

## Risk Assessment of Accidents in the Conception Phase of Engineering Projects

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**Abstract.** This paper presents the result of a survey conducted with specialists to show the importance of mitigating project engineering inadequacies that can lead to severe labor accidents and also shows an example of application of risk assessment in the construction of a bicycle lane project. This topic is quite important because some serious accidents have occurred in the execution phase of a project engineering, caused by project inadequacies. Lives have been lost due to project engineering inefficiencies, and this paper intends to alert of the criticality of this issue, which is only addressed when a major accident occurs. The objective of this paper is to show the difficulties faced by many project managers and engineers generally when they have to adapt the project engineering to the existing safety work norms in the final execution phase, once the initial phase of the project engineering was not well performed, by giving practical examples that have occurred in the industry. As a methodological approach, a project management checklist (PMC), is proposed as a key element of this methodology to be customized to each engineering project together with the probability and impact matrix to categorize the level of each risk as high, extremely high or medium. The study also includes a broad research of the literature on the theme as well as two field studies, one with project management and labor safety engineering professionals and another with various companies to know what they thought about this topic and the measures they are taking to eliminate serious accidents in their businesses. The study demonstrates that risk assessment can identify serious accident risks in the conception phase of projects and basic engineering. This paper provides responses to an important research question. As a result, the method revealed that 60% of the companies researched are only concerned with potential serious accident risks in the execution phase of the projects, probably due to the high costs of experienced manpower in the initial phase when the risks are somehow hidden since the project hasn't started yet. The study recommends Prevention through Design (PtD), i.e. It is of extreme importance to identify risks in the conception phase of projects and basic engineering, prevent occupational injuries and control them during work operations. As a final recommendation, risk assessment should be considered mandatory by the Project Engineering Management Organization and the Engineering and Architecture Councils and part of all the construction inspections made by the public and private engineering companies in Brazil and in other countries.

**Keywords:** Conception Design Phase, Basic Project Engineering, Preliminary labor accident risk analysis, Prevention through Design (PtD)

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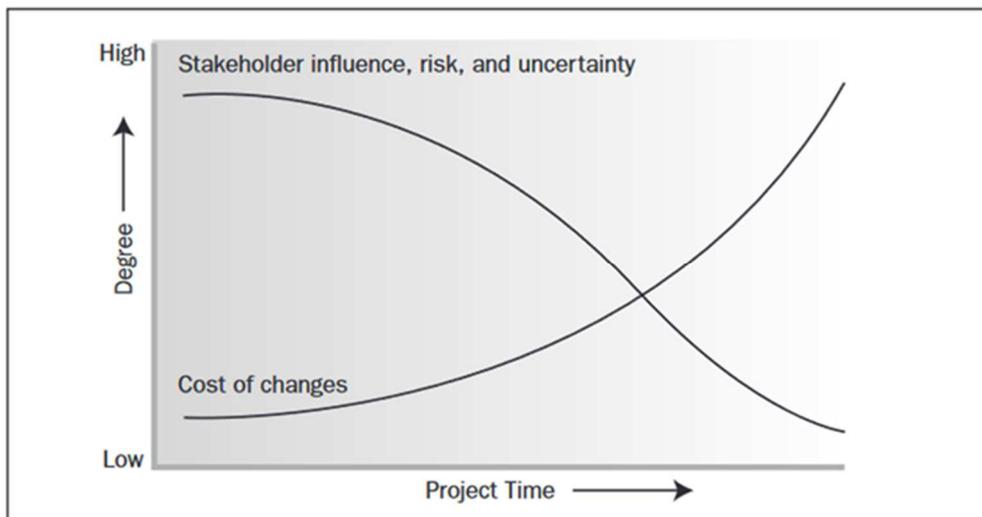
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## **Risk Assessment of Accidents in the Conception Phase of Engineering Projects**

### **1 Introduction**

The Risk Assessment of Accidents in the Conception Phase of Engineering Projects is key to ensure success in any project. Ahmad et al. (2019) recommend that an accident risk analysis be done early in the projects to eliminate accidents during execution. Gambatese et al. (2008) cited that in the United States out of a sample of 224 fatal accidents, 42% had some sort of cause and effect relation with the initial development phase of their projects engineering. Banda et al. (2019) claims that, in order to make it as safe as possible, it was crucial to do the risk analysis in the initial phase of its autonomous vessel project specifically. According to Kletz and Amyotte (2010) the identification and understanding of risks comes before avoiding and reducing them. Vasconcelos and Barkokébas Junior (2015) also mention that the elimination of potential risks in the beginning of the project makes it more effective, cheaper, and more practical. According to Whittington et al. (1992) and Suraji et al. (2004), a significant proportion of injuries originate from decisions made during design. Furthermore, researchers have demonstrated that approximately 22% of all construction injuries and 42% of fatalities could have been prevented through adjustments made in design of a construction project (Behm, 2005; Atkinson and Westall, 2010). According to Kamardeen (2015) falls are a leading cause of workplace fatalities and serious injuries in Construction globally. They represent 30 – 50% of construction fatalities in developed nations. Prevention and control of falls are therefore an urgent necessity in construction. Embracing Prevention through Design (PtD) principles in design practices is recognized an effective way to eliminate fall hazards at source and can significantly reduce the number of fatalities in construction. According to Toole and Gambatese (2008) the proactive elimination of hazards must be done by designers during the conceptual and detailed design of a facility. The study demonstrates a practical method that was created to easily identify serious accident risks in the conception phase of projects and basic engineering, comprised by a checklist and a probability, and the impact matrix. Carter and Smith (2006) take into consideration of risks in terms of the probability of their occurrence and the severity of their consequences provides the general rationale behind safety risk assessments. Sanni-Anibire et al. (2020) uses a checklist to register the biggest risks in projects and calls attention to the importance of having a multidisciplinary team to do the accident risk analysis.

Kyeong Kim et al. (2020) employ a risk matrix to categorize risks in a process called HAZID, considering important to use it in the initial phase of a project to help to eliminate accidents. Khodeir and Nabawy (2019) utilize the checklist method to register risks in its case project. Pereira et al. (2015) approach the direct impact that accidents in the transformation industry has on productivity and highlights the importance of having an effective safety management system that enhances economic performance. They also presents a method of probabilistic analysis to identify system flaws that have direct impact on operational costs. None of the above-mentioned studies covered the Risk Assessment of Accidents in the Conception Phase of Engineering Projects. In order to fill this gap in the literature, this study includes a broad research of the literature on the theme as well as two field studies, one survey with 52 project management and labor safety engineering professionals and another one with various companies to know what they thought about this topic and the measures they are taking to eliminate serious accidents in their businesses. This paper presents the result of a survey conducted with specialists to show the importance of mitigating project engineering inadequacies that can lead to severe labor accidents. The survey shows that some serious accidents that occur in the execution phase of a Project Engineering are caused by project inadequacies. These accidents could be avoided if labor accident risks were regularly identified in the initial phases to guarantee that all of the technical labor safety norms and the best industry practices were enforced to eliminate the likelihood of serious accidents that can cause absence from work, disabilities and fatalities. López-Archillos et al. (2014) mention that there are many studies of Prevention through Design (PtD) which conclude that a large percentage of construction injuries could have been avoided or reduced if occupational safety had been considered in the design phase and during the project itself. According of Hinze and Wiegand (1992) several construction researchers argue that significant reductions in construction injury rates could be achieved by considering worker safety during the design of a project, not just during the construction phase. According to Walline (2014) in Australia, “Of the 210 identified workplace fatalities, 77 (37%) definitely or probably had design-related issues involved. Design contributes to at least 30% of work-related serious non fatal injuries”. Lives might have been lost due to Project Engineering inadequacies as well as the lack of Prevention through Design (PtD) initiatives, and this paper intends to alert the authorities, the organizations that govern international project management certifications and the engineering companies of the criticality of this issue, which is only addressed when a major accident occur. Some others authors have briefly discussed this theme in their articles.



**Figure 1 – Impact of variable Based on Project Time**

Source (PMBOK, 5th Edition, 2014)

According to the final field survey, Table 2, 60% of the surveyed companies said that they only control the risk of accidents at work during the project's execution phase, because it is very expensive to do risk control in the initial phases of the project and also because there is not a lot of data and documents to be analyzed. Figure 1 illustrates the idea that, the cost of changes and correcting errors, typically increases substantially as the Project approaches completion. Stakeholder influences, risk, and uncertainty, (as illustrate in Figure 1) are greatest at the start of the project. These factors decrease over the life of the project.

The study also presents an example of application of risk assessment in the construction of a bicycle lane project. The results from the literature review and from the field study provide responses to the three following research questions:

- 1- Are companies in general concerned with the identification of potential serious labor accident risks in the conception of projects and basic engineering?
- 2- What is the ideal methodology to identify potential serious labor accident risks in the conception of projects and basic engineering?
- 3- What is the importance of identifying potential serious labor accident risks in the conception of projects and basic engineering?

## 2. Objectives

The general objective of this study is to present the result of survey and a field study about the importance of risk assessment of Accidents in the Conception Phase of Engineering Projects and demonstrate a practical example of application of risk assessment in a specific project. The study

objective is also to show that risk assessment can reduce the levels of serious accidents in the industry and can be employed during the initial conception phases of projects and basic engineering with the involvement of the main stakeholders, addressing all the serious accident risks in the Projects Engineering as well as the answers to all of the identified and registered risks.

### 3 Methods

Besides the research in the literature, the study was conducted both quantitatively and qualitatively and 2 surveys were carried out. The objective of the initial one was to obtain information from 52 specialists, 100% received, in labor security and project management engineering and the objective of the final one was to demonstrate what some engineering and various business areas have actually been doing regarding the topic as well as their practical results. There were two different questionnaires for the studies, and they were elaborated using “google forms”. In order to show the practical application of risk assessment in a practical case, a checklist, Table 1, was created as a key element of this study to be customized to each Project Engineering together with the probability and consequence matrix, Figure 2, to categorize the level of each risk as high or extreme. A Project Management Checklist (PMC) and a Risk Matrix (RM) were applied to a bicycle lane project in the city of Rio de Janeiro in 2016 that caused two deaths when unexpected sea waves have destroyed it. Both the checklist (PMC), Table 1, and the risk matrix (RM), Figure 2, are used during a formal meeting with the project manager (PM), who is the leader, and the multidisciplinary team, which is part of the project team. It is important that the labor security engineer and the necessary technical specialist are always present. Sanni-Anibire et al. (2020) mention the need of the multidisciplinary team to do the Project Risk Analysis. The following steps are recommended for the risk identification meeting (RIM): The PM is nominated during the initiation phase (PMBOK, 5th edition, 2014); The PM assigns the team that will participate in the meeting (RIM). The RIM team elaborates the PMC (questions about the project that may reveal potential risks and serious labor accidents), Table 1; brainstorming techniques might be used (PMBOK, 5th edition, 2014, page 115). The RIM team uses the RM, Figure 2, to classify the most serious risks found in the project and inserts the results on the PMC, Table 1. The RIM team answers the questions on the PMC, Table 1, and analyses whether they were considered in the engineering project, highlighting the items that could present any serious accident risks. The RIM team elaborates an action plan with implementation deadlines of all the “no” answers on the PMC, Table 1. The RIM team rewrites the PMC, Table 1, in case all the answers were “yes”. If all the answers on the PMC are “yes”, the PMC should be rewritten because the questions probably are not reflecting all the potential serious accident risks of the engineering project.

The risks appointed in the questions, Table 1, are classified firstly in the risk matrix, Figure 2, as to their degree of extreme or high severity and the result is marked yes or no in the column referring to Likelihood x Consequence, in the check list, Table 1, and then an action plan is established for each risk.

**Table 1 – Check List**

Source: Author

Questions	Yes	No	Likelihood x Consequence (extreme or High) Yes or No	Action Plan in case No (x)
Did the project anticipate the reinforcement of the structure to withstand the surf of the sea in Leblon Beach?		x	Yes	Redesign the project to include the reinforcement in the structure. The project will only be approved if this item is accomplished.
Did the Project anticipate a communication route for bikers and pedestrians to block the path of the bicycle lane during storm surges in Leblon Beach?		x	Yes	Involve the municipal government to guarantee that the communication route is effective.

		Consequences →				
		A	B	C	D	E
Likelihood ↑	V	Medium 5	High 10	High 15	Extreme 20	Extreme 25
	IV	Medium 4	Medium 8	High 12	High 16	Extreme 20
	III	Low 3	Medium 6	Medium 9	High 12	Extreme 15
	II	Low 2	Low 4	Medium 6	High 8	Extreme 10
	I	Negligible 1	Low 2	Medium 3	High 4	Extreme 5
Consequence scale 1		Description 1	Description 2	Description 3	Description 4	Description 5

**Figure 2 – Risk Matrix**

Source: (Peace, 2017)

Only the risks selected in the risk matrix, Figure 2, with a degree of, extreme or high severity, should have an Action Plan in the conception design phase and answered “yes” in the checklist of Table 1 (otherwise the cost to analyze all the risks would be too high in the beginning of the Conception Design Phase).

#### 4 Results

Table 2 presents 10 cases briefly experienced by the authors, regarding four preventive actions against the risks.

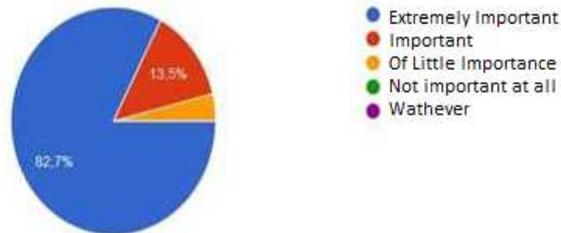
**Table 2 – Survey Result**  
Source: Author

#	Company	Business Units	Results of the Survey
1	A	Pneumatics	All of the big projects developed by the Engineering area have protocol defined by the group where all the investments are approved after the analysis and the technical report of the security area that does the risk analysis and defines measures to eliminate risks. The company's risk analysis tool was used. We use TCIR – Total Case Incident Rate to measure the results. There was a 60% reduction rate in the last 3 years. However, we cannot attribute this result to the analysis of new projects alone. We can't claim that the progress is exclusively due to the risk analysis process of new projects.
2	B	Oil Exploration and Production	We use HAZID - Hazard Identification, HAZOP - Hazard & Operability Studies, FRED - Fire, Release, Explosion and Dispersion (Shell's consequence modelling tool), Safety Case, Bow Tie; Zero Fatalities achieved (Brazil), Zero process safety incidents (Tier1 and Tier 2) for over 400 days
3	C	Engineering and Civil Works Construction	We use the Preliminary Risk Analysis and no relevant result achieved at the moment.
4	D	Distribution of Oil and Sugar Cane products	We use Task Safety Analysis; Zero LTI in the last 5 years and reduction in TRCF, currently in 3 and a 0,26 rate ;4- 3 to 5 years to achieve those results.
5	E	Engineering and Construction Assembly	with identification and risk analysis only in the execution of projects.
6	F	Mining	with identification and risk analysis only in the execution of projects.
7	G	Brazilian Navy	with identification and risk analysis only in the execution of projects.
8	H	Engineering and Construction Assembly	with identification and risk analysis only in the execution of projects.
9	I	Consultative Engineering	with identification and risk analysis only in the execution of projects.
10	J	Engineering Projects e Renewable Energy Source Equipment Assembly	with identification and risk analysis only in the execution of projects.

Note: LTI – Lost Time Injury; TRCF - Total Recordable Case Frequency;

The survey was answered by labor safety and Project Management Professionals and it highlighted the importance of a practical method to identify potential serious accidents in the initial phase of the projects and basic engineering, pointing out the use of the checklist, the risk matrix and the probability and impact matrix as ideal. The result is presented in Figure 3, around 96% of the answers show the importance of having a risk matrix to identify potential risks in conception project and basic engineering.

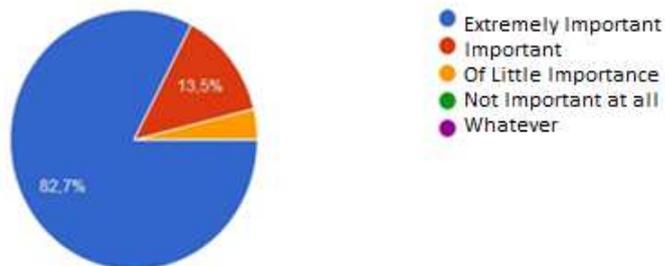
In this practical method, what is the importance of having a risk matrix to help to identify the potential most severe labor accident risks in basic engineering?



**Figure 3 – Field Survey Result**

The result presented in Figure 4 and, around 96% of the answers show the importance of identifying the potential labor accident risks in conception project and basic engineering.

What is the importance of identifying the potential labor accident risks in basic engineering when there are only incipient ideas, the scope and the conception of the project yet to be executed?



**Figure 4 – Field Survey Result**



## 5 Conclusion

As proposed in the introduction, this study provides responses to three questions proposed initially. The survey with specialists and companies proved to be useful and revealed important information. In response to the first question, the field survey showed that 60% of the companies, Table 2, are concerned with potential serious accident risks only in the execution phase of the projects, probably due to the high costs of experienced manpower in the initial phase when the risks are somehow hidden since the project has not started yet. Figure 1 answers this question, if the risks are mitigated from the beginning of the project, the total project cost will be much lower. In response to the second question of this paper, that is “what is the ideal methodology to identify potential serious labor accident risks, the final survey with the companies showed that 40% of the company have used a preliminary risk assessment to identify serious labor accident risks. The study created a practical method to ensure the principles of Prevention through Design (PtD) and showed the importance of the topic by analyzing the current literature and broadening its knowledge base. In response to the third question, “what is the importance of identifying potential serious labor accident risks in the conception of projects and basic engineering”, the answers to the survey on Figure 3, revealed that more than 96 % of people answered “extremely important and important”. of identifying potential serious labor accident risks in the conception of projects. The two deaths caused by the project of the bicycle lanes in Rio de Janeiro could have been avoided if the method proposed in this study had been used since all the serious accident risks would have been identified and eliminated. As a final recommendation, the use of this practical methodology should be considered mandatory by the Project Engineering Management Organization and the Engineering and Architecture Councils and part of all the construction inspections made by the public and private engineering companies in Brazil and in other countries.

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