THE VIABLE BUSINESS PRACTICE OF OPTIMIZING THE OCCUPATIONAL ACCIDENTS COST: A MICROECONOMIC APPROACH

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Abstract
Occupational Safety and Health (OSH) is a social requirement but enterprises often see it merely as a legal obligation. Occupational accidents impose a significant economic burden on societies, extending beyond medical and compensation costs, as they result in losses due to reduced productivity, social consequences, and a burden on the health and welfare systems of regions. Through a microeconomic analysis, this paper evaluates the cost of occupational accidents and examines the tradeoff between their prevention and recovery components to determine the optimal security level that minimizes the total accident cost. The analysis emphasizes the need for firms to incorporate the costs of occupational accidents into their strategic planning and operations, demonstrating the effectiveness of optimizing these costs as a business practice. The ultimate purpose of this paper is to contribute to the culture that OSH should not be seen as an obligation but as a strategic asset for companies seeking sustainability, as, in the long run, it reduces risks, enhances business profitability, promotes anthropocentric development and life quality, and demonstrates corporate social responsibility. Overall, calculating the total occupational accident cost and choosing the appropriate prevention strategy are elements contributing to a safer, more efficient, and viable working environment.

Keywords: Occupational Safety and Health; OSH; prevention costs; direct and indirect accidents cost; sustainable working environment.

JEL Classification Codes: D50; R00; R13.

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1. Introduction

Occupational Safety and Health (OSH) is a critical pillar not only for labor policy but also for the overall maintenance of social cohesion and the economic sustainability of regional economies (Jilcha and Kitaw, 2017; Reis et al., 2020; Ruxho and Ladias, 2022a; Ruxho et al., 2023). Beyond social harm, occupational diseases and occupational accidents impose a significant economic burden on societies (Dembe, 2001). Occupational accidents and diseases cause annual costs of up to 4% of GDP in the EU regions (Tompa et al., 2021). These costs do not only regard medical and compensation costs but also indirect losses due to reduced productivity, the resulting social consequences, and the burden on the health and welfare systems of the regions (Concha-Barrientos et al., 2005; Takala et al., 2014). The modern labor market, described by technological changes (Acemoglu, 2002), flexible forms of employment (Benner, 2008), and social and psychological pressures (Ullah et al., 1985), makes OSH particularly relevant not only for the avoidance of occupational accidents but also for the improvement of the overall workers quality of life (Pacheco and Riano-Casallas, 2017; Andersen et al., 2019). The COVID-19 pandemic (Tsiotas and Tselios, 2022; Tsiotas et al., 2023; Tsoulias and Tsiotas, 2024) has highlighted the need for new standards of occupational protection (Michaels and Wagner, 2020; Michaels et al., 2023), which include, beyond physical safety, mental health, ergonomics, and safety in teleworking situations. The increasing trend of accidents is due to many factors such as inadequate controls (Zwetsloot et al., 2011), understaffed labor inspection services (Liao and Chiang, 2012), lack of a culture of prevention (Kim et al., 2016), and inadequate training (Aziz and Osman, 2019) of workers. In this context, investment in prevention (Kim et al., 2016; Andersen et al., 2019; Walters et al., 2022) is emerging, beyond social and moral imperative, as a purely cost-effective strategy. On the contrary, companies following and investing in OSH policies reap faster than expected desired results, such as increased productivity, fewer leaves, reduced compensation, and an improved public and social image (Abdul Aziz et al., 2019; Andersen et al., 2019; Shabani et al., 2023).

The European experience has shown that the combination of institutional framework, training, internal monitoring, and worker participation leads to a dramatic reduction in occupational risks (Leka et al., 2011; Economou and Theodossiou, 2015; Iavicoli, 2016; Walters et al., 2022). In Scandinavian (Nordic) Countries, for example, OSH is treated as an investment (Holmberg and Lundberg, 1989; Karlsen, and Hempel Lindoe, 2006; Hanvold et al., 2019), projecting its effects in terms of reduced welfare costs and increased competitiveness. Despite the efforts given for the reduction in occupational accidents, Greece (Drakopoulos et al., 2012; Tatsaki et al., 2019; Politis et al., 2025) and many European countries (Gagliardi et al., 2015; Jakob et al., 2021) continue to face shortcomings such as poor prevention, the absence of a national strategy on occupational diseases and the lack of incentives for companies to implement modern and efficient OSH policies. For example, in Greece (Drakopoulos et al., 2012; Tatsaki et al., 2019; Politis et al., 2025), relevant data from fragmented and poorly documented sources show that a large proportion of the insured working population is involved in an occupational accident during their working life. In Greek legislation (Drakopoulos et al., 2012; Nicolaidou et al., 2017), the responsibility for the prevention of occupational hazards lies mainly with enterprises, however, the existence of a demanding legal framework lacking internal control mechanisms, targeted training, and a culture of prevention of occupational accidents is not a comprehensive solution. In terms of OSH culture, treating occupational safety as a cost rather than an investment exposes companies to greater risks and costs in the long term.

In terms of economic theory (Krugman and Wells, 2009), the total cost of OSH for a company consists of two main components, the cost of prevention and the recovery cost (Ruser and Butler, 2010), which in turn is complex and is divided into direct (time losses, productivity losses, material damage, etc.) and indirect (compensation, legal costs, medical costs, administrative costs, etc.). The prevention cost curve follows a mechanism of increasing returns to scale as a function of the level of safety, while the accident cost curve behaves inversely (Oi, 1974; Ruser and Butler, 2010). Given their joint contribution to total costs, these two curves add up to an optimal equilibrium point representing the minimum total cost. Provided that achieving absolute safety against occupational accidents is theoretically impossible (as unforeseen factors, mechanical failures, and human errors are subject to stochasticity), it is a challenge to identify the optimal level of safety at which investment in prevention yields the maximum benefit at the minimum cost. The theoretical approach to the relationship between prevention costs and safety levels describes that excessive savings in protection measures ultimately lead to an exponential increase in losses (Oi, 1974; Keane, 2015). Instead of aiming for the lowest possible cost, it is important to find the cost that minimizes overall risk. Therefore, occupational safety and health (OSH) should not be viewed merely as an expense, but rather as a valuable investment. Countries that have invested heavily in prevention have saved huge amounts of money in the long term while gaining competitiveness.

In this context, this paper attempts to present the conceptual and theoretical dimensions of the costs of

occupational accidents through the prism of (micro)economic theory (Krugman and Wells, 2009) and to highlight the microeconomic mechanisms that lead to their optimal treatment as a sustainable practice. The critical research question addressed and attempted to be answered in this paper is not the one-dimensional techno-economic approach of how much it costs to implement safety policies, but the extended sustainable perspective that claims to assess how expensive it is not to implement them. Through the overall theoretical approach, this paper aspires to inspire the development of an integrated system of collecting and analyzing statistical data on the costs and consequences of accidents, both at regional (Ladias et al., 2023; Tsiotas and Kallioras, 2025), national (Beha and Ruxho, 2024; Ruxho et al., 2024; Tsiotas and Polyzos, 2024; Tsiotas et al., 2025), and wider (Polyzos and Tsiotas, 2025; Tsiotas and Polyzos, 2025) levels. Such an integrated approach is likely to encourage OSH business initiatives leading to a national strategy to address occupational accidents and illnesses and the psychosocial burden at workplaces. The following sections attempt to highlight the dimensions of a comprehensive study of the costs of occupational accidents for building a safe, efficient, just, and sustainable working environment.

2. The cost of occupational accidents

The debate on the reduction of occupational accidents should not be limited to a metric approach to cost-benefit analysis (Ramos et al., 2020; Lestari et al., 2021) because the impact of occupational accidents goes beyond numbers. Although the economic incentive of firms (which is about maximizing profit) can indeed act as a driver for preventive measures (Kankaanpaa, 2010), it is clear that the absence of social variables in the equation creates a fundamental deficit in understanding the true scale of the problem. The social impact of occupational accidents, such as the psychological burden (Ullah et al., 1985), the reduction in the quality of life of workers (Pacheco and Riano-Casallas, 2017; Andersen et al., 2019), and the consequent effects on their family environment, is extremely difficult to quantify precisely. This is due either to the impossibility of systematically recording all the relevant variables or to the absence of a comprehensive methodology for their assessment. However, the fact that these variables cannot be quantified does not imply that they should be ignored. The problem is exacerbated by the fact that firms often treat occupational safety as a 'negative externality' (Ramos et al., 2016), namely as a cost that does not directly affect the product or production process of the company. This approach creates the conditions for the emergence of an 'imperfect market' (Krugman and Wells, 2009), namely an economic structure in which the real costs of OSH are not borne by the producer but are passed on to society (Dickens, 1984), as the recovery costs with the costs of occupational accidents are borne by society as a whole (and not exclusively by the enterprise on a microeconomic scale). From a Pigouvian viewpoint (Barnett, 1980; Pouliakas and Theodossiou, 2013), state intervention to incorporate these social costs into business practices is not only a regulatory but also a stabilizing act, as it ensures that firms make decisions not only based on their immediate private interests but also based on social benefit. To understand this relationship, we can develop a fundamental mathematical framework based on economic theory (Krugman and Wells, 2009), which expresses the total costs (CT) of workplace health and safety undertaken by a business can be broken down into three components shown in relation (1):

$$C_T = C_P + C_A = C_P + (C_D + C_I) \quad (1)$$

where C_P expresses the prevention costs (Ruser and Butler, 2010; Nagata et al., 2014), namely the costs of preventive measures such as training of workers, purchase of protective equipment, modernization of machinery, etc., and of setting up an operational OSH system· C_D expresses the direct costs (Nagata et al., 2014; Steel et al., 2018), namely the damage caused by accidents, such as loss of production, damage to equipment or product, costs of replacing staff or interruption of work, etc.)· and C_I expresses indirect costs (Steel et al., 2018), which are longer-term and often implicit or indistinguishable costs such as compensation, medical and legal expenses, loss of reputation and loss of productivity due to the impact of the accident on the working climate. Jointly C_D and C_I produce the recovery accident costs C_A.

In a plane diagram (Figure 1), in which the horizontal axis (x) describes the level of safety (S) and the vertical axis (y) the costs (C) of occupational accidents, the relationship (1) is described by two opposing curves. The first concerns the prevention cost (C_P), which follows a pattern of decreasing returns to scale with increasing safety levels. This mechanism expresses that, at an initial stage, small investments in OSH offer significant improvements, but in later stages, increasingly larger expenditures are required for equivalent increases in the level of safety. Conversely, the cost of accident remediation ($C_A = C_D + C_I$) decreases as safety increases, but cannot be reduced to zero, as it is impractical to eliminate human error and unforeseen events. According to equation (1), the synthesis of these two curves produces the total cost curve (C_T), which has a characteristic convex U-shape showing a minimum ($C_{\min}$) at a given level of safety S_{opt}.

This point expresses the optimum safety level at which the undertaking achieves maximum efficiency (minimizing the cost of occupational accidents) and constitutes a point of equilibrium in terms of the competitive relationship between the investment expenditure on prevention and the expenditure on compensation for occupational accidents.

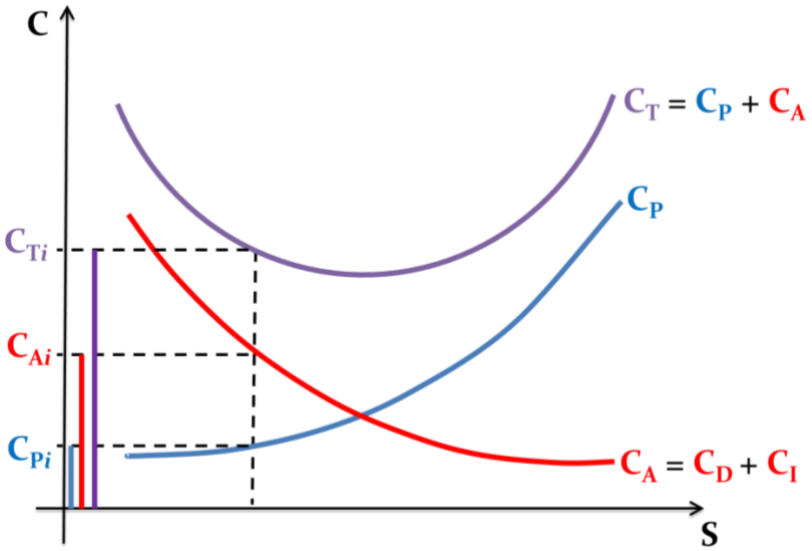

Figure 1. The cost curves of occupational accidents in a safety-cost level model.

Despite the usefulness of this theoretical approach, its application in practice faces significant challenges. Firstly, the availability of reliable statistical data (Abikenova et al., 2023) is a key factor for the accuracy of the calculations and the representativeness of the estimates. In addition, social awareness (Wahrini et al., 2019) plays a key role in determining the priorities of companies, prompting them to invest more in safety, even where the direct economic benefit is not obvious. Technological advances (e.g. the use of the Internet of Things, artificial intelligence, intelligent security surveillance systems, etc.) can transform the cost-security relationship (Rajendran et al., 2021), reducing the cost of prevention (C_P) while increasing the level of security (S), causing an overall downward shift in the total cost curve. In the short run, an employer attitude that does not take into account the indirect costs (C_I) of occupational accidents may appear more profitable at first sight. However, in the long run, it proves to be unsafe, as workplace accidents can harm the corporate image, bring legal consequences, and be unprofitable, leading to a loss of confidence among the workforce and consumers (Andersen et al., 2019). In this context, accident prevention must be seen not as an unnecessary expense but as a strategic investment (Pecillo, 2020) that increases the viability and competitiveness of the company in the long term. The State, for its part, must ensure that businesses do not pass on the external consequences of insecurity to society (Krupavicius et al., 2024) as a whole (Dufour et al., 2020), by creating a regulatory framework for businesses to incorporate the full social costs into their accounting model and by promoting labor as a value and not solely as a means of production.

3. Minimizing the total cost of accidents and determining the optimum level of safety

3.1. Microeconomic definition of the equilibrium condition

Minimizing the total cost of occupational accidents (Figure 2) is a fundamental objective for any company seeking to determine the optimum level of safety in economic terms.

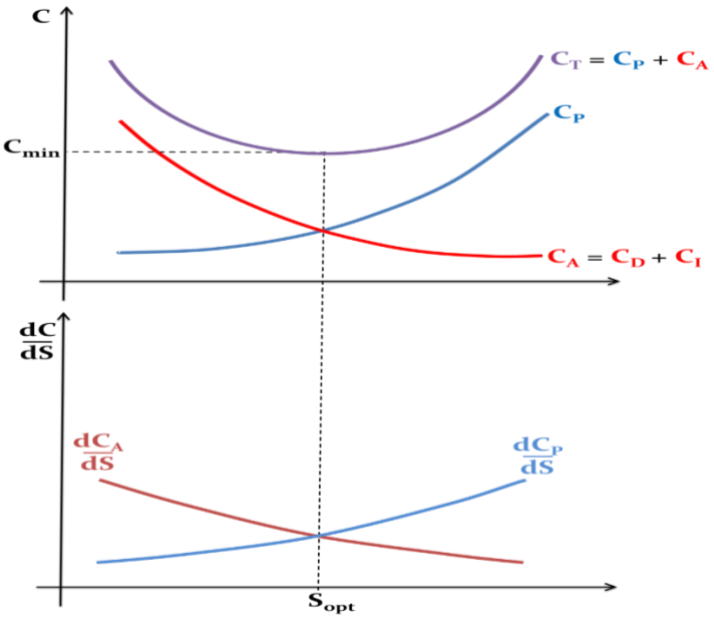

Figure 2. The occupational accidents' optimum (minimum cost) S_{opt} defined by the equilibrium point of the marginal propensities between prevention and accident costs.

The basic condition that defines this point results from the zeroing of the first derivative (Krugman and Wells, 2009) of the total cost:

$$\frac{dC_T}{dS} = \frac{d(C_P + C_D + C_I)}{dS} \quad (2)$$

which leads to the equality of the absolute values of the marginal cost (Krugman and Wells, 2009) of prevention and the marginal cost of accidents, according to the mathematical expression (3):

$$(2) \Leftrightarrow \left| \frac{dC_p}{dS} \right| = \left| \frac{d(C_A)}{dS} \right| \quad (3)$$

where C_P is the prevention cost, C_A ($C_A = C_D + C_I$) is the accident cost, and S is the safety level. The intersection of the two derivatives curves determines the optimum safety level S_{opt} (Figure 2), for which the total cost of the undertaking $C_T = C_P + C_A$ is minimized; S_{opt} is the equilibrium point at which the full substitution of prevention costs for accident costs is achieved. Beyond this point, an increase in the level of safety causes a disproportionate increase in prevention costs without a corresponding reduction in accident costs, making the investment inefficient.

3.2. The countervailing corporate strategies in out-of-equilibrium positions

It is interesting to note that for each total cost level $C_i > C_{min}$ there are two levels of security (S_1 and S_2) on either side of S_{opt} that yield the same cost (C_i), as it is shown in Figure 3. Although the cost equality $C(S_1) = C(S_2)$ expresses the same economic outcome, as a whole, these two points represent different corporate strategies. In particular, in S_1 the firm assumes high accident costs by choosing low investment in prevention, while in S_2 the reverse is true. The choice between these strategies depends on the level of risk the firm is willing to take, combined with market stability, the business strategy for the firm's social image, and external institutional factors.

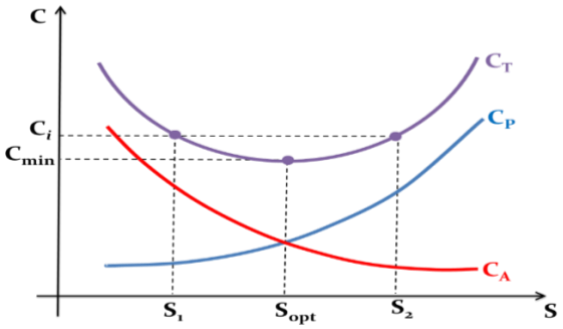

Figure 3. Each cost C_i above the optimum level $C_i > C_{min}$ corresponds to a pair of security levels (S_1 and S_2) on either side of S_{opt}.

The analysis shown in Figure 3 is based on the neoclassical assumption of economic rationality (Krugman and Wells, 2009) that business decisions are made through the optimization of exclusively economic criteria. The practice, however, appears nuanced as a number of variables in the firm's internal (e.g. corporate culture, the human capital of the firm, etc.) and external (e.g. pressures from government control mechanisms, existing labor legislation, prevailing labor market conditions, etc.) environment influence the observed behavior of the firm. Consequently, the observed level of safety adopted by a firm is often not identical to the theoretically optimal S_{opt}, but fluctuates around it, showing small or large deviations depending on the mechanism by which the conditions of the business environment change.

3.3. Shifts from equilibrium

The disturbance analysis in this section assumes that shifts in the prevention cost (C_P) and accident cost (C_A) curves can arise from factors originating either from the internal or external environment of the firm. For example, on the internal environment side, a firm may invest either in staff training (Aziz and Osman, 2019), in the purchase of modern equipment (Rajendran et al., 2021), or in the relocation of workers (Hassanain and Ibrahim, 2021) to positions commensurate with the level of risk, or even in the creation of combined prevention models. Each of these strategies can bring about a different level of safety S at a different overall cost. From an external perspective, if under the current institutional framework of insurance policy, accident costs are fully borne by the insurer, then the firm may downgrade prevention (Figure 4), whereas if the firm bears a large part of the accident costs, then it is forced to increase the need for prevention (Figure 5).

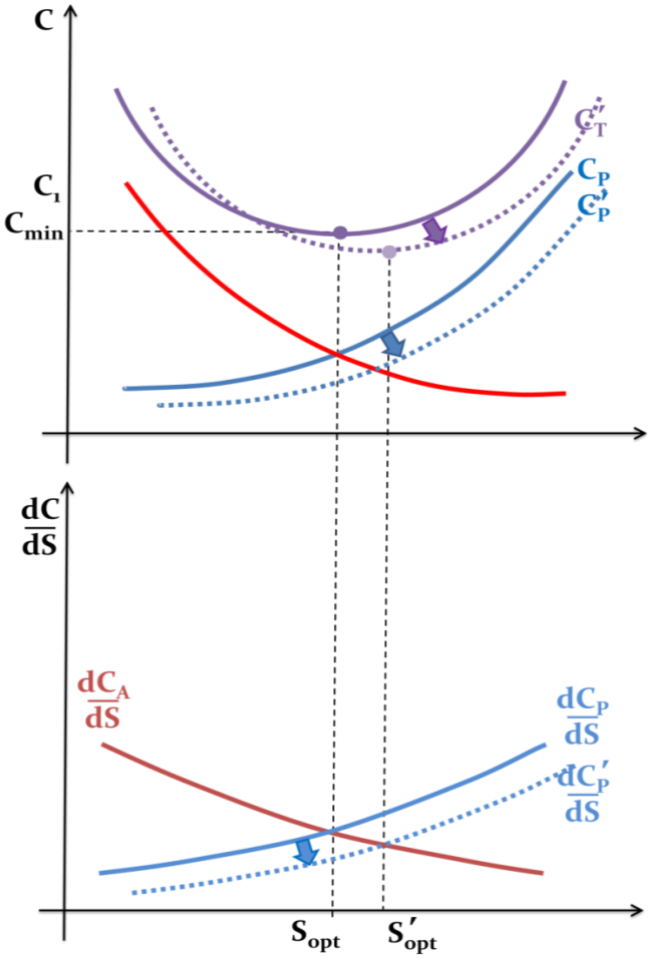

Figure 4. A shift of OSH costs equilibrium when a firm downgrades the prevention costs.

In this context, when the C_P curve shifts upwards, e.g. due to increased equipment prices or stricter safety regulations, then higher prevention costs are required for the same level of safety. This implies a

decrease in Sopt (namely $S'_{opt} < S_{opt}$) with a simultaneous increase in the minimum total cost ($C_{min} > C'_{min}$). Conversely, when the C_P curve shifts downwards, e.g. due to technological advances or more efficient allocation of prevention resources, then Sopt increases and the minimum total cost decreases. This shift suggests that with less investment, the firm achieves higher levels of safety, which makes it more competitive. A similar effect is brought about by shifts in the C_A accident cost curve. If, for example, direct or indirect accident costs (such as compensation, delays, legal costs, social outcry, loss of reputation, etc.) increase, then the C_A curve shifts upwards. This makes it more advantageous to increase prevention costs, leading to a higher optimal level of S_{opt} safety. Conversely, in cases where accident costs are decreasing, e.g. due to government subsidies, insurance coverage, or lax controls, the C_A curve shifts downwards and the firm can choose a lower level of prevention without a significant burden on overall costs:

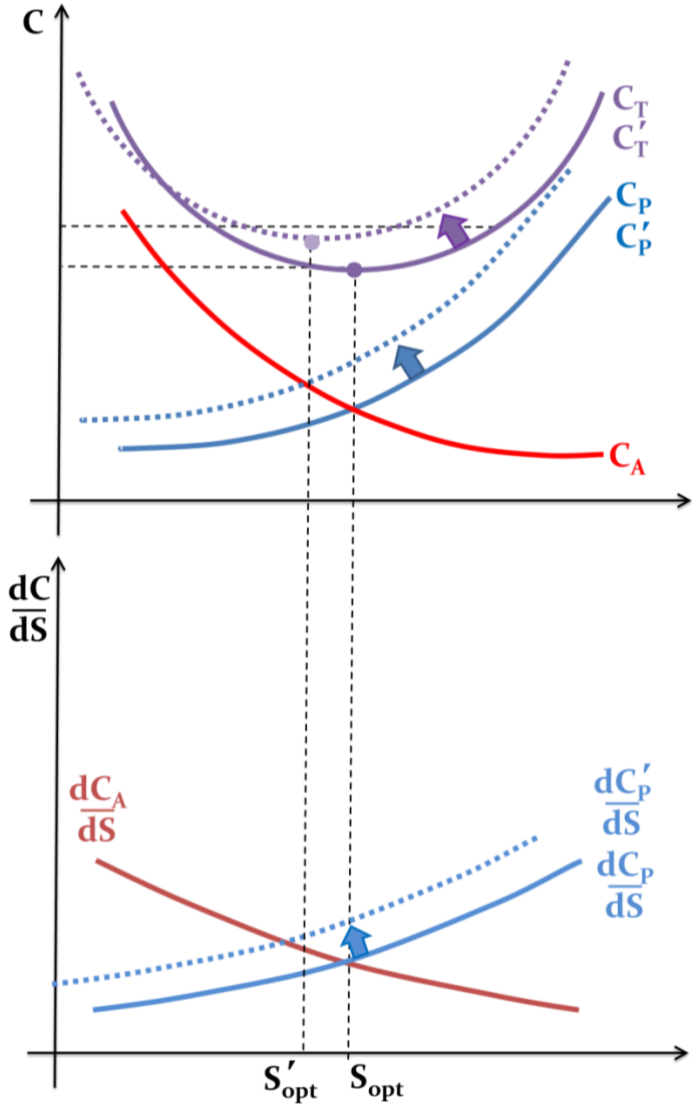

Figure 5. A shift of OSH costs equilibrium when a firm upgrades the prevention costs.

4. Sustainable practices resulting from minimizing the overall cost of occupational accidents

The previous microeconomic analysis has highlighted the importance for each company of periodically reviewing its cost curves. Changes in the factors affecting either C_P or C_A can lead to a new optimal level of safety (Figures 4 and 5), with direct consequences for the operation and viability of the business. In the prevention cost pillar, corporate targeting should be oriented towards shifting the C_P curve downwards, through the optimization of prevention policies (Takala et al., 2014; Andersen et al., 2019) that incorporate the benefits of technological advances (Rajendran et al., 2021), upgrading infrastructure, the organizational structure of the firm (Khandan et al., 2017), good time and human resource management, improving the level of training, cultivating a corporate OSH culture (Kim et al., 2016), and the quality of cooperation with the workforce.

Examples of strategies that can lead to an improvement in the level of safety without a proportionate

increase in prevention costs are raising awareness of the use of protective equipment (Michaels and Wagner, 2020; Michaels et al., 2023), redistributing staff to jobs (Hassanain and Ibrahim, 2021) according to their degree of risk, or even the appropriate organization of working hours to reduce fatigue (Rosa, 2017; Cunningham et al., 2022). The preceding microeconomic analysis has shown that the orientation of a company's occupational accident management strategy is a decisive factor in achieving satisfactory levels of safety in an economically sustainable manner. A well-designed prevention strategy (Takala et al., 2014) can lead to the achievement of safety levels that result not only in the lowest possible overall cost but also promote the social responsibility of the enterprise. However, the optimum level of safety achieved at the S_{opt} point is not a static parameter, but a dynamic situation that changes with the conditions of the internal and external environment of the company, so that its attainment is a continuous objective. In terms of the sustainability implication (Polyzos, 2022; Ruxho, 2024; Sepetis et al., 2024) of the preceding analysis, through the efficient management of total health and safety costs at work, beyond economic efficiency (optimization in the economic pillar), social acceptance (optimization in the social pillar) and harmonious coexistence with the environment required ensuring social health (optimization in the economic pillar) are achieved (Kavouras et al., 2022; Vitrano et al., 2023; Bikfalvi et al., 202; Jain et al., 2024). A company seeking to reduce C_T must therefore take account of the dynamic balance between prevention and accidents, namely, it must not value accident costs in the short term but in the long term, an approach guided by the principles of sustainable management and optimization.

Towards the thematic organization of the stages through which the process of accounting for the impact of an occupational accident passes, the conceptual framework of Figure 6 is introduced, which can provide a roadmap for the overall valuation of the total cost of occupational accidents. This thematic diagram can be read both at the level of estimating a potential accident (prevention) and at the level of valuing a contributory accident (response). At the planning level, each enterprise must record the risks (potential accidents) to which its production factors are exposed at the stages of its production process and operations. Then for each accident, whether taken as a design entity or a contributory event, its total cost can be estimated through the illustrated stages in the proposed process in Figure 6. The figure illustrating the process of estimating the total cost of accidents can be used by any company regardless of its industry.

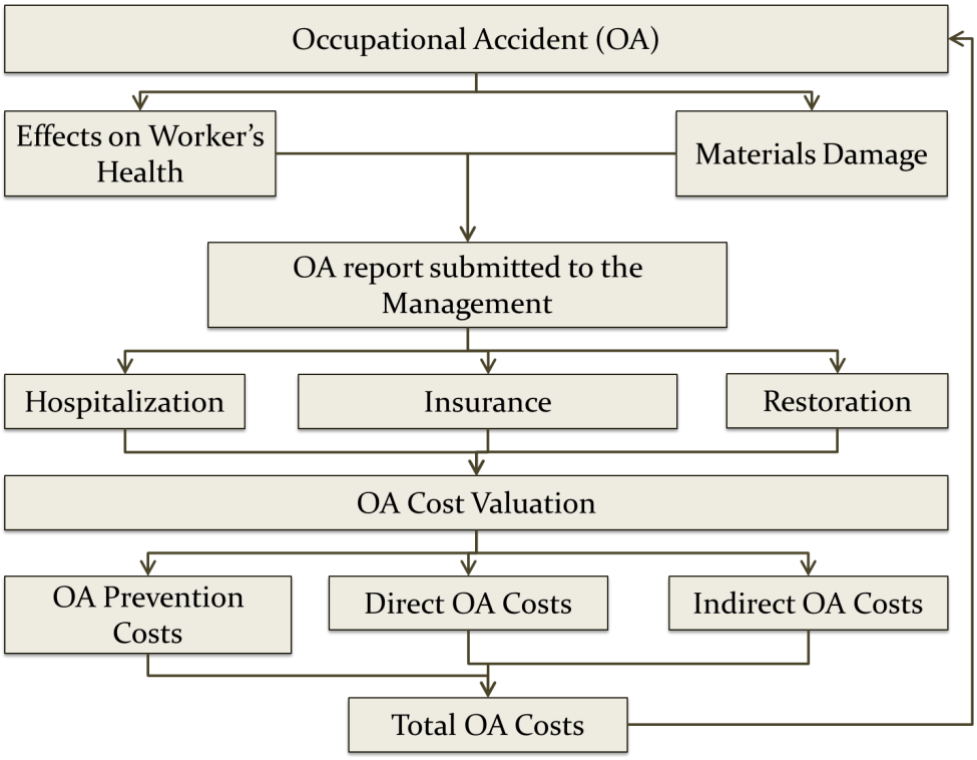

Figure 6. The proposed conceptual framework for the overall valuation of the total occupational accident cost.

Initially, the accident assessment must consider whether there are any effects on the health of the workers or possible material damage to equipment, plant, or products produced. In the event of an accident, these effects shall be communicated to the competent management for further management and accounting.

At the planning level, it is the relevant directorates that provide the techno-economic (Rajendran et al., 2021) and related information for each type of accident. This information includes medical costs, compensation, insurance contributions, equipment rehabilitation costs, and other costs directly related to the accident (Concha-Barrientos et al., 2005; Takala et al., 2014; Andersen et al., 2019). In the final stage, the systematic recording of all these data leads to a comprehensive picture of the financial costs of the accident. When the organization of the enterprise allows for the recording and keeping of the relevant data over time, then the accounting of the costs of occupational accidents can lead to more accurate estimates. This approach allows better decisions to be made on investments (Ruxho and Ladias, 2022b; Polo et al., 2025) in prevention and the adoption of OSH policies. The introduction of a system of regular recording and processing of OSH-related costs, from the initial planning of activities to their final production operation, is therefore becoming crucial to the success of the method. The company that seeks to understand in depth the costs of safety and to enjoy the long-term benefits offered by its optimization must recognize the importance of recording, organizing, and utilizing occupational health and safety information.

5. Conclusions

The microeconomic analysis in this paper has highlighted the importance of factoring the costs of occupational accidents into the strategic planning and operation of a modern business. Determining the economically optimal level of safety should not be treated solely as a theoretical process, but as a practical objective directly linked to the sustainability, competitiveness, and social responsibility of the company. Businesses' approach to OSH must go beyond the passive limits of mere compliance with the requirements of the legislation in force.

Businesses must become aware that the reduction of accidents and a general improvement in the level of safety at work cannot be achieved automatically through a mechanism of exogenous institutional regulation. Instead, it is linked to the maturation of the enterprise and the structural and operational improvement of its production processes. The more a company goes deeper in the direction of optimizing its production processes, the more it becomes aware of the added value of occupational health and safety in achieving its sustainability objective. In other words, the reduction in occupational accidents on a microeconomic scale is the result of the progress the company has made in moving toward its optimal operating levels. Progress in this direction passes through good organizational practices, operational upgrades, adoption of new technologies, and research based on reliable collection and evaluation of cost data.

By keeping detailed data on the costs of prevention, management, and remediation of occupational hazards, and by calculating actual rather than apparent costs, it is possible to develop a framework for a holistic assessment of the safety level of occupational accidents that promotes the sustainability of enterprises. Overall, OSH should be seen not as an obligation, but as a strategic asset for companies seeking sustainability. A company that integrates prevention into its operations reduces risks and at the same time enhances its long-term profitability by investing in preserving human life and demonstrating its corporate social responsibility.

In this context, calculating the real cost of accidents and choosing the appropriate prevention strategy are integral elements of this journey towards a safer and more efficient working environment.

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