

Organizational factors: a case study of the cost-benefit of implementing control measures in precast structure constructions

Fatores organizacionais: estudo de caso do custo-benefício na implantação de medidas de controle em obras com estrutura pré-moldada

Factores organizativos: un estudio de caso sobre la relación coste-beneficio de la aplicación de medidas de control en las obras de estructuras prefabricadas

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Abstract

This paper aims to demonstrate the implementation of systematic inspection systems at construction sites as a company's risk management strategy for identifying deviations, as well as to propose low-cost implementation organizational solutions. The methodology was divided into 5 parts. The first step consisted of a literature review, whose objective was to find documents and scientific productions relevant to the theme discussed in this article. Next, a check-list was prepared based on Regulatory Standard 18 (NR 18) - Conditions and Environment at Work in the Construction Industry and others. With the documentary part (check-list) finished, the field procedures were performed on site. After the construction was finished and the reports delivered, a survey of the non-conformities found was conducted so that the data could be analyzed. Finally, a cost-benefit analysis of the implemented control measures was performed. The irregularities that most occurred during the project's execution were: unprotected vertical rebar ends; employees not wearing PPE and insufficient number of sanitary installations. The safety indicators showed that the cycles where Structure, Masonry and Internal Sealing, Building Installations, and Finishing activities were performed simultaneously were the ones with the highest rate of irregularities. Finally, it was found that for each unit value invested in security control measures, the protection with financial liabilities from penalties is 16 times higher. Therefore, every cost aimed at adequate working conditions for employees reflects positively on the accounting management of civil construction sites.

Keywords: Civil construction; Workplace safety; Organizational factors; Investment in control measures.

Resumo

O presente artigo tem como objetivo demonstrar a implantação de sistemas de inspeção sistemáticas em obras como estratégia de gestão de riscos da empresa na identificação de desvios, bem como propor soluções organizacionais de baixo custo de implantação. A metodologia foi dividida em 5 partes. A primeira etapa consistiu na revisão da literatura, cujo objetivo era encontrar documentos e produções científicas relevantes ao tema discutido neste artigo. Em seguida, foi elaborado um check-list fundamentado na Norma Regulamentadora 18 (NR 18) - Condições e Meio Ambiente de Trabalho na Indústria da Construção e outras. Com a parte documental (check-list) finalizada, foram realizados os procedimentos de campo na obra. Após finalizada a obra e os relatórios entregues, foi realizado levantamento das não conformidades encontradas para que os dados fossem analisados. Por fim, foi realizada a análise de custo-benefício das medidas de controle implementadas. As irregularidades que mais ocorreram durante a execução do projeto foram: pontas verticais de vergalhões desprotegidas; funcionários sem usar o EPI e número insuficiente de instalações sanitárias. Os indicadores de segurança mostraram que os ciclos onde eram realizadas simultaneamente atividades de Estrutura, Alvenaria e Vedação Interna, Instalações Prediais e Acabamento, foram os com maior índice de irregularidades. Por fim, foi verificado que para cada valor unitário investido em medidas de controle de segurança, a proteção com passivos financeiros de multas é 16 vezes maior. Desta forma, todo custo voltado para adequar as condições de trabalho dos colaboradores reflete positivamente para a gestão contábil das obras da construção civil.

Palavras-chave: Construção civil; Segurança do trabalho; Fatores organizacionais; Investimento em medidas de controle.

Resumen

Este artículo pretende demostrar la aplicación de sistemas de inspección sistemática en las obras de construcción como estrategia de gestión de riesgos de la empresa para identificar desviaciones, así como proponer soluciones organizativas de bajo coste de implantación. La metodología se dividió en 5 partes. El primer paso consistió en la revisión bibliográfica, cuyo objetivo fue encontrar documentos y producciones científicas relevantes para el tema tratado en este artículo. A continuación, se elaboró una lista de comprobación basada en la Normativa 18 (NR 18) - Condiciones y medio ambiente de trabajo en la industria de la construcción y otras. Una vez completada la parte documental (lista de comprobación), se llevaron a cabo los procedimientos sobre el terreno. Una vez terminado el trabajo y entregados los informes, se realizó una encuesta sobre las no conformidades encontradas para poder analizar los datos. Por último, se realizó un análisis de costes y beneficios de las medidas de control aplicadas. Las irregularidades que más se produjeron durante la ejecución del proyecto fueron: puntas de barras de refuerzo verticales sin protección; empleados que no utilizaban EPI y número insuficiente de instalaciones sanitarias. Los indicadores de seguridad mostraron que los ciclos en los que se realizaron simultáneamente las actividades de Estructura, Albañilería y Sellado Interior, Instalaciones del Edificio y Acabado fueron los que presentaron el mayor índice de irregularidades. Por último, se ha comprobado que por cada valor unitario invertido en medidas de control de la seguridad, la protección con responsabilidades financieras de las multas es 16 veces mayor. De este modo, todo gasto destinado a adaptar las condiciones de trabajo de los empleados se refleja positivamente en la gestión contable de las obras de construcción civil.

Palabras clave: Construcción; Seguridad laboral; Factores organizativos; Inversión en medidas de control.

1. Introduction

The civil construction sector accounts for 3.3% of Brazil's Gross Domestic Product (GDP) and is set to increase by 4% by 2021, even with the pandemic, according to data from the Brazilian Civil Construction Industry Chamber (CBIC). The sector also has around 200 thousand establishments (companies and branches) competing in the civil construction chain. In addition, the sector employed about 7.6 million people, 7.3% of the activated population of Brazil in 2018 (CBIC, 2021). Therefore, the civil construction production chain is competitive and plays an important role in the generation of employment and income, as well as in the development of the Brazilian economy.

The competitiveness in the civil construction market requires companies to invest in the reduction of losses related to its process. According to Barkokébas et al. (2020) losses are responsible for reducing the competitiveness of companies. Occupational accidents can be considered losses that hinder business performance. According to Aminbakhsh et al. (2013), the costs of accidents in construction impact the financial success of construction organizations and affect the overall costs of the construction. Therefore, investing in the prevention of accidents corroborates in the reduction of losses providing a gain in competitiveness of the construction company.

Accidents generate unplanned costs (Ferreira et al., 2012), which reduces the competitiveness of companies' products and, as a result, weakens the economies of nations. Studies show that 18% of deaths at work occur in low- and middle-income countries, while 5% in high-income countries (Takala et al., 2014). Construction in turn is responsible for 21% of deaths at work in the United States of America, (OSHA, 2017), while in Great Britain this percentage is 28% (HSE, 2018). According to studies by Silva (2017) and Costa (2014), the death rates in emerging countries tend to be even higher.

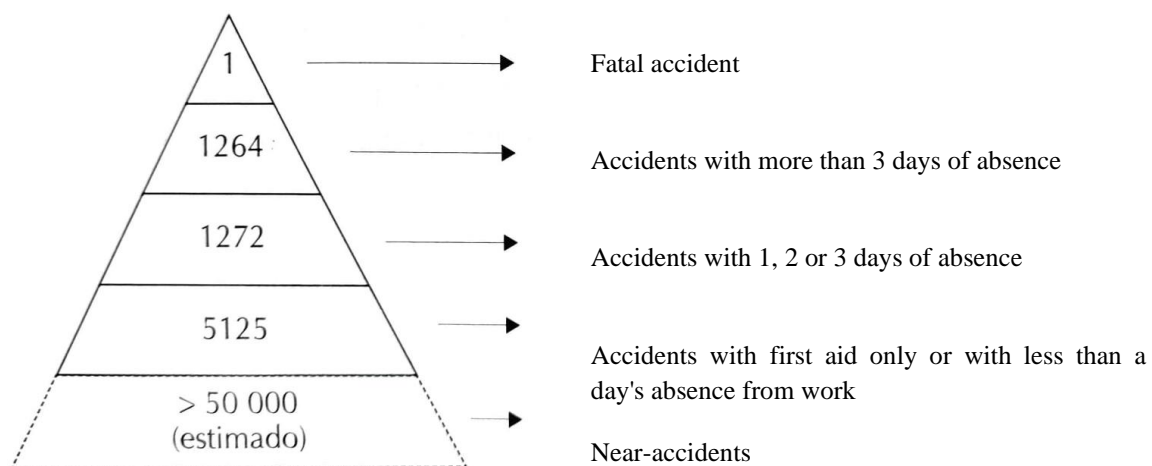
It should be noted that such losses correspond to nearly 4% of global gross domestic product, according to data from the International Labor Organization - ILO (ILO, 2015). According to data from the Global Competitiveness Report 2020 (World Economic Forum, 2020), competitive companies in high-income countries tend to invest more resources in managing risks related to industrial and work processes. The same report also shows that companies that developed safety policies during the pandemic prospered even during the COVID-19 scenario. Therefore, well-established and prosperous companies invest in managing work-related risks.

Risk management consists in identifying, evaluating and controlling possible conditions with the potential to cause work accidents. Inspection procedures and safety audits are risk management tools that allow the control of situations with potential to cause accidents. According to Ferreira et al. (2012), safety inspections are beneficial because they allow the

anticipation of risks, minimizing possible costs with accidents. Risk management is part of the company's loss control strategy. According to Gurcanli et al. (2015), the costs with the process safety are part of the project in order to protect the losses related to occupational accidents. Thus, the investment in inspections and audits of occupational health and safety - OHS positions such corporate area not only as strategic in the worker protection, but also strategic for the protection of the capital of the business itself.

In the context of worker and capital protection, the legal deviations regarding occupational safety issues imply the occurrence of occupational accidents, which in turn imply in the loss of business capital that implies in the loss of competitiveness and profitability of the enterprise. Skiba and Lehder (2005) studied data on accidents at work in the industrial sector, from German Mutual Insurance Companies, and proposed the distribution shown in Figure 1.

Figure 1 - Accident pyramid.



Source: Skiba e Lehder (2005).

According to Figure 1, there is a relationship between near misses and fatal accidents. Therefore, deviations are responsible for both minor losses (near misses) and fatalities.

In this context, safety inspections and audits play the role in the identification of occurrences of deviations. According to Cardoso (2017), deviations are considered a situation outside the safety, environmental and occupational health standards that has the potential to cause harm to people, property or impact the environment. Deviations are the minor occurrences that precede serious and fatal accidents. For Van Der Schaff and Kanse (2004), minor occurrences, called incidents, have the same cause patterns of fatalities. Deviations may originate from human, technical or organizational factors. Thus, fatal accidents and incidents are caused by human, technical and organizational factors that can be identified in advance through systematic inspections and audits.

Safety inspections are strategies responsible for bringing to light failures in the occupational safety control. According to Barkokébas et al. (2020), inspections are responsible for the identification of hazards and the solutions capable of solving them effectively. The solutions to the problems found are usually low cost. According to Gerald et al. (2009), 80% of the problems are simple to solve and have organizational factors as their origin. Thus, identification and control of organizational factors are strategies of low aggregate cost for the control of risks and with prospects of good results.

The management of organizational factors depends on the investment in low cost corporate actions. According to Li et al. (2015), the investment in training, people development and implementation of small safety adjustments result in positive impacts to the organization. The construction enterprises seek for safety measures with low cost. The dynamics of the

construction production according to Zhou et al. (2015) requires from the process alternatives of rapid implementation for the effective control of risks. Therefore, construction managers try to invest in low-cost organizational measures to control the process risks.

The civil construction has as a characteristic the constant change of work scenarios. According to Rosa Filho (2019), construction is composed of multiple services of short cycles with labor exchange that varies according to the stage of the work. Systematic inspections (audits) work with risk management strategy with emphasis on mapping changes. According to PMI (2017), audits help in the investigation of problems to define solutions. Therefore, systematic inspections (audits) are characterized as a risk management tool for constructions to identify problems and propose organizational alternatives of low implementation cost.

Given the above, this paper aims to demonstrate through a case study the implementation of systematic inspection systems in construction sites as a risk management strategy of the company in the identification of deviations, as well as to propose organizational solutions of low implementation cost. In addition, it demonstrates the cost-benefit of investing in organizational solutions for occupational safety on the protection of the enterprise's capital.

2. Methodology

The present work consists of a case study referring to work safety audits in an educational project. From the audits, technical reports were generated whose data were qualitatively treated. The methodology of this work was divided into 5 parts, as follows: Literature review, check-list structuring, field procedures, data organization and treatment and cost composition of control measures.

2.1 Literature review

The first stage consisted of the literature review, whose objective was to find documents and scientific productions relevant to the theme discussed in this article. The theme was searched in periodicals, annals of events, doctoral theses and master's dissertations indexed in databases. For the sake of comprehensiveness, the following keywords were used: occupational safety, occupational health and safety, civil construction, cost, risk management, safety guidelines and safety investments, as well as their translations into English. The search was made in the title, abstract and keywords. The information and discussions contained in this article were based on academic productions found through systematic review in SCOPUS and Science Direct.

2.2 Structuring the check-list

For the development of this work it was applied the methodology Barkokébas (2004), which guides the preparation of check-list for application in the field. Thus, a check-list was prepared based on Regulatory Standard 18 (NR 18) - Conditions and Environment at Work in the Construction Industry and others. Figure 2 shows part of the check-list applied in the project.

Figure 2 - Check-list applied at the enterprise.

IND.	GRUPO	NR	DESCRIÇÃO	MARCAÇÃO				NÚMERO DE REPETIÇÕES
				REF	CO	DES	GIR	
001		18.4.2.11.4	Existe no local de refeições bebedouro?	4				
002		18.37.2	É fornecido ao trabalhador água potável, na proporção de 1 x 25 e de forma que o trabalhador não se desloque mais que 100 metros? Não sendo permitido o uso de copo coletivo.	4				
003		18.6.5	Os taludes com profundidade superior à 1,25m tem sua estabilidade garantida?	4				
004		18.8.8	Os materiais retirados das escavações estão sendo depositados a uma distância superior a da metade da profundidade da escavação?	4				
005		18.7.2 e)	O disco da serra é mantido afiado e travado?	4				
006		18.7.2 e)	A bancada da serra é provida de cotão, cunelo divisor e coletor de serragem?	4				
007		18.9.4	Durante a desforma devem ser viabilizados meios que impeçam a queda livre de seções de fôrmas e escoramentos?	4				
008		18.11.6	As mangueiras possuem mecanismo contra o retrocesso de chamas na saída do cilindro e chegada do maçarico?	4				
009		18.12.5.7	Existem escadas de mão junto a redes e/ou equipamentos elétricos sem proteção?	4				
010		18.13.1	Estão sendo instaladas proteções coletivas onde há risco de queda de trabalhadores ou projeção de materiais?	4				
011		18.13.2	Existem aberturas no piso, sem o fechamento provisório?	4				
012		18.13.3	Os vãos de acesso aos poços de elevadores encontram-se com fechamento, permanente ou provisório?	4				
013		18.13.6	Em todo perímetro da construção dos edifícios com mais de 4 pavimentos ou altura equivalente, foi instalada uma plataforma principal (bandeja)?	4				
014		18.13.7	Estão sendo instaladas plataformas secundárias a cada 3 pavimentos acima da plataforma principal?	4				
015		18.14.12	Guinchos de coluna "tipo Velox" são providos de dispositivos próprios de fixação?	4				
016		18.14.19	Pessoas são transportadas em equipamentos de guindar não projetados para este fim?	4				
017		18.14.21.13	Os acessos aos guinchos, tem barreiras que impeçam a exposição de parte do corpo dos trabalhadores?	4				
018		18.14.21.16	As cancelas dos guinchos são impedidas de abrir sem que a cabine esteja no pavimento?	4				
019		18.14.23.1	No caso de edifício em construção com 8 ou mais pavimentos, a partir do quinto pavimento já consta a instalação de pelo menos um elevador de passageiros?	4				
020		18.14.24.12	As áreas de cargas ou descarga estão isoladas somente permitindo o acesso de pessoas envolvidas na operação?	4				
021		18.14.25.4	Os elevadores de cremalheira, possuem sensor que so permita o deslocamento da cabine, com as portas e cancelas fechadas?	4				
022		18.15.2	Os andaimes devem ser dimensionados e construídos de modo a suportar, com segurança, as cargas de trabalho a que estarão sujeitos? (Memória de Cálculo)	4				
023		18.15.3	O piso dos andaimes tem forração completa, bem como está travado e nivelado?	4				
024		18.15.6	Existe Guarda-Corpo no andaime, o mesmo está em bom estado e de acordo com o item 18.13.5?	4				
025		18.15.7	Foram removidos itens de segurança dos andaimes?	4				
026		18.15.8	Estão sendo utilizados bancos, escadas ou outro material, sobre o piso do andaime, para atingir maior altura?	4				
027		18.15.9	O acesso aos andaimes está sendo de forma segura? Escada fixada a estrutura do andaime?	4				
028		18.15.10	Os andaimes possuem sapatas e são mantidos nivelados e sobre piso que resista a sua carga?	4				

Source: Occupational Safety and Hygiene Center - NSHT (2018).

According to Figure 2, in total, the check-list has 192 applicable items to be audited. It contains 20 items related to the living area; 8 items allusive to demolition, excavations and rock disassembly; 6 items related to carpentry; 5 items with respect to steel frames; 3 items with respect to concrete structures; 4 items allusive to welding and hot cutting; 10 items regarding stairs, ramps and walkways; 8 items regarding protection against falls from heights; 12 items regarding movement and transport of materials and people; 13 items regarding scaffolding; 5 items regarding aerial work platforms; 4 items regarding cables and ropes; 5 items regarding masonry, coatings and finishes; 3 items regarding roofs and coverings; 11 items regarding safety in electrical installations; 15 items regarding safety in machines, tools and miscellaneous equipment; 4 items regarding personal protection equipment - PPE; 8 items regarding storage and stocking of materials; 1 item regarding fire protection; 2 items regarding signaling; 2 items regarding order and cleaning; 3 items regarding lighting; 3 items regarding working at height and 37 items regarding mandatory documentation.

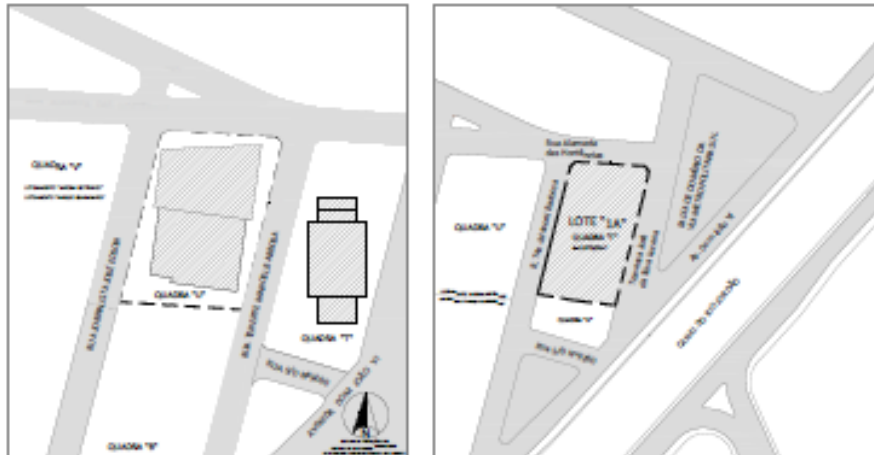
2.3 Field procedures

With the documentary part (check-list) finalized, the field procedures were carried out on site.

2.3.1 Object of study (work)

The object of study is an educational development of elementary school and kindergarten type built in the city of Recife, Pernambuco, Brazil. The school occupies 6,524.93 m², with occupation index of 100% of the land, considering built area, green areas, circulation and vehicle parking spaces. The object of study consists of two buildings connected by an internal street, three multi-sports courts (one suspended), a library with more than 100m², laboratories, classrooms and living areas, according to the scheme shown in Figure 3. The project had as a construction technology used precast concrete parts.

Figure 3 - Schematic of the educational enterprise.



Source: NSHT (2018).

The architectural design of the development includes two building units named "T block " and "U block ". The T block has 3 floors, being the ground level for access and two levels of rooms. The U block has 5 floors, with a semi-underground level for garages, a ground level and three levels of rooms.

2.3.2 Observation (audit and technical reports)

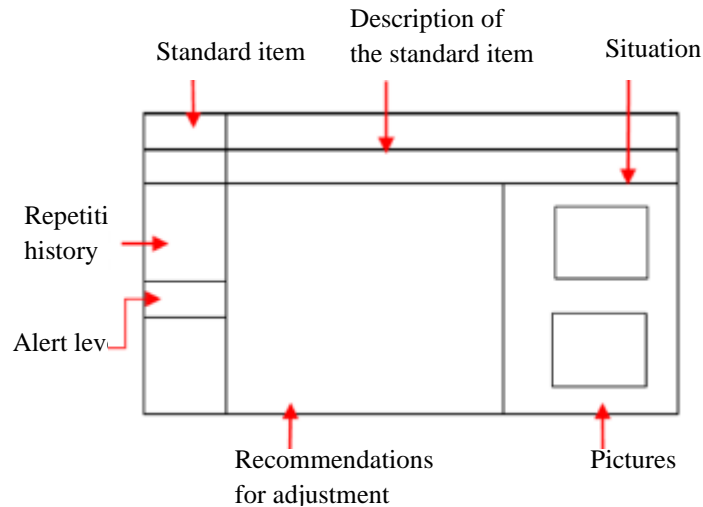
The observation of the data occurred through technical visits to the site without prior notice, in order to collect data close to the reality of the routine of the work. That is, minimizing the attempts of corrections or omissions of irregularities facing the legal requirements of health and safety at work applicable. Thus, the work was found in its normal state of development, whose information tended to reflect the habits of the company in its routine activities.

In total, eight visits were made to the construction site, being applied the structured check-list. Each incursion was called "Cycle", therefore, Cycles I, II, III, IV, V, VI, VII and VIII were performed. The audits had an interval of 30 days and a duration of 8 hours, including the entire working day of the construction site employees. They followed the entire evolution of the work, contemplating the following phases of the same: Foundation (FO); Structure (ST); Masonry and Internal Sealing (MIS); Building Installations (BI) and Finishing (FI).

The deviations and irregularities were identified and quantified. Subsequently, both the deviations in the field and the irregularities present in the company's documents were analyzed. Observations were noted considering the irregularities found in the field, as well as problems pointed out by the employees themselves through conversations during the visits. At the end of each visit, technical closing meetings were held with the site leaders, where the critical points were discussed and fixed immediately, as well as the best way to correct the main deviations and alternatives to prevent their repetition were discussed.

Finally, within a maximum period of 1 week, the company responsible for the work received a technical report that included the observations and surveys made during the audits. Figure 4 shows the structure of the documents studied in the study.

Figure 4 - Structure of the reports.



Source: NSHT (2018).

2.4 Organisation and treatment of data

After completion of the work and the reports delivered, a survey of the non-conformities found was conducted so that the data could be analyzed.

2.4.1 Classification of deviations

The classification of deviations was performed according to the Barkokébas Júnior (2004) methodology. The checklist items were classified as: compliant - CO, disagreed - DIS and serious and imminent risk - SIR. And their definitions are given below:

- **Serious and imminent risk** - Work conditions with potential to cause occupational accident or disease of serious or fatal nature (Ex: periphery openings, exposed energized parts).
- **Disagreement** - Situations in disagreement with the standards (Ex: materials obstructing circulation routes, poorly dimensioned living areas).
- **Compliant** - Standards compliant situations.

2.4.2 Handling of information

The treatment of information occurred through the development of objective and measurable indicators suitable for the monitoring of the management performance. Presented, comparing different periods, they evaluate the company performance under various approaches, becoming a thermometer for the objectives and goals determined by the organization (Barp et al, 2014). The indicators make it possible to know the real situation that one wants to change, in addition to establishing priorities, choose the beneficiaries, identify the objectives and translate them into goals and, thus, being able to effectively monitor the progress of the work, evaluate the processes, adopt the necessary redirections and verify the results and impacts obtained (SESI, 2010).

Thus, the collected data were treated and the following safety indicators were developed: Quantitative Indicator - IQT, Qualitative Indicator - IQI, Economic Indicator - EI and Saturation Indicator - SI, described below:

- **Quantitative Indicator:** Presents the performance of the work with respect to safety conditions and hygiene at work throughout the inspections carried out. The quantitative data classified as Compliant, Non-Compliant and Serious and Imminent Risk, according to the OSH legislation in force in Brazil, are presented.
- **Qualitative Indicator:** Presents qualitatively, the incidence of irregularities recorded in the Quantitative Indicator, identifying the items of NR-18 and other regulatory standards.
- **Economic Indicator:** Presents the possible costs related to occupational safety liabilities in fines calculated according to NR 28 - Inspections and Penalties, taking into consideration the criteria adopted by the Ministry of Labor and Employment - MTE.
- **Saturation Indicator:** Presents the quantity of SIR (Serious and Imminent Risk) found, throughout the audits, for a group of 100 workers. This indicator is represented by equation 1.

$$IS = \frac{N^{\circ} \text{ de G.I.R}}{N^{\circ} \text{ de Trabalhadores}} \times 100 \quad (\text{Equation 1})$$

After the treatment of the data and the structuring of the indicators, it was possible to suggest alternatives for good work practices, specific for the control of irregularities that presented a higher frequency during the course of the work.

2.5 Cost Composition of Control Measures

Throughout the execution of the project, one of the reasons that led to an improvement in OHS performance on site was the implementation of operational measures at the service fronts. Such adjustments were made in order to neutralize the risk conditions and meet the requirements indicated by the reports of systematic audits in OHS.

In the topic of the results that speaks of such adjustments, an estimate of the cost that the company responsible for the execution of the project had to disburse for their implementation is presented. To arrive at such values, it was used the table of the National System of Prices and Indexes for Civil Construction - SINAPI, with data from the time when the work was performed (2018), provided by Caixa Econômica (Federal Savings Bank) (2021). According to previous studies and the professional experience of the authors, the values of each input were collected from the SINAPI table, so that the respective normative adequacy could be achieved, and thus, the final cost estimate for such a measure could be implemented. Each operational measure was analyzed separately as shown in Table 1.

Table 1 - Columns of the safety investment analysis spreadsheet.

Deviation (1)	Classification (2)	EI (NR-28) (3)	Investment description (TABLE SINAPI) (4)	Quantity (TABLE SINAPI) (5)	Unit (TABLE SINAPI) (6)	Safety investment (TABLE SINAPI) (7)	Economy (8)
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Source: Adapted from Barkokébas Júnior (2004) and SINAPI (2021).

Where the first column presents the description of the normative deviation to be adjusted and its classification, according to the Barkokébas Júnior (2004) methodology, comes right after in the second column. Knowing that each type of irregularity has a respective fine liability, in the third column, it is shown this value based on the table of fines established by the text of NR - 28 at the time of the work and which is used in the EI (Economic Indicator). The next three columns (4, 5 and 6) show how the inputs used to adjust the regulatory deviation are described in the SINAPI table, the quantities of each that were necessary to perform the adjustment and the unit of measure for each, respectively. In the seventh column is presented the sum of the values of the inputs and thus, we have the cost of the investment made by the company responsible to correct the

irregularity. Finally, the last column presents the difference between the values of column (3) and column (7), showing the savings achieved by the company through the safety investment made.

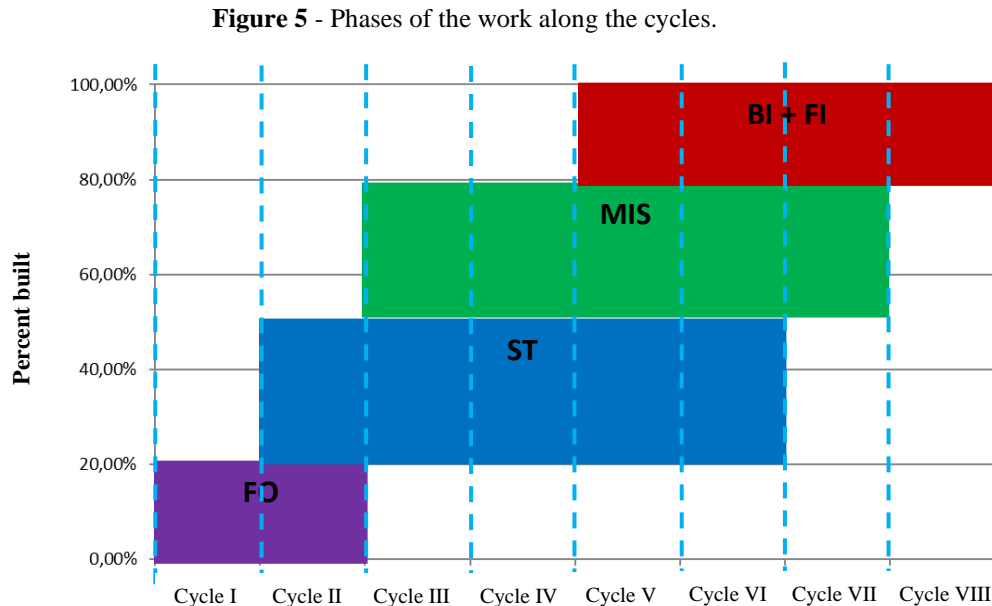
In view of globalization and the international relevance factor, the columns referring to economic indicators (3, 7 and 8) were converted into dollars. Thus, the values found in Brazilian currency were multiplied by 5, the approximate value of the dollar at the time this study is being developed (Infomoney, 2021).

3. Results and Discussion

The results were divided into the following three categories.

3.1 Descriptive statistics of the indicators

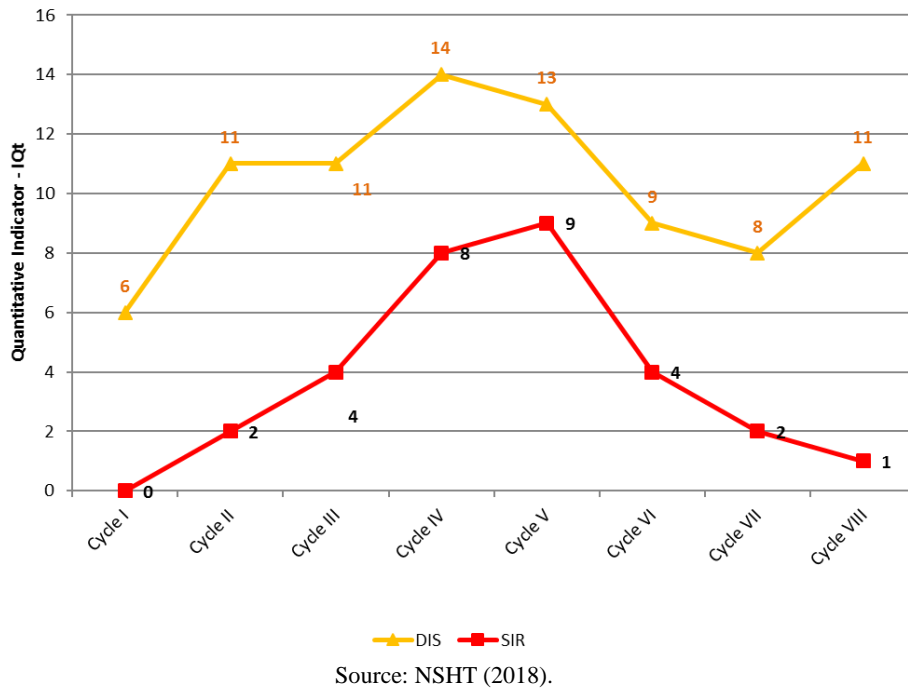
The chart in Figure 5 was developed to illustrate the evolution of the percentage of the construction work built over the audit cycles performed. With it, it is possible to indicate the types of activities that were found at the time of the safety inspection of the project.



Legend: FO - Foundation; ST - Structure; MIS - Masonry and Internal Sealing; BI - Building Installations and FI - Finishing.
Source: Adapted from NSHT (2018).

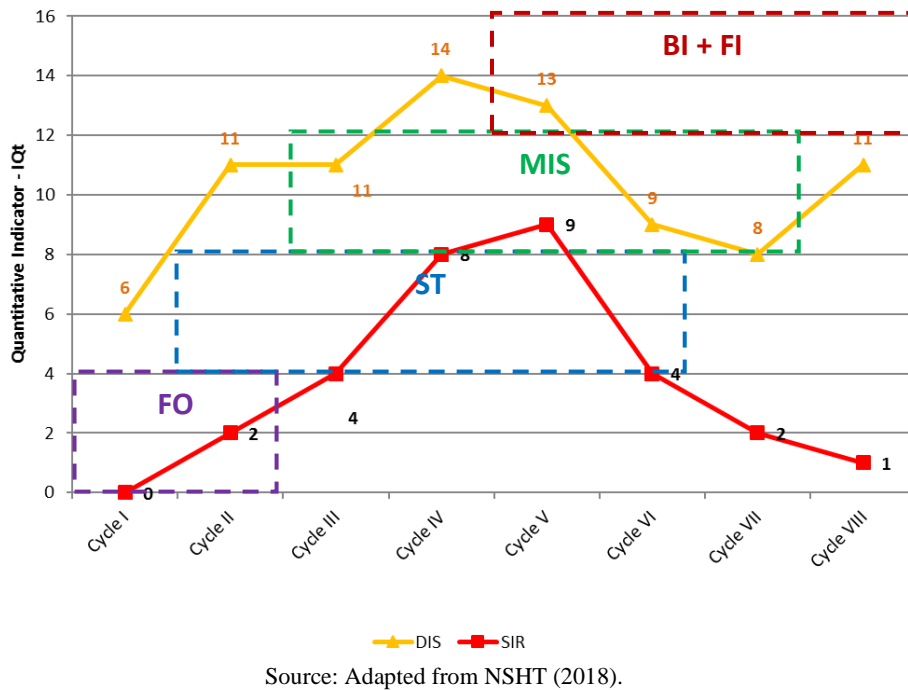
According to Figure 5, the 8 cycles of inspections corresponded to the complete monitoring of the project. For Freitas et al (2021) works executed in 8 months are considered fast and have challenges in the management process. The Quantitative Indicator reported in Figure 6 presents the frequency of incidence of non-conformities. The quantitative indicator showed uniformity in relation to the number of disagreements, with a maximum point with 14 disagreements in Cycle IV, a period with a large number of contractors on site, and a minimum point with six disagreements in Cycle I, due to the construction still being in the beginning, and consequently, the reduced number of activities and employees. Regarding the SIR, the indicator shows that it had an increasing trend until it reached its maximum value and then suffered a decline until the end of the site visits. For a better view of the site performance in relation to Disagreements and Serious and Imminent Risks - SIR, Figure 6 was generated without the compliance data.

Figure 6 - Quantitative indicator without conformities.



In order to aggregate the information from the graphs in Figures 5 and 6, Figure 7 indicates the activities that were being performed at the site in each result of irregularities found.

Figure 7 - Quantitative indicator combined with construction phases.

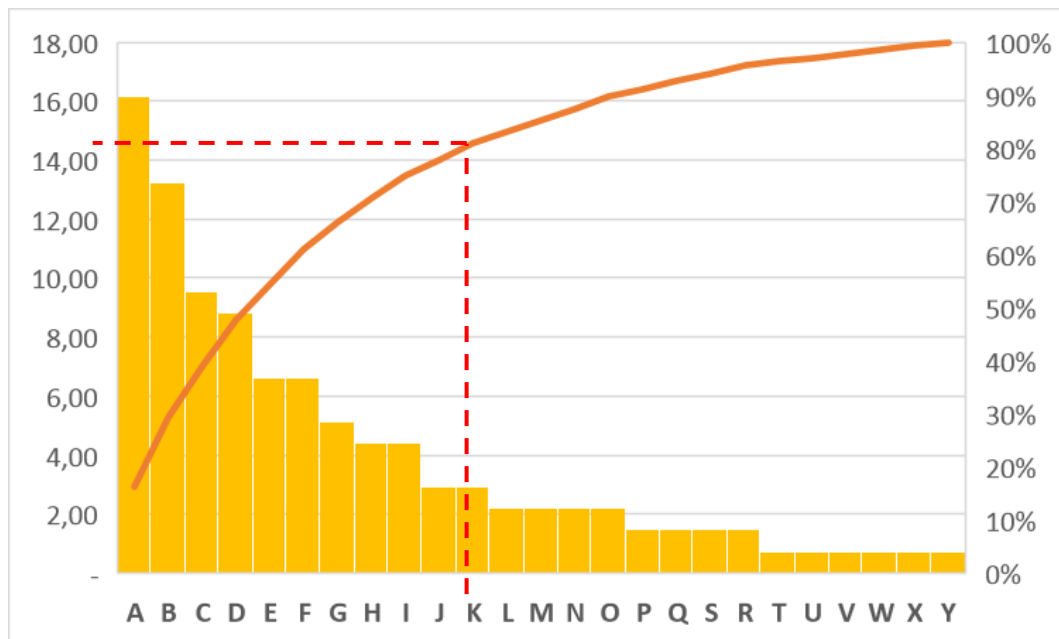


Analyzing the graph in Figure 7, we see that the highest incidence of normative deviations occurred in Cycles IV and V. This is justified by the fact that during these cycles there was a larger amount of activities to be performed on site, involving the phases of Structure (ST), Masonry and Internal Sealing (MIS) and the beginning of the Building Installations and Finishing

(BI+FI), the latter precisely in the cycle with the highest incidence of irregularities (22). According to Soares Júnior et al (2021), the more activities being performed, the greater the number of workers involved, causing the amount of causes for possible accidents to also be greater, making it normal to have an increase in the amount of irregularities found in OHS audits. Therefore, the drop in the number of serious and imminent risks (SIR) contemplated during the technical visits is due to the measures that were requested to be implemented in the reports of previous audits and the gradual decrease of activities being carried out on the work fronts and the number of staff working at the site. This fact is justified by observing the drop in the number of irregularities as soon as the activities of the Structure phase (ST) of the works were terminated.

Thus, for the direction of the company's actions, it is necessary to identify the irregularities, relating them to the legal and regulatory requirements. Figure 8 shows the Pareto distribution with respect to items in non-compliance with regulatory standards. This distribution allows visualizing where the 80% of the causes of deviations in relation to the standard are concentrated. The indicator shown in Figure 8 allows the direction of management in occupational safety for resolution of the most frequent causes.

Figure 8 - Pareto distribution for qualitative indicator of disagreements.

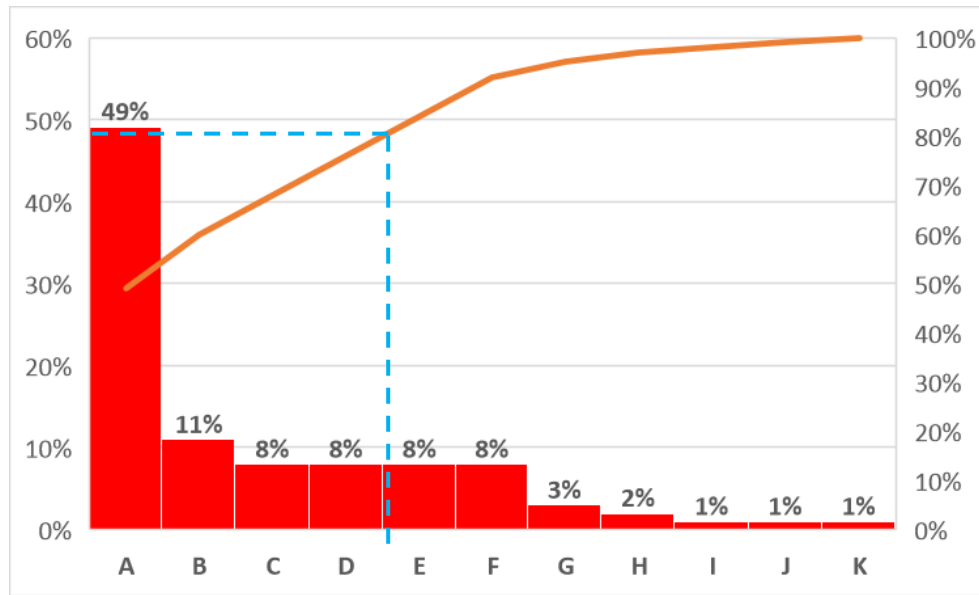


A: ITEM 18.4 - Living area; B: NR-6 - PPE; C: ITEM 18.13 - Protective measures against falling from height; D: ITEM 18.12 - Ladders, ramps and walkways; E: ITEM 18.15 - Scaffolding; F: ITEM 18.21 - Electrical installations; G: ITEM 18.7 - Carpentry; H: ITEM 18.14 - Movement and transportation of materials and persons; I: ITEM 18.26 - Fire protection; J: NR-10 - Safety in Services with Electricity; K: ITEM 18.29 - Order and cleaning; L: ITEM 18.3 - PCMAT; M: ITEM 18.8 - Steel Frames; N: ITEM 18.24 - Storage and stocking of materials; O: ITEM 18.27 - Safety signs; P: NR-12 - Safety at Work in Machinery and Equipment; Q: ITEM 18.6 - Excavations, foundations, and blasting rock; R: ITEM 18.22 - Miscellaneous machinery, equipment, and tools; S: NR-18 - Annex IV; T: NR-17 - Ergonomics; U: ITEM 18.23 - Personal Protective Equipment - PPE; V: ITEM 18.30 - Hoardings; W: NR-22 - Safety in Mining; X: NR-24 - Sanitary and Comfort Conditions in the Workplace; and Y: NR-34 - Working Environment and Conditions in the Naval Construction, Repair, and Dismantling Industry. Source: NSHT (2018).

According to Figure 8, it is possible to see that the highest frequency of disagreements is related to ITEM 18.4 - Living Area, totaling 16.18% of the occurrences, followed by Personal Protective Equipment - NR 06 (13.24%) and ITEM 18.13 - Protection Measures Against Falls from Height (9.56%).

Like the disagreements, the situations of Serious and Imminent Risk (SIR) are also part of the amount of non-conformities. For a better visualization of the GIR found, Figure 9 presents the Pareto distribution of the items in SIR.

Figure 9 - Pareto distribution for qualitative SIR indicator.



A: ITEM 18.8 - Steel frames; B: ITEM 18.15 - Scaffolding; C: NR-6 - PPE; D: ITEM 18.11 - Welding and hot cutting operations; E: ITEM 18.13 - Protective measures against falling from heights; F: ITEM 18.23 - Personal protective equipment - PPE; G: NR-18 - Annex IV; H: ITEM 18.24 - Storage and stockpiling of materials; I: ITEM 18.6 - Excavations, foundations and rock dismantling; J: ITEM 18.21 - Electrical installations; and K: NR-35 - Work at Height.
Source: NSHT (2018).

Analyzing the data presented in Figure 9, it is possible to verify that the highest amounts of SIR found are related to Item 18.8 - Steel Frames, with 49% of occurrences, and then, Item 18.15 - Scaffolding, representing 11% of the total.

As shown previously through the graphs in Figures 8 and 9 and surveying information from the safety reports, these were the irregularities that occurred most during the execution of the project:

- Vertical rebar ends unprotected;
- Employees not wearing PPE;
- Insufficient number of toilet facilities and no container for used paper;
- Incomplete guardrail system for collective protection;
- Absence of guardrails and footings on scaffolding; and
- Employees not securing their harness to the lifeline.

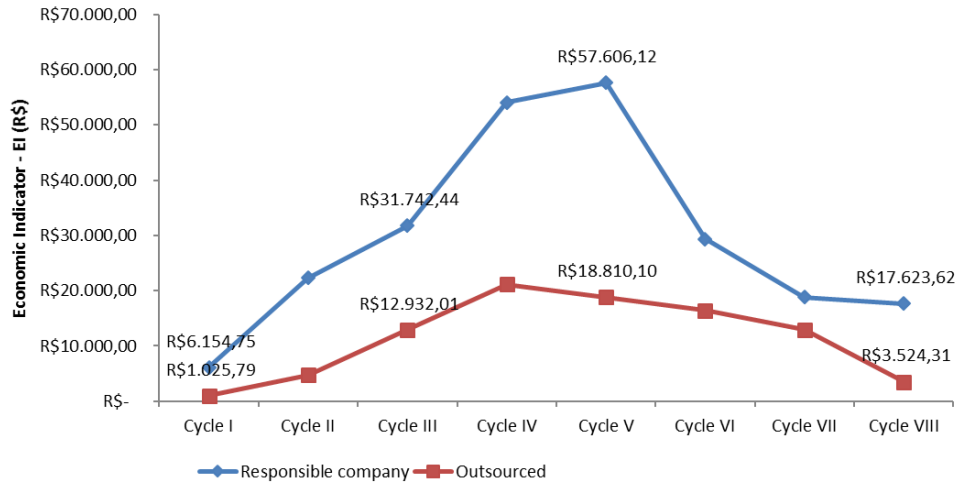
Lima et al. (2021) performed a similar methodology in a construction site with on-site construction process and raised the most frequent normative deviations:

- Risk of employees, materials and equipment falling;
- Debris obstructing passages and posing a landslide risk;
- Materials stored without meeting the requirements of safety standards;
- Employees not using PPE;
- Machinery and equipment without the safety devices.

Thus, regulatory irregularities concerning site organization, storage of inputs and equipment without safety devices, are indeed more difficult to appear in precast concrete works. However, issues related to fall protection and employees not using PPE are present both in on-site and precast concrete works.

The Qualitative Indicator presented above, through the graphs in Figures 8 and 9, pointed out the main aspects found in the work that contributed to the increase of operational risks of the construction. It should be noted that such irregularities are subject to fines, in case of inspection by the responsible Brazilian agency. In this context, the Economic Indicator shown in the graph of Figure 10 reflects the financial liability in fines that the company could pay in the event of a fine. It should be noted that this value is obtained from the tables of gradation of fines established by NR 28 - Inspections and Penalties.

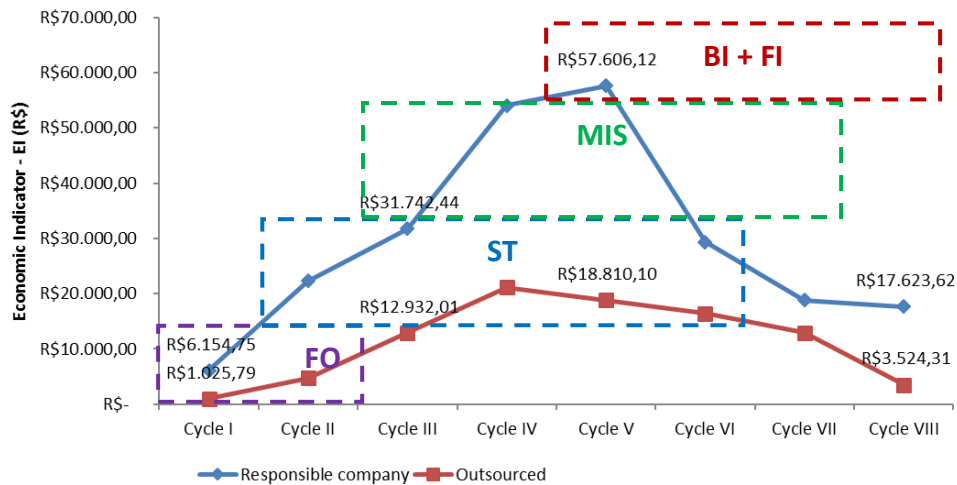
Figure 10 - Economic Indicator Responsible Company x Outsourced Companies.



Source: NSHT (2018).

In the same way as was done in Figure 7, Figure 11 indicates the phases of the work during the EI values over the safety audit cycles.

Figure 11 - Economic Indicator combined with construction phases.



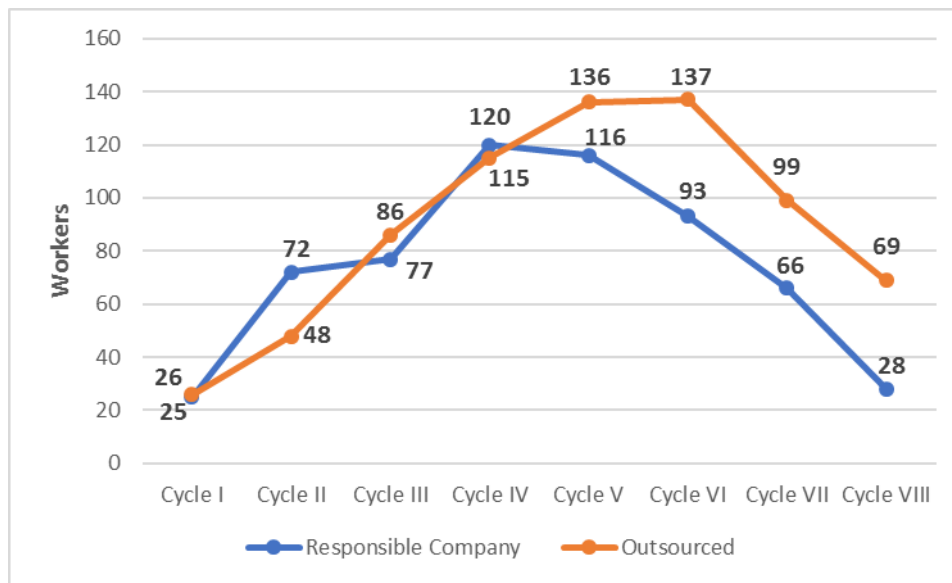
Source: Adapted from NSHT (2018).

It is possible to see that the liability of the Responsible Company (RC) is directly proportional to the liability of the outsourced companies. This situation is justified by the proportional number of employees of the RC and third parties in all phases of the work. It is possible to verify that, as well as the SIR curve in the IQt, from Cycle I to Cycle V there was a growth in the Economic Indicator, both of the RC and the contractors, with the highlight for a more accentuated growth of the RC.

From Cycle V onwards, there was a tendency for the indicator to decrease, both for the RC and the outsourced companies. In view of the above, it is possible to perceive a. Because as the company develops its safety management throughout the work and the amount of activities and employees begin to decrease, it is natural a trend of improvement of the work in relation to compliance with labor laws (Dezan, 2017).

With regard to the number of employees involved in the construction work, according to Figure 12, the RC only presented a higher number of employees than the outsourced employees in Cycles II and IV. Confirming the important role of outsourced employees in the EI data.

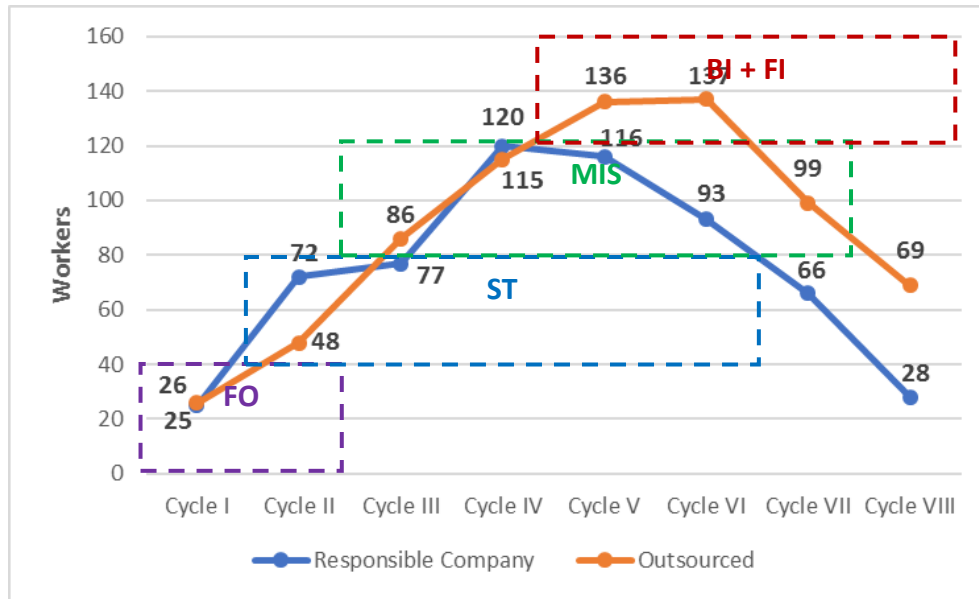
Figure 12 - Evolution of the workforce on site.



Source: NSHT (2018).

The more service fronts are opened at the construction site, it is natural that more workers are involved in the work (Freitas et al., 2021). Figure 13 shows that as new stages were starting and new service fronts were opening, the total workforce on the site followed this increase in the number of activities to be performed at the site. Just like the graphs in Figures 7 and 11, the highest values occurred in Cycles IV and V, with 235 and 252 workers in total, respectively. Confirming the influence of the number of workers in the occurrence of non-conformities cited by Soares Júnior et al. (2021).

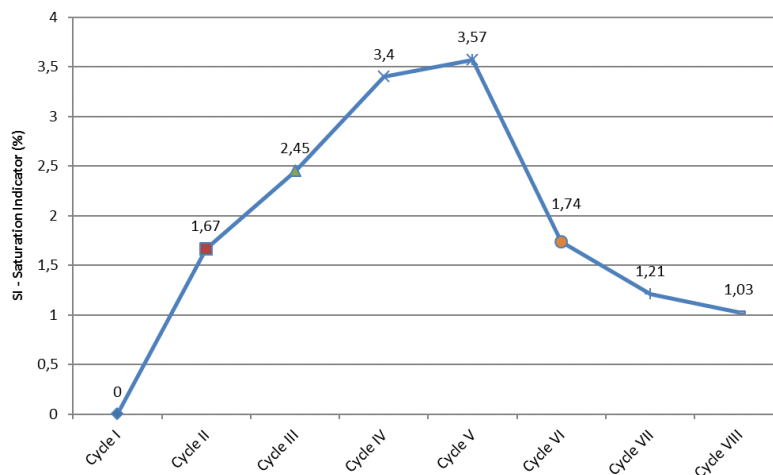
Figure 13 - Evolution of workforce combined with the phases of the project.



Source: Adapted from NSHT (2018).

The Qualitative and Economic Indicators shown above present an overview of the work in relation to the requirements inspected by the Ministry of Labor. It is noteworthy that situations that offer risk to the lives of workers, besides being an item with high liability of fines, also causes stoppages, embargoes and interdictions and can cause high economic losses (Fernandes et al., 2021). Based on this information, the Saturation Indicator presented in Figure 14 represents the number of SIR found, throughout the audit cycles, for a group of 100 workers.

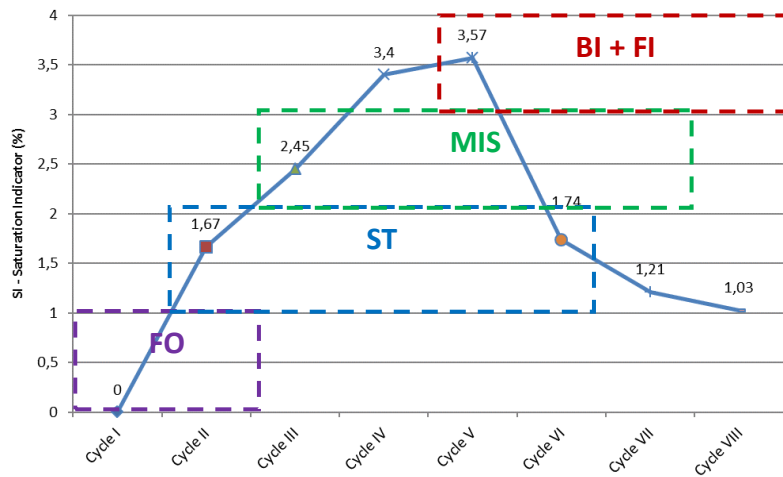
Figure 14 - Saturation Indicator.



Source: NSHT (2018).

Similarly to previous analyses, Figure 15 shows the grouping of information between the Saturation Indicator (SI) and the evolution of the construction phases.

Figure 15 - Saturation indicator combined with the stages of construction.



Source: Adapted from NSHT (2018).

According to Figure 15, it is possible to see that there was an oscillation during the construction period, as well as the curve of the SIR in the IQT. Until Cycle V there was an increase in the saturation indicator, corresponding to the peak of 3.57 SIR/100 workers, this shows that the conditions with potential to cause serious and fatal accidents (SIR) increased until that month. From September on, a decrease in the saturation index was observed, consequently, the number of SIRs decreased, causing a lower potential of serious and fatal accidents, reaching 1.03 SIR/100 workers in December.









Therefore, the charts of the Economic and Saturation Indicators (Figures 11 and 15) followed the behavior of the Quantitative Indicator of Non-Conformities, especially the SIR curve (Figure 7). Indicating that the number of regulatory deviations directly impacts the performance of all indicators of occupational safety, especially those related to situations of serious and imminent risk.





3.2 Cost x benefit analysis of risk control

According to J. Lee et al. (2020), the purpose of standards is to accommodate the changing environmental and social demand around a company. López-Alonso et al. (2013), showed that several studies have analyzed the economic aspect of health and safety at work and some have shown that employers do not consider that investing in safety is financially profitable; in other words, the costs associated with accidents at work are not considered so high that the company needs to invest in health and safety with the sole purpose of avoiding these costs.

Specific changes were made at the site in order to neutralize the risk conditions and comply with the requirements pointed out by the systematic OHS audit reports. To exemplify, Table 2 shows some of the organizational corrections made throughout the audit cycles.

Table 2 - Savings gained through security investments.

Non-conformitys	BEFORE	AFTER
Switchboards without signalling and safety interlocks		
Cutting materials without a suitable workbench		
Places with risk of falling without collective safeguards		
Working under the action of bad weather		
Scaffolding not in accordance with the projects		

Low wiring subject to mechanical impacts		
Gas cylinders and flammable materials without adequate place for storage		

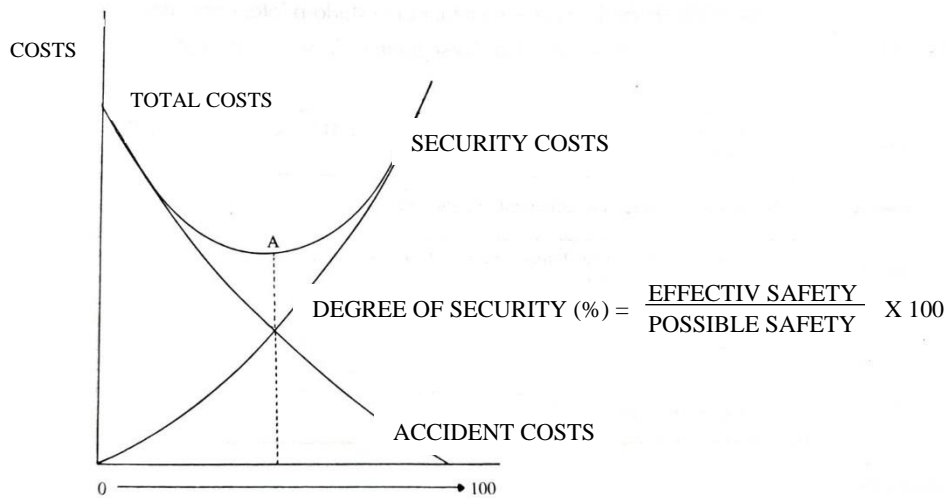
Source: Adapted from NSHT (2018).

The operational measures presented in Table 2 prevent the company from being fined in the event of an infraction notice. Analyzing each correction implemented according to Table 1, the company needed to disburse a total amount of R\$ 2,011.47. If it were to receive labour fines for the non-conformities raised, it would pay the amount of R\$ 32,216.00, according to the regulatory standard on Inspection and Penalties (NR-28, 2020). Therefore, the cost of safety corresponds to 6.24% of the capital exposed in fines.

It is noticed that the company obtained savings of 96.2% of the amount it would pay in case of a fine from the responsible inspection agencies. Implementing organizational measures in the production process of civil construction companies brings economic benefits for them (Fernandes et al., 2021). Thus, the data indicate that for every dollar invested in safety control measures, companies developing a work similar to the one analyzed in this work, avoid paying another 16 dollars in fines related to inspections by regulatory agencies. That is, in commercial constructions with precast concrete structure, for each unit amount invested in safety measures, the protection against possible financial liabilities of fines is 16 times higher.

Then, the results revealed that rules and regulations were a significant moderator of the effects related to control within an organization. Therefore, as well as studies by Adeleke et al. (2017), it was proven that organizational interventions based on safety legislations caused companies to considerably reduce the occurrence of risks in their constructions. The graph in Figure 17 shows the importance of investment in safety.

Figure 17 - Cost-benefit analysis of safety.



Source: Miguel (2014).

Analyzing the graph in Figure 17, one notices that as the costs with preventive safety measures increase, the curve with total accident costs decreases. Thus, looking at the economic criterion, when the degree of safety of the enterprise improves, the company is obtaining financial return. It can be concluded that investing in safety generates a cost-benefit for the company, employees and the country, being of utmost importance in the construction sector or in any sector (Almeida, 2018).

4. Final Considerations

Analyzing the graphs of safety indicators and the one referring to the number of workers on site, we saw that the number of normative deviations directly impacts the performance of all indicators of occupational safety, especially the SIR curve. Thus, we conclude that during the period when activities of Structure (ST), Masonry and Internal Sealing (MIS), Building Installations and Finishing (BI+FI) are performed, is where we find the peak values in the indicators and number of workers on site. Therefore, this is the critical moment for work safety in commercial precast concrete construction sites.

Analyzing the financial point of view, it was found that investments aimed at improving the degree of safety of the work have as a direct consequence the protection of capital subject to pay labor fines. In this work, it was shown that each unit value invested in safety control measures, the protection with financial liabilities of fines is 16 times higher. Thus, every cost aimed at adapting the working conditions of employees reflects positively for the accounting management of civil construction works.

Organizational measures of safety at work have low implementation cost. For the present case, such investment corresponded to 6.45% of the capital exposed in fines, without considering direct and indirect costs due to work accidents.

Given the information presented, it is possible to verify the improvement in OHS performance of the work. Such improvement reflects directly not only in the maintenance of the production process, avoiding losses and unwanted downtime, but also in maintaining the physical integrity and health of all workers on site. The results also propose that the organizational interventions have the consequence of reducing the occurrence of risk in construction projects.

Finally, it is important that further studies analyzing the performance of safety systems in the construction industry be conducted so that they are increasingly implemented in the industry. And it is recommended for future work, cost-benefit analyses of the implementation of organizational measures in other types of construction for the constant advancement of the sector in relation to occupational safety.

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