than 900 fatal and serious accidents that occurred between 2002 and 2016, involving workers from the Italian logistics industry. The reports of these accidents are included in the accident database of the Italian National Institute for Insurance against Accidents at Work (INAIL) (INAIL, 2019). Data used in this study include previously unanalyzed official accident reports available only in Italian in the INAIL database. The research methodology adopted in this study for the identification of the causes of accidents is the investigation approach proposed in (Botti *et al.*, 2020) and based on the Five Whys technique (Leino and Helfenstein, 2012). The approach allows defining a visual, structured, and deductive temporal sequence of the events that lead to the accident and their interactions in a formal logical hierarchy (Figure 1).

The first level cause defines the main determinant of the accidents, e.g. the malposition of the hands in proximity to an operating machine. Such cause is also defined as the "apparent cause" of the event. The adoption of an improper procedure, i.e. the second-level cause, justifies such misbehavior. Common causes for the adoption of an improper procedure are the lack of safety guards or the complete absence of a machinery protection system. The investigator finds the causes of the events in the accident reports. The answer to the fifth Why in the causes hierarchy is the "root cause" of the event. The complexity of the investigation process depends on the dynamics of the investigated accidents. The better the accuracy of the description in the event reports, the higher the reliability and the consistency of the results. Information on the reports may not be accurate and the language adopted to describe the events reflects the heterogeneity of the technicians and physicians who fulfilled the reports (Botti, Melloni and Oliva, 2022). For these reasons, the investigation of the root causes is difficult and, in some cases, not possible. Hence, the third category of accident causes defined in this study, i.e. the "almost-root cause", identifies the closest causes to the actual root causes of the investigated accidents. In this study, the investigation was performed with the support of a research team including a full-time Professor and two researchers with multiple years of experience in occupational health and safety.

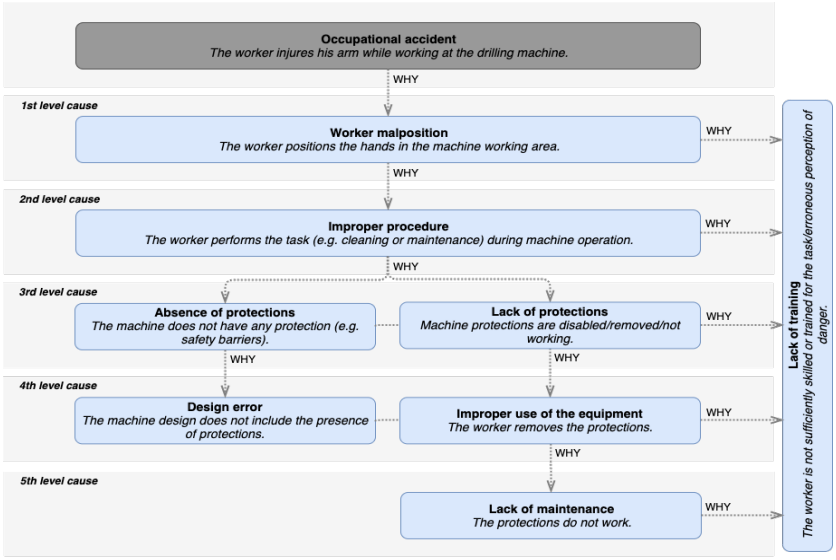

Fig. 1. Causes hierarchy for the investigation of apparent and root causes of occupational accidents (Botti et al., 2020).

III. Results

Table I shows the distribution of the serious accidents that occurred in Italy between 2002 and 2018, in the logistics industry. The highest incidence of the accidents was registered in the North-West and in Central Italy, where the logistics industry is mostly present. These two territories together registered 72% of the serious accidents that occurred during Transportation and Warehousing (TW), and 67% of the serious accidents occurred in the Wholesale and Retail Trade (WRT) (Table I). The distribution of the accidents in these two categories is from the Infor.MO database (INAIL, 2019). INAIL collects the reports of the occupational accidents in the Infor.MO database in different categories, based on the ATECO 2007 classification of economic activities. Such classification is the Italian version of the European Nace Rev. 2 nomenclature in the Regulation (EC) no 1893/2006 of the European Parliament (European Union, 2006). Table II shows the distribution of the fatal accidents that occurred in Italy between 2002 and 2018, in the logistics industry. The highest incidence of the accidents was registered in the North-West and North-East of Italy. These two territories together registered 66% of the fatal accidents that occurred during transportation and warehousing, and 68% of the fatal accidents occurred in the wholesale and retail trade (Table II). Data in Table II show a slight shift of the events from the data in Table I, which revealed that the North-West and the Centre of Italy registered the highest incidence of serious accidents. The distribution of logistics companies in the Italian territory in Table III supports the interpretation of the data in Tables I and II. Specifically, the high incidence of fatal and serious accidents in the North-West of Italy may be due to the high number of logistics company in such area. Then, the events that occurred during warehousing activities were selected for the further steps of the investigation in this paper.

TABLE I
DISTRIBUTION OF THE FATAL ACCIDENTS OCCURRED IN THE ITALIAN TERRITORY DURING LOGISTICS OPERATIONS BETWEEN 2002 AND 2018.

	Transportation and Warehousing (TW)	**Wholesale and Retail Trade (WRT)**
North-West	35% (137)	34% (54)
North-East	31% (118)	34% (55)
Centre	21% (80)	16% (26)
South and islands	13% (51)	16% (25)
Total	100% (386)	100% (160)

TABLE II
DISTRIBUTION OF THE FATAL ACCIDENTS OCCURRED IN THE ITALIAN TERRITORY DURING LOGISTICS OPERATIONS BETWEEN 2002 AND 2018.

	Transportation and Warehousing (TW)	**Wholesale and Retail Trade (WRT)**
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Centre	21% (80)	16% (26)
South and islands	13% (51)	16% (25)
Total	100% (386)	100% (160)

TABLE III
DISTRIBUTION OF LOGISTICS COMPANIES IN ITALY, IN 2019 (ISTAT, 2022).

	Transportation and Warehousing (TW)	Wholesale and Retail Trade (WRT)
North-West	28% (29,153)	25% (254,522)
North-East	24% (24,691)	18% (187,758)
Centre	22% (22,630)	22% (208,002)
South and islands	27% (28,532)	27% (377,710)
Total	100% (105,006)	100% (1,027,992)

A. Serious accidents

The most common types of incidents that lead to the serious accidents resulting from warehousing activities occurred after the contact with a moving object or vehicle, the speed variation or the overturning of the vehicle, the fall of objects from above, and the fall of the injured worker from height (Table IV).

TABLE IV
INCIDENTS, RISK FACTORS, AND WORK ACTIVITIES THAT LEAD TO SERIOUS ACCIDENTS OCCURRED DURING WAREHOUSE ACTIVITIES.

	TW (90 cases)	WRT (21 cases)
Incidents		
Contact with a moving object or vehicle	23%	24%
Speed variation or the overturning of the vehicle	23%	10%
Fall of objects from above	21%	14%
Fall of the injured worker from above	14%	38%
Risk factors		
Industrial trucks	80%	71%
Work at height	4%	10%
Work activities		
Material handling	70%	43%
Manual material handling	11%	24%
Transit	11%	24%

Industrial trucks are the most common risk factors for serious accidents that occurred during warehouse activities. Figure 2 shows the apparent causes of the investigated serious accidents. These results are confirmed, regardless of the risk factor that was present when the accidents occurred. An example of the first, i.e. the worker misplacement, is the case of a worker who got off the industrial truck and stood close to the forks to sustain the unstable materials on the pallet when the objects eventually fell and hit his leg. The voluntary adoption of an improper procedure is, for example, the case of a worker who got injured while trying to reach the upper locations of the rack inside a warehouse by jumping on the forks of the industrial truck. Interference and worker misplacement were the leading apparent causes of the serious accidents that occurred during transit operations.

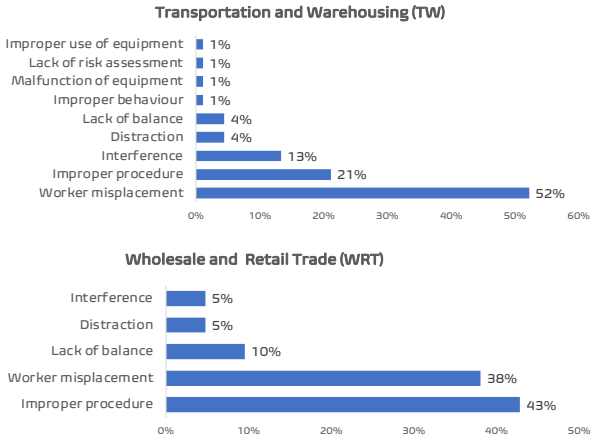

Fig. 2. Apparent causes of the serious accidents occurred during warehousing activities.

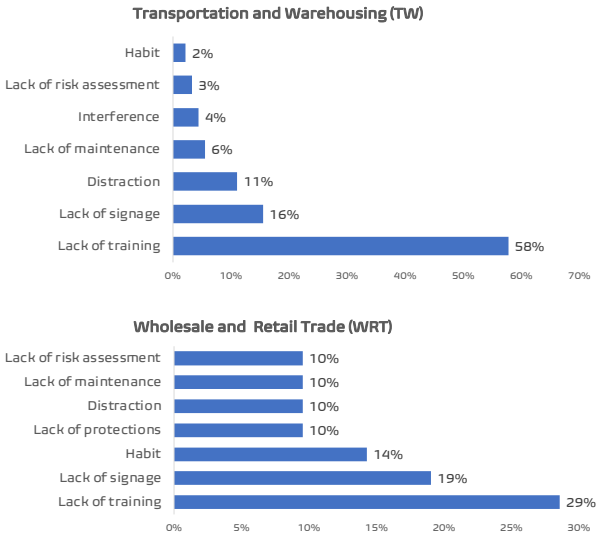

Fig. 3. Root causes of the serious accidents that occurred during warehousing activities.

The investigation of the causes of the accidents using the methodology introduced in Section II revealed that the worker misplacement (52% of TW and 38% of WRT) and the voluntary adoption of an improper procedure (21% of TW and 43% of WRT) were the most frequent apparent causes of the investigated events. Lack of training (58% of TW and 29% of WRT) and lack of proper signage (16% of TW and 19% of WRT) appeared to be the most frequent root causes of the serious

accidents that occurred during warehouse activities. Figure 3 shows the apparent causes of the investigated serious accidents. These vehicles determined most of the serious accidents occurred during warehouse activities. Not surprisingly the results reveal that material handling is the work activity that the injured workers were most frequently performing when the accidents occurred.

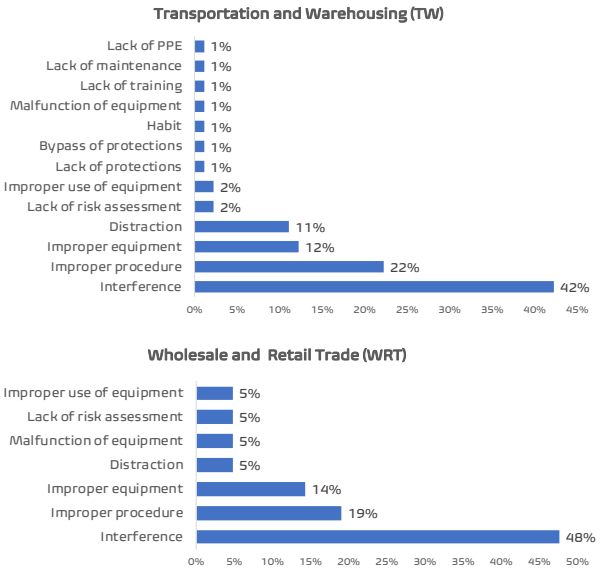

Fig. 4. Almost-root causes of the serious accidents occurred during warehousing activities.

Figure 4 shows the almost-root causes of the investigated serious accidents. Interference was the most frequent almost-root cause of the serious accidents that occurred in TW (42%) and WRT (48%). For example, this is the case of a worker who was handling a tank with an industrial truck when he lost control of the container. The tank fell from its support and hit a second worker, who was transiting nearby.

B. Fatal accidents

The most common types of incidents leading to the fatal accidents occurred during warehousing activities were due to the speed variation or the overturning of the vehicle, the fall of objects from above, the contact with a moving object or vehicle, and the fall of the injured worker from height (Table V).

Industrial trucks are the most frequent risk factors that caused the fatal accidents investigated in this study. Also, material handling was the most common work activity that the workers were performing when the fatal events occurred. The investigation of the apparent causes of fatal accidents confirmed the findings from the investigations of the serious accidents, i.e. worker misplacement (59% of TW and 42% of WRT) was the leading apparent cause of the events, followed by the adoption of an improper procedure (34% of TW and 32% of WRT).

TABLE V
INCIDENTS, RISK FACTORS, AND WORK ACTIVITIES THAT LEAD TO FATAL ACCIDENTS OCCURRED DURING WAREHOUSE ACTIVITIES.

	TW (76 cases)	**WRT (19 cases)**
Incidents		
Speed variation or the overturning of the vehicle	29%	26%
Fall of objects from above	28%	26%
Contact with a moving object or vehicle	21%	5%
Fall of the injured worker from above	12%	37%
Risk factors		
Industrial trucks	61%	63%
Other vehicles for material handling	18%	5%
Work activities		
Material handling	50%	58%
Transit	38%	16%
Manual material handling	5%	16%

Figure 5 shows the apparent causes of the investigated serious accidents. These findings are confirmed, regardless of the risk factor that was present at the time of the event, e.g. the industrial truck or any other vehicle adopted for material handling. Worker misplacement was the leading apparent cause of accidents that occurred during transit operations (79% in TW and 100% in WRT). Conversely, the worker misplacement and the voluntary adoption of an improper procedure were equally found for accidents that occurred while the workers were performing material handling.

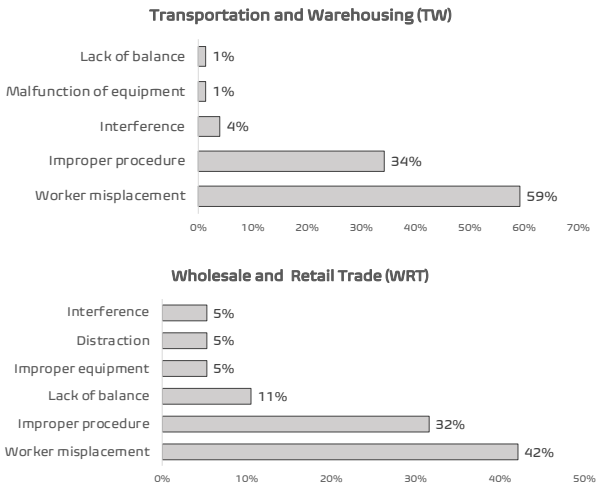

Fig. 5. Apparent causes of the serious accidents occurred during warehousing activities.

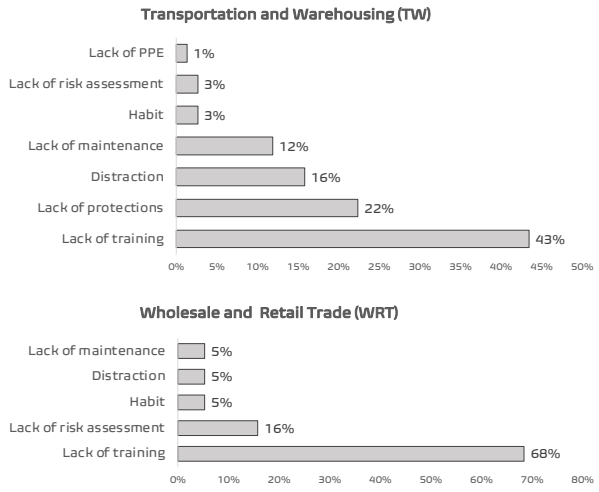

Fig. 6. Root causes of the serious accidents that occurred during warehousing activities.

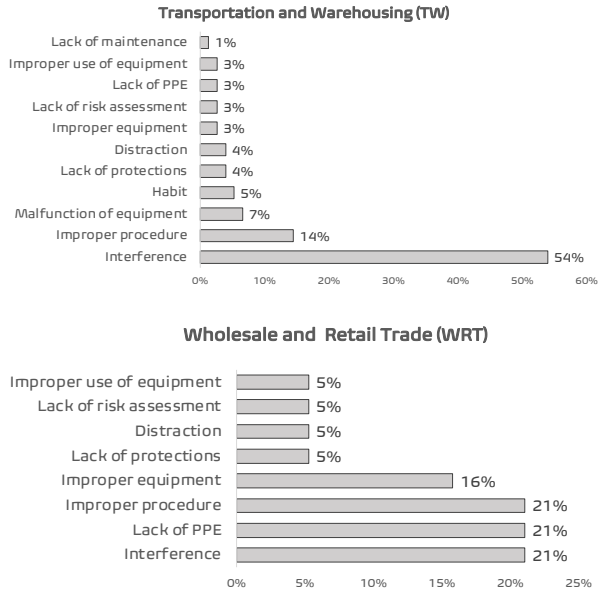

Fig. 7. Almost-root causes of the fatal accidents occurred during warehousing activities.

IV. Discussion

The findings of this study show that the contact of the injured worker with moving objects or vehicles, the variation of movement of the vehicle or transport system, and the falling of objects from above were the most common types of accidents that occurred in logistics. Industrial trucks were, by far, the most frequent risk factors that triggered the investigated events, regardless of the severity of the injury. Material handling was the activity that the injured workers were usually performing when the accidents occurred. The results of the investigations of the causes of accidents revealed that the voluntary adoption of an improper procedure and the misplacement of the worker appear to be the leading apparent causes of the events. A superficial reading of these results would suggest finding the determinants of these events in people's behaviour and human factors. However, previous studies suggest that a deeper investigation is necessary to identify the root causes of such behaviours and the motivations driving the workers to adopt the improper procedures or to position themselves in high-risk conditions (Mosconi *et al.*, 2019; Botti, Melloni, and Oliva, 2022). Data in the accident reports should include information about both the apparent and the root causes of the events. Occupational physicians and safety technicians who prepare the accident reports must be trained and informed about the modalities to investigate the determinants of accidents and to fulfil the accident reports. Nevertheless, the modalities to collect and analyze the data in the reports may differ, depending on the industry and the sensibility of the person filling. Also, participative and holistic approaches to occupational health and safety developed with and by the workers produce higher results, compared with top-down approaches conceived by the top management without the contribution of the workers. Workers should be actively involved in the design and the assessment of health safety management policies. A recent study investigated the internal and external factors involved in ethical management systems in shipping and logistics companies, aiming to understand the impact of these factors on organizational performance variables and each level of an ethical management system. The results reveal that internal factors such as openness and internal integrity produce positive effects on the use of an ethical management system. Furthermore, the authors found a positive relationship between the use of an ethical management system and company performance (LEE and CHO, 2022). Hence, a holistic approach is necessary to further understand the results in this paper and the determinants of serious and fatal accidents that occur in logistics. Some studies are investigating the effects of aging on the occupational health and safety of the workers in the logistics industry and the learning effects and mental fatigue of forklift drivers (Loske and Klumpp, 2021; Batson, Newnam and Koppel, 2022). In this study, the lack of training appears to be the leading root cause of the investigated events. However, the investigation of root causes was difficult because of the lack of information on human factors and other intermediate causes that lead to occupational accidents. For this reason, a new set of causes of accidents was defined, i.e. the almost-root causes of the events. Interference is the most frequent almost-root cause of the serious and fatal accidents in this investigation. However, a participative and holistic approach is necessary to further investigate the drivers of serious and fatal accidents in logistics, on which preventive strategies should focus.

V. Conclusions

The investigation introduced in this paper aimed at finding the answers to the following research questions: "Is it possible to understand the causes of the occupational accidents that occur during logistics

operations?" and, if so, "Is it possible to design ad-hoc preventive strategies that can address such causes?". The answer to the latter question is positive and compulsory. Safety managers must design ad-hoc occupational health and safety strategies for the prevention of accidents and injuries in their workplaces. However, this is possible when the dynamics of accidents and the causes of workers' unsafe behaviors are known. The findings in this paper reveal that material handling operations performed with industrial trucks or with other handling equipment are the warehouse operations with the highest incidence of occupational accidents. Industrial managers, safety professionals, and practitioners should be aware of the high risk of injuries and fatalities associated with these activities. The methodology adopted for the investigations in this research supports the investigation of the causes of fatal and serious accidents. The main limitation of this study was the limited accuracy of the information available, in the Infor.MO database, about the dynamics of the accidents. The information in the accident reports allowed the authors to draw strong and confident conclusions about the apparent causes of the investigated events, i.e. the misplacement of the workers and the voluntary adoption of improper procedures. The same confidence was not possible during the analysis of the root causes of the accidents. However, the analysis of the almost-root causes suggests that high attention is necessary when two separated activities take place in the same work area since they may collide and cause an occupational accident. More efforts are necessary to fully understand the reasons that drive workers' unsafe behaviors. The prevention of occupational accidents in logistics cannot prescind from the elimination of such behaviors. Hence, the future steps of this research will investigate the root causes of workers' unsafe behavior during logistics operations using the participative technique of the focus groups with the workers. Multiple focus groups with the workers from different logistic companies will take place in the next year, aiming to fully understand the root causes of workers' unsafe behaviors during warehousing activities. Finally, such participative approach will increase the workers' risk perception and stimulate their ability to find effective solutions for improving occupational health and safety in their workplace.

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