

## The use of prevention through design as a management tool: a systematic review

A utilização da prevenção através do projeto como ferramenta de gestão: uma revisão sistemática

El uso de la prevención a través del proyecto como herramienta de gestión: una revisión sistemática

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### Abstract

The Prevention Through Design – PtD can be used as a project management and coordination tool, which aims to reduce the number of accidents in civil construction. Therefore, it is necessary to understand the occupational health and safety scenario to establish preventive control measures. In this sense, it is important that prevention is effective, whether in the concept design or execution phase. Thus, this study aims to investigate works that have addressed the PtD, seeking to analyze its usability as a management tool, also pointing out its positive and negative aspects. The methodology followed the guidelines of the Preferred Report Items for Systematic Reviews and Meta-Analysis (PRISMA), using keywords in agreement with the Boolean descriptor “AND” such as: “prevention through design”, “management”, “construction”, “occupational safety”, “design” and “design for safety”. Initially, 624 articles were found, but with the application of filters, 30 articles remained for full reading. After the complete reading, 14 articles were included for detailed analysis. It was observed that in underdeveloped countries, the tool is not applied. However, in more developed countries the Prevention Through Design – PtD tool is highly requested for accident prevention. Finally, it is understood that there is a cost linked to the accident management tool, however it is seen that when it is implemented, the number of accidents is reduced, which makes the tool effective.

**Keywords:** Prevention through design; Project management; Risks; Civil construction.

### Resumo

O Prevention Through Design – PtD, também conhecido como Prevenção através do Projeto, pode ser utilizado como ferramenta de gestão e coordenação de projetos, que visa colaborar na redução do número de acidentes na construção civil. Portanto, é necessário compreender o cenário da segurança e saúde do trabalho para estabelecer medidas de controle preventivo. Neste sentido, é importante que a prevenção possua efetividade, seja na fase de concepção do projeto ou de execução. Dessa forma, o presente estudo tem como objetivo investigar trabalhos que tenham abordado

o PtD, buscando analisar sua usabilidade como ferramenta de gestão, pontuando também seus aspectos positivos e negativos. A metodologia seguiu as orientações dos Itens de Relatório Preferidos para Revisões Sistemáticas e Meta-Análises (PRISMA), utilizando palavras-chave em concordância com o descritor booleano “AND” como: “prevention through design”, “management”, “construction”, “occupational safety”, “design” e “design for safety”. Inicialmente foram encontrados 624 artigos, porém com a aplicação dos filtros restaram 30 artigos para leitura completa. Após a leitura completa, 14 artigos foram incluídos para análise detalhada. Foi observado que em países subdesenvolvidos, a ferramenta não é aplicada. No entanto, em países mais desenvolvidos a ferramenta Prevention Through Design – PtD, é bastante requisitada para prevenção de acidentes. Por fim, entende-se que existe um custo atrelado a ferramenta de gestão de acidentes, no entanto é visto que quando existe a sua implementação, o número de acidentes sofre redução, o que torna a ferramenta eficaz.

**Palavras-chave:** Prevenção através do projeto; Gerenciamento de projeto; Riscos; Construção civil.

### Resumen

El Prevention Through Design – PtD, también conocido como Prevención a través del diseño, se puede utilizar como una herramienta de gestión y coordinación de proyectos, cuyo objetivo es colaborar en la reducción del número de accidentes en la construcción civil. Por lo tanto, es necesario comprender el escenario de seguridad y salud en el trabajo para establecer medidas de control preventivo. En este sentido, es importante que la prevención sea efectiva, ya sea en la fase de diseño o ejecución del proyecto. Así, el presente estudio tiene como objetivo investigar trabajos que hayan abordado el PtD, buscando analizar su usabilidad como herramienta de gestión, puntuando también sus aspectos positivos y negativos. La metodología siguió los lineamientos de Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA), utilizando palabras clave de acuerdo con el descriptor booleano “AND” tales como: “prevention through design”, “management”, “construction”, “occupational safety”, “design” e “design for safety”. Inicialmente se encontraron 624 artículos, pero con la aplicación de filtros quedaron 30 artículos para lectura completa. Después de la lectura completa, se incluyeron 14 artículos para un análisis detallado. Se observó que en los países subdesarrollados no se aplica la herramienta. Sin embargo, en los países más desarrollados, la herramienta Prevención a través del diseño – PtD es muy solicitada para la prevención de accidentes. Finalmente, se entiende que hay un costo ligado a la herramienta de gestión de accidentes, sin embargo se ve que cuando se implementa se reduce el número de accidentes, lo que hace que la herramienta sea efectiva.

**Palabras clave:** Prevención a través del proyecto; Gestión de proyectos; Riesgos; Construcción civil.

## 1. Introduction

Occupational accidents have been present in the construction industry for a long time. Although the rates have decreased over the years, the sector still has risks that need control, considering that civil construction is among the five sectors in which most work accidents occur in Brazil (Dataprev, 2016). Still, it is believed that the main causes of work accidents are related to behavioral aspects of the worker, failures and supervision, lack of analysis and risks, and non-compliance with legislation (CBIC, 2017).

One of the project management and coordination tools to reduce the number of accidents is Prevention through Design – PtD. According to NIOSH - National Institute for Occupational Safety and Health (2015), PtD is defined as addressing the need for safety and health in the design process to eliminate or minimize work-related risks and hazards associated with the construction, manufacture, use, maintenance and disposal of facilities, materials and equipment. PtD is characterized as a passive safety measure, being preferable because it does not require worker intervention and works regardless of the occurrence of unforeseen events (Driscoll et al., 2008).

In research conducted by Vasconcelos (2013), reports of 1328 serious and fatal occupational accidents in Brazil, Canada, the United States, Portugal and Singapore were collected and analyzed and it was found that 60.8% of the accidents could have been avoided through the project. From this total of analyzed accidents, the author showed that 35.1% could be avoided through conception projects, 27.2% of accidents could be avoided through execution projects, and 9.6% of accidents could be avoided through equipment projects.

In this context, it can be said that the benefits of using PtD are characterized in addition to preventing injuries and diseases, improving the company's productivity and the management of production and operating costs, being compliant with the legislation and reducing costs in general (Vasconcelos, 2013). The minimization of costs entails economic benefits, since

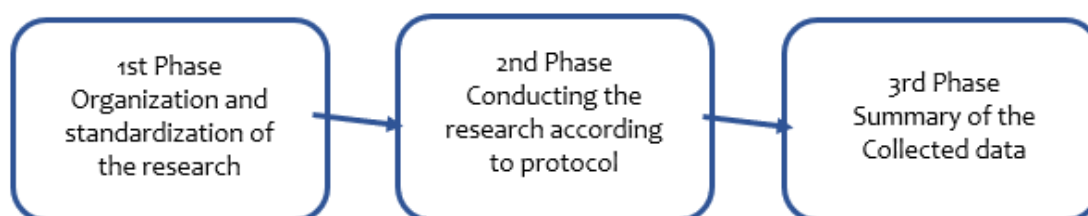
expenses with worker injuries are dispensed with, the probability of embargoes and interdictions is reduced, and improvisations are eliminated.

Therefore, the objective of this research is to investigate the techniques that used prevention through design, seeking to analyze its usability as a management tool, where the positive and negative aspects will also be presented.

## 2. Methodology

Systematic reviews and meta-analyses are essential tools to summarize evidence accurately and reliably, because they consist of the recognition and detailing of the studies found, the systematic evaluation of metadata according to their protocol and the succinct collection of coherent information from the researched universe (Liberati et al., 2009). For Munzlinger, Narcizo and De Queiroz (2012), the systematic review is an activity of sequential execution that has a final objective, having its steps presented in Figure 1.

**Figure 1** - Phases of a systematic review.



Source: adapted from Munzlinger, Narcizo, and De Queiroz (2012).

To plan the present research, relative to the definition of the objective, of the aspects to be addressed and of the keywords, some studies referring to the theme were first analyzed. According to the characteristics of the analyzed studies, Table 1 was created with the summary of the research protocol.

**Table 1** – Research protocol.

Item	Content
<b>Objectives</b>	Investigate the techniques that used the PtD, seeking to analyze its usability as a management tool, relevance, and to identify positive and negative aspects.
<b>Results</b>	Find existing case studies and/or research using the PtD tool and what barriers prevent the full use of this tool.
<b>Keywords</b>	“prevention through design”; “management”; “occupational safety”; “design”; “construction”; “design for safety”; “management”.
<b>Idioms</b>	English and Portuguese
<b>Database</b>	Scopus
<b>Inclusion criteria</b>	Publication time: 2016-2021; Languages: English, Portuguese; Knowledge areas: Civil Construction; Approach: The use of Prevention through Design - PtD as a Management tool in Civil Construction.
<b>Exclusion criteria</b>	Approach: Articles that addressed risk prevention tools other than PtD
<b>Research questions</b>	* What are the prospects for using prevention through the project as a management tool? * What are the main difficulties and/or barriers faced to implement the prevention tool through the project?

Source: Authors.

After the identification and definition of the keywords in the primary study, literature searches were conducted to find relevant journal documents regarding the applicability of Prevention Through Design - PtD in civil construction. The literature

exploratory methodology used to conduct this research followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Liberati et al., 2009). The articles found were searched in the Scopus database. The keywords defined in English, for reasons of comprehensiveness, were: "prevention through design"; "management"; "occupational safety"; "design"; "design for safety"; "management"; "construction".

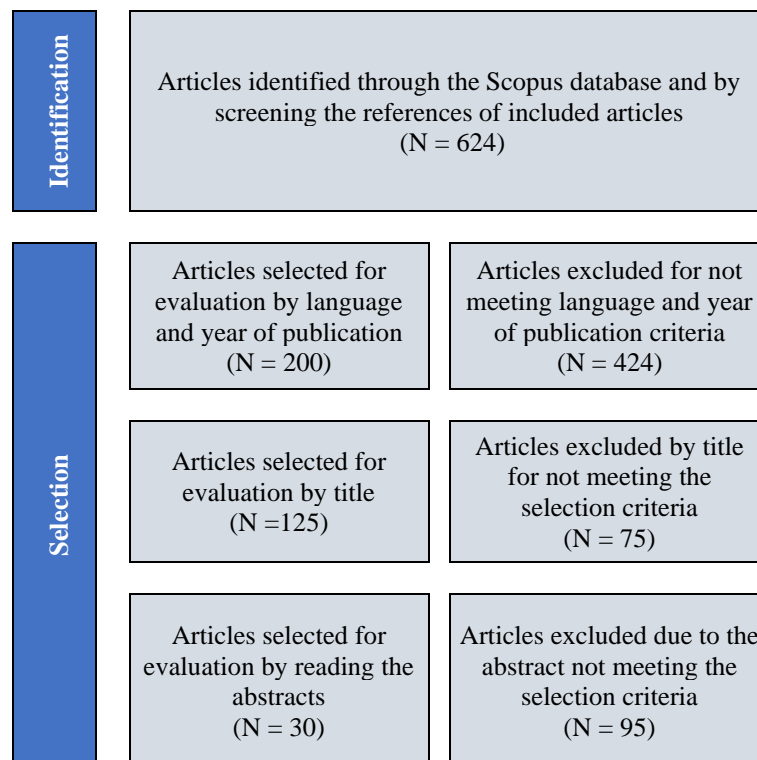
The inclusion criteria included articles published in the last five years, in English, and that addressed the use of Prevention through Design - PtD as a management tool in Civil Construction. As exclusion criteria, articles that addressed risk prevention tools other than PtD were excluded.

The selection process was illustrated through a flowchart, showing the article selection steps. Subsequently, a qualitative analysis of the articles was performed, aiming to classify the articles included in the review in order to show information such as the methods applied, type of analysis addressed and other characteristics of the research.

### 3. Results

At first, with the combination of pre-established keywords, 624 articles were found, distributed in the Scopus database. Continuing the selection process, the criteria of year (2016-2021) and language (English) were inserted in the search, resulting in the number of articles reduced to 200. Subsequently, the selection was made by reading the titles (75 excluded), leaving 125 articles. Next, the abstracts were read (95 excluded) and the studies were fully read for inclusion (16 excluded). Finally, with the adopted criteria, 14 articles were included for analysis in this review. The article selection process is illustrated in the flowchart in Table 2.

**Table 2** – Research flowchart.





**Table 3 - Characterization of research for the qualitative analysis.**

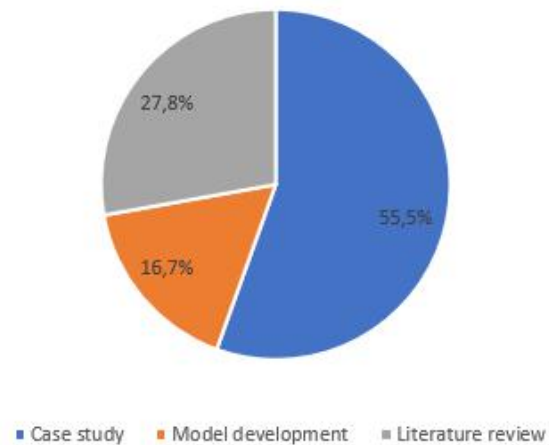
N.	Author (year)	Methodology	Analysis	Aspects	Type of Study	Relevance
1	Sun and Liao (2019)	Development of model from questionnaires and checklists. Case study: elevator design and evaluation of simulations performed.	Quantitative and Qualitative	-	Model development and case study	The application of the proposed system dynamics model served to increase the safety of a system by design, providing insight into PtD and its impact on working conditions.
2	Toole, Asce and Erger (2018)	Literature review	Qualitative	Cost reduction, increased productivity and quality. Companies provide only the design service, not taking responsibility for construction, running the risk of lawsuits. Lack of designers specialized in PtD.	Literature review	The study addressed the use of PtD and its positive and negative aspects for companies. The fact that PtD has been required for more than two decades in Europe and is encouraged by NIOSH suggests that PtD achieves the expected benefits.
3	Ibrahim, Belayutham and Mohammad (2021)	Case study using a structured questionnaire and semi-structured interviews. Data were collected and analyzed using descriptive statistics and data coding.	Quantitative and Qualitative	-	Case study	OHS education is limited and the level of PtD education in civil engineering programs is almost non-existent in Malaysia. Therefore, the study shows that institutional dynamism is needed in the context of incorporating OHS and PtD issues.
4	Ibrahim et al. (2019)	Pragmatic methodological approach by questionnaire and discussion forum through workshop. Data analysis was performed with statistics, specifically Fisher's Test and ANOVA.	Quantitative and Qualitative	-	Case study	Knowledge of PtD needs to be improved to its implementation. This requires the integration of PtD discipline in higher education, continuing education and educational resources that can facilitate its diffusion in the construction industry.
5	Manu et al. (2018)	Structured questionnaire and use of descriptive statistics for data treatment.	Quantitative and Qualitative	The literature highlights the importance of PtD knowledge, education, and training for implementation in OSH, yet many designers in developing countries do not use PtD.	Case study	PtD practice among architects is low, despite a high level of knowledge of the DfS concept. In addition, engagement in PtD training is low, despite high interest in undertaking PtD professional development training.
6	Jin, Gambate and Liu (2019)	Developing a model in BIM, conducting a case study to test and verify the proposed method.	Quantitative and Qualitative	Identification of activities and risk areas. A limitation of the study is the need for validation of the tool.	Model development and case study	The innovative proposed tool helps designers assess construction risks and has the potential to incorporate the higher levels of hierarchy of risk controls.
7	Toh, Goh and Guo (2016)	Survey questionnaire and interviews. Statistical methods used for data analysis.	Quantitative and Qualitative	Identifying the hazards at the source and during the design phase. The barriers are lack of resources and knowledge on the subject and also lack of commitment.	Case study	The implementation of PtD can improve training programs, establish a community with good PtD practices, and develop courses at third-party institutions.
8	Goh and Chua (2016)	Survey questionnaires for engineers and interviews with construction professionals.	Quantitative and Qualitative	Lack of security experience, lack of understanding of construction processes, typical contract terms, and professional fees are some barriers.	Case study	Contractual agreements between clients and designers and the effectiveness of different approaches to the DfS process is necessary to ensure its implementation.
9	Fagnoli and Lombardi (2020)	Systematic review of how BIM improves safety in construction	Qualitative	There is growing interest in this field of research in recent years. However, few articles have studied BIM-based tools for training activities, and there have been a small number of articles dealing with worker behavior	Literature review	Provide an overview on the status quo of BIM applications to increase occupational safety on construction sites, and also in eliciting research trends and emerging themes in the last decade of literature.

N.	Author (year)	Methodology	Analysis	Aspects	Type of Study	Relevance
10	Manu et al. (2019)	The study employed three iterations of expert focus group discussion and a subsequent three-round Delphi technique accompanied by the application of analytical voting hierarchy process.	Quantitative and Qualitative	It reveals the superiority of the competency category which features prominently the DfOSH experience, knowledge and skill of the design team and the strategy category which features prominently top management commitment to DfOSH.	Case study	The results should allow design firms and other industry stakeholders (such as the clients who nominated them) to better understand the DfOSH capability of designers. In addition, design firms should be able to prioritize efforts/investments to increase their DfOSH capability.
11	Lee, Kim and Choi (2020)	Literature review and collection of site safety management cases and subsequent data analysis. Development of risk assessment using BIM.	Quantitative and Qualitative	The content of the design review guidelines for safety is insufficient and cannot be applied in practice because legislators neglected to consider existing safety management. According to South Korea lacks clear criteria for the domestic risk rating process.	Case study	Items related to hazard recognition were defined based on foreign cases in this study, and used for evaluations in design for safety. A BIM-based risk factor recognition method, hazard extraction, and the risk rating estimation method for the extracted items were proposed by the study.
12	Soh, Jeong and Jeong (2020)	Literature review, structured questionnaire and calculation and analysis of weighting factors	Quantitative and Qualitative	In South Korea, construction project professionals have no sense of responsibility during the DfS process.	Literature review and case study	Improvements that should be made to PtD in South Korea from the perspective of project and construction workers are highlighted. The results can be used as a basis for improving measures of LTP.
13	Izam et al. (2020)	Systematic review of studies on PtD in the construction domain.	Qualitative	They provide insights that relate designers and elements of PtD, however the attributes listed in the study are limited for industries other than the construction sector.	Literature review	The study provides a valuable platform for designers to promote and adopt prevention culture (e.g., reduce OSH risk in the workplace) through design activities, subsequently stimulating better safety performance.
14	Adaku, Ankrah and Ndekugri (2020)	Systematic review on designer attributes and model development.	Qualitative	Provides a basis for future research to test designer attributes, however models have not been validated and indicators need to be specified	Literature review and model development	The models can provide guidelines for projects, where clients should think about what skills, knowledge attributes, and experience they should expect from prospective designers in relation to their engagements. Similarly, the templates can serve as a guide for designers with regard to developing PtD competencies

Source: Authors.

By analyzing Table 3, it can be seen that 55.5% of the types of research studies were case studies, with the use of field methods, as shown in Figure 3. 27.8% were found to be literature review on PtD, its application and incorporation in academia. Another 16.7% were model development related to PtD development in BIM and identification of design factors, providing insight for the application of prevention through design in future studies.

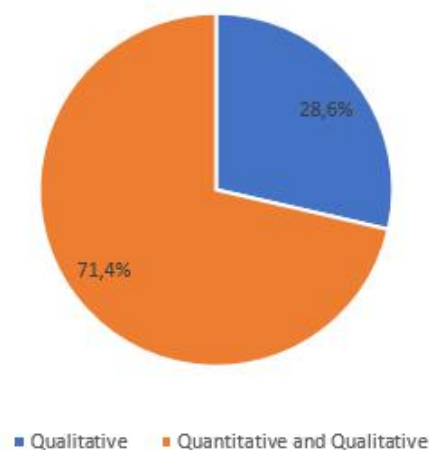
**Figure 3** – Research object of study.



Source: Authors.

It was also noted that 28.6% of the studies performed qualitative analysis. Another 71.4% performed both quantitative and qualitative analysis. There were no studies that used only quantitative analysis (Figure 4).

**Figure 4** – Research type of analysis.



Source: Authors.

The methodological procedures used listed the development of models from structured questionnaires and interviews conducted with professionals. The use of these techniques was also applied to case studies, in which some statistical methods were used so that the results could be achieved. Other procedures were characterized by the use of literary and systematic reviews. Regarding the perspectives of the research, it was sought to list the positive and negative points of the studies, highlighting the issue of costs, productivity, resources and responsibilities linked to prevention through the project. Finally, to characterize the relevance of the studies, some points were identified in the research, linked to the knowledge of professionals in relation to PtD, its impact on working conditions, the practice of this tool and its implementation.

#### 4. Discussion

Prevention through design, when well employed, has its due importance due to its accident reduction potential. In terms of occupational safety, the PtD helps to avoid undesirable events not only in the construction site, but also in the conceptual phase, since well configured projects dispense future improvisations, often found after such events.



It is highlighted in 14.3% of the researches the need for the incorporation and integration of prevention through design in civil engineering and architecture programs, in order to facilitate the practice and its diffusion in the construction industry (Ibrahim; Belayutham; Mohammad, 2021; Ibrahim et al., 2019). Moreover, the authors Hossain et al. (2018) claim that in fact, universities in some countries do not address occupational safety in undergraduate architecture and engineering courses and that a large part of the professionals working in the design area also lack knowledge in the construction process, which is necessary to implement PtD efficiently.

It is inferred that the trend of publications in the area is to increase over the years, since the search for accident reduction is a common factor among professionals in view of the incalculable social and economic impacts. Toole, Asce and Erger (2018) comment that in Europe PtD has been required for more than two decades in order to reduce such impacts, in addition to bringing benefits to the construction industry. Some of these benefits are listed by 21.4% of the studies, being directly linked to the minimization of costs for companies, since expenses with worker injuries are dispensed with, the probability of embargo and interdiction is reduced and improvisations are eliminated; increased productivity and the ease of identification of activities and risk areas by professionals (Toole; Asce; Erger, 2018; Jin; Gambatese; Liu, 2019; Toh; Goh; Guo 2016).

With regard to methodological procedures, 57.1% of the research cited the use of structured questionnaires, interviews, and focus groups. The use of the mentioned techniques sought the opinion of professionals and collaborators about the application and use of PtD in the construction sector, aiming its better incorporation in the market (Sun; Liao, 2019; Ibrahim; Belayutham; Mohammad, 2021; Ibrahim et al, 2019; Manu et al., 2019; Jin; Gambatese; Liu, 2019; Toh; Goh; Guo, 2017; Fagnoli; Lombardi, 2020; Soh; Jeong; Jeong, 2020).

On the other hand, another 35.7% of the papers were linked to literature reviews, which aimed to analyze the aspects of PtD, from the investigation of research that addressed the use of the tool to improve construction safety. In addition, from the reviews it was possible to provide insights that relate designers and the elements of the tool, promoting prevention culture (Toole; Asce; Erger, 2018; Fagnoli; Lombardi, 2020; Soh; Jeong; Jeong, 2020; Izam et al., 2020; Adaku; Ankrah; Ndekugri, 2020).

Also, 21.4% of the included articles had as methodological procedures the development of models, some built through statistical methods, to delineate the interaction between the workplace, cognition and workers' behavior, aiming at a better identification of risks through design, during the decision-making process. Other models created were intended to serve as a basis for future research that is linked to empirical tests regarding attributes of designer competence. Otherwise, the importance of validating these models is stressed, to ensure their effectiveness of use (Sun; Liao, 2019; Jin; Gambatese; Liu 2019; Adaku; Ankrah; Ndekugri, 2020).

In contrast, some negative points are listed in the research. In 14.3% of the papers, some barriers to the implementation of PtD in construction are mentioned, linked to the lack of resources by companies, and the little knowledge and lack of commitment of designers (Toh; Goh; Guo, 2016; Goh; Chua, 2016). Finally, similarly, another 14.3% address that companies and professionals only provide the design service, and do not take responsibility for the construction (Toole; Asce; Erger, 2018; Soh; Jeong; Jeong, 2020).

It is known that there is some fear on the part of designers regarding the legal responsibilities, for fear of greater obligations in their function. In general, the lack of skills in designing to reduce health and safety risks often makes professionals feel uncomfortable (Toole; Gambatese, 2008). However, such fear is not observed in countries where the responsibility for safety is shared with designers, as is the example of some countries in the European Union. For Vasconcelos (2013), in these countries, the difficulties are linked to the practical part, since professionals have difficulty in knowing how their project can ensure the worker's health, as well as recognize the risks to modify the projects, since the materials available

for consultation are reduced.

## 5. Conclusions

This study shows that Prevention Through Design has the potential to reduce undesirable events at construction sites and in the conceptual phase. As seen, in Europe, PtD has been required for over two decades in order to reduce these impacts and bring benefits to the construction industry. These benefits were addressed in part of the studies analyzed, being related to the minimization of costs for companies, with the reduction of expenses with workers' injuries, reduction of the probability of embargo and interdiction, and increase of productivity in the activities.

However, some of the studies mention some challenges that hinder the implementation of TOD in construction. Among them are the lack of resources by the companies, little knowledge, lack of ability and lack of commitment of the designers. It is noticeable, however, that in European Union countries, designers are less afraid to design for risk reduction because of the shared responsibility for safety. In general, through the studies in which they were presented, one can see the great importance of integrating the Prevention through Design - PtD tool in every construction process.

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