CEMS Hg Sensor Installation Project Risk Analysis Using Severity Index

Izzati Winda Murtia), Galuh Ajeng Bidasarib), and Andhika Eko Prasetyoc)

Department of Engineering Management, Universitas Internasional Semen Indonesia, Gresik, Indonesia

a) Corresponding author: [izzati.murti@uisi.ac.id](mailto:izzati.murti@uisi.ac.id)

b) [galuh.bidasari19@uisi.ac.id](mailto:galuh.bidasari19@uisi.ac.id)

c) [andhika.prasetyo@uisi.ac.id](mailto:andhika.prasetyo@uisi.ac.id)

**Abstract.**  In response to high industrial competition and environmental concerns in Indonesia, PT XYZ is enhancing its environmental awareness by implementing the Continuous Emission Monitoring System (CEMS) technology to monitor emissions at five disposal points. A key focus is the CEMS Hg (Mercury) unit in the coal processing section. Initially, the company did not conduct a risk analysis for this project, resulting in the absence of a risk list. To address this, a risk assessment was carried out using Severity Index method during the Engineering, Procurement, and Construction phases. Data collection involved depth interviews from project supervisors, head of project supervision department, and user from environmental department at PT XYZ. The research identified six critical risks: periodic document approval monitoring by project control, creating and submitting Standard Operational Procedures at the kick-off meeting, coordinating with procurement services to include the tender administration document processing schedule, having a contractor representative on standby to monitor progress, conducting environmental characterization (soil inspection) for each supervised area, and the water volume is not controlled even though it has been drained. These recommendations aim to improve risk management in similar future projects.

**Keywords:** CEMS, EPC, Project, Risk

# INTRODUCTION

Regarding Indonesia's high degree of competitiveness in the industrial sector, companies compete to improve their performance by continuing to innovate in terms of developing business processes and establishing better infrastructure [1] This development has a beneficial influence on human wellbeing, but it is inversely proportionate to the environmental impact, notably air pollution and particulates, which affect the surrounding area's air quality index [2]. PT XYZ is one company that emit pollutants, including air pollution and particulates. PT XYZ is in Gresik Regency and takes part in the agro-industry and agro-solution sectors. This company is Indonesia's largest comprehensive fertilizer producer, with a production capacity of roughly 10 million tons/year comprised of 6.5 million tons/year of fertilizer products as well as 3.9 million tons/year of non-fertilizer items. PT XYZ, a national fertilizer company, as consistently examines the environmental impact of its operational activities. This is demonstrated by PT XYZ's achievement of the 2021 Gold PROPER award. PROPER is an Environmental Management Company Performance Rating Assessment Program [3]. To preserve the company's Gold PROPER status in 2021, PT XYZ aims to raise environmental awareness by utilizing Continuous Emission Monitoring System (CEMS) technology. Continuous Emission Monitoring Systems (CEMS) are specialized technologies designed to monitor and report emissions from industrial sources in real-time [4]. These systems are critical for ensuring compliance with environmental regulations and for managing emissions effectively. CEMS is a system that captures gas and/or dust (particulates) in the chimney and then connects the emission values to a computer program. CEMS can make it easy to track the amount of exhaust gas emissions produced on a regular basis [5]. As a result, PT XYZ implemented CEMS at five distinct locations around the factory. One of the installation projects carried out at PT XYZ is the installation of CEMS Hg (Mercury) in the Coal Utility Unit. The installation project is worth IDR 3,300,000,000 and is planned to be completed within 357 days.

The initiation of a new project often introduces new risks that must be managed carefully [6]. Risk is the uncertainty of events that can occur, which cannot be eliminated but can be reduced or avoided [7]. Recent research emphasizes that risk is inherently associated with uncertainty and cannot be eliminated, but it can be managed, reduced, or avoided through strategic approaches. This involves not just defensive measures but also proactive strategies to turn potential risks into opportunities​ During the implementation of EPC projects, significant risks arise in each phase, impacting project objectives related to cost, quality, and completion time. Risks that are not identified in a timely manner can lead to price increases and other negative consequences. Effective risk management is therefore essential to ensure caution and awareness throughout the project. It also helps identify high-potential risks that could hinder or create opportunities within the project. Key components of the risk management framework include communication and consultation, defining scope, context, and criteria, risk assessment (identification, analysis, evaluation), risk treatment (transfer, acceptance, mitigation, avoidance), and ongoing monitoring and review. Additionally, it involves documenting and reporting the risk management process and its outcomes comprehensively.

Conducting a thorough risk analysis is crucial when implementing new technologies in an industrial setting. This process helps in identifying potential uncertainties and hazards that could impact the project's success [8]. According to recent studies, failure to conduct an effective risk analysis can lead to severe consequences, including financial losses, project delays, and damage to the organization's reputation. For instance, a lack of risk assessment might result in unforeseen costs, such as those arising from unanticipated project delays or technical failures, which can significantly inflate the project's budget and erode profitability. Moreover, ineffective risk management practices can lead to missed opportunities, such as failing to capitalize on emerging technologies or market trends, which competitors might exploit. Furthermore, inadequate risk management can lead to compliance issues, especially in industries with stringent regulatory requirements, thereby exposing the company to legal penalties and further financial burdens ​[9].

During the project implementation process for installing the CEMS Hg (Mercury) Coal Unit, no risk analysis was carried out, so the company does not yet have a risk list for the project. The aim of this research is to determine, identify and determine the highest risk control response that exists in the installation of a CEMS. Considering that the installation of CEMS is a project that has the potential to be carried out repeatedly at other locations in the factory, a risk assessment process is needed as a lesson learned reference for decision making in responding to potential risks in similar projects. The limitation of this research is that the respondents studied are project supervisors and the party requesting project supervision services (users) of the CEMS Hg (Mercury) coal unit at PT XYZ, this research does not take into account the project budget and other financial aspects, the risks taken are operational risks during engineering, procurement and construction processes on the project, the impact criteria used are impacts that influence the project implementation time, risk identification focuses on activities that experience delays.

Based on the description above, risk assessment research using Severity Index methods to analyse project risks in the Engineering, Procurement, and Construction phases is required. The Severity Index is a risk assessment tool that determines existing risk controls by merging data from several respondents. The Severity Index, also known as Risk Impact or Risk Severity, is a crucial component in risk management that quantifies the potential harm or adverse effects resulting from a risk event [10]. It assesses how severe the consequences of a particular risk could be if it materializes. This metric is essential because it helps prioritize risks, guiding organizations on where to focus their risk mitigation efforts. High severity risks demand more attention and resources due to their significant potential impact, while low severity risks may require minimal intervention.

# METHODS

Problem Identification: The initial stage involves identifying unassessed risk issues within the project. This step is crucial as it lays the groundwork for understanding potential vulnerabilities that could impact the project's success [11]. Identifying these risks early on enables the formulation of strategies to manage them effectively, ensuring that all significant factors are considered before proceeding with the project.

Literature Review: The next phase is a comprehensive literature review, which involves collecting data from various sources such as journals, books, and previous studies. This process helps in understanding the existing body of knowledge on the topic and identifying gaps that the current research can address. It also provides insights into established methods and practices in risk management, which can be adapted or improved upon in the current study [12]. Data Collection: Data collection is divided into primary and secondary sources. Primary Data: This includes conducting interviews, field observations, FGD and distributing questionnaires. These methods provide firsthand information about the risks and challenges associated with the project, directly from those involved or affected by it. Secondary Data: This involves reviewing project documents and related reports. Secondary data helps in corroborating the findings from primary sources and provides additional context to the risk factors identified [12]. Based on the identification of problems in the project supervision section which has not implemented risk management, its implementation in this CEMS project begins with problem identification and literature study. To facilitate data analysis, literature reviews and data collecting were conducted both through interviews and direct observation and through project documents. Data collected from project supervisors, head of project supervision department, and user from environmental department at PT XYZ are very useful to help the team gathered focus information for FGD.

Then the data from the FGD results is analyzed to obtain a risk value using the severity index principle. The impact and potential of each response were sought after determining the source of risk using the Fault Tree Analysis technique, as seen in **TABLE 2**. There are standards that have been established to make risk classification easier for respondents. The following **TABLE 1** is a risk probability and impact criteria used referring to ISO 31000:2018.

**TABLE 1.** Likelihood

|  |  |  |
| --- | --- | --- |
| Probability | Description | Scale |
| Very unlikely | An impossible event | 0% |
| Unlikely | Not occur | 0% < likelihood ≤ 20% |
| Possible | May occur occasionally | 20% < likelihood ≤ 50% |
| Likely | There's a big chance of happening | 50% < likelihood ≤ 80% |
| Very likely | An event that was practically inevitable | 80% < likelihood≤ 100% |

Source: [13]

**TABLE 2.** Impact on work completion timeline

|  |  |  |
| --- | --- | --- |
| Impact | Description | Delay (day) |
| Negligible | Does not affect the work completion schedule | 0 |
| Minor | Does not hamper the work completion schedule, subject to a fine of less than 2% | 1-8 |
| Moderate | Potentially hampers the work completion schedule | 9-17 |
| Significant | Hampering the work completion schedule | 18-25 |
| Severe | Really hampers work time and project completion | > 25 |

Source: [13]

Following the collection of each respondent's evaluation data, the criteria and risk impacts are calculated using the severity index formula as follows:

(1)

ai = assessment constant

xi = assessment frequency

i = 0,1,2,3,4,……n

After the calculations are carried out, they are categorized according to the **TABLE 3** as follows:

**TABLE 3.** Severity index category

|  |  |  |
| --- | --- | --- |
| Category | Score | Scale |
| Very unlikely/Negligible | 0 ≤ SI < 12.5% | 1 |
| Minor/Unlikely | 12.5% ≤ SI < 37.5% | 2 |
| Moderate/Possible | 37.5% ≤ SI < 62.5% | 3 |
| Significant/Likely | 62.5% ≤ SI < 87.5% | 4 |
| Severe/Very likely | 87.5% ≤ SI < 100% | 5 |

Source: [13]

Following the determination of the severity index value for potential and impact, the risk severity is classified as low, medium, or high, and then converted into a scale to simplify the multiplication between probability and impact. A probability impact matrix can be used to determine the severity of risk: [13]:

(2)

R = Risk; P = Probability; I = Impact

This conversion allows for a standardized assessment of risk, making it easier to prioritize and manage different risk levels. After obtaining the data analysis results, conclusions are drawn in the form of the highest risk outcomes and the response to addressing the highest risks on the project [13]:

1. Transfer: For some risks, transferring them may be the best option. This can be accomplished through traditional insurance or by assisting third parties in taking risks in different ways.

2. Accept: this is a broad action for unavoidable external risks or risks that are still below the company's tolerance limitations.

3. Mitigate: make measures to lessen potential dangers.

4. Prevent: risk response procedures that have been prepared from the beginning to prevent risks that may develop in a variety of other circumstances.

# RESULTS AND DISCUSSION

To effectively identify risks in a project involving the installation of new technology, utilizing Focus Group Discussions (FGD) and interviews is essential. These methods provide a platform for gathering diverse viewpoints and insights from various stakeholders, including technical experts and project team members [14]. The information gathered through FGD is critical for creating a comprehensive risk assessment, which is crucial for planning and implementing effective risk mitigation strategies in this project. Risk identification is carried out using the FGD and interview method with respondents. The identification step is divided into three process variables, namely Engineering, Procurement, and Construction, to make it easier to find the underlying cause of each risk, as presented in **TABLE 4**.

**TABLE 4.** Risk identification

|  |  |
| --- | --- |
| Risk ID | Risk Variable |
| Engineering | |
| 1A | Unmatched drawing specification |
| 1B | The supporting documents sent are incomplete |
| 1C | Project manager of main contractor has another project being handled |
| 1D | PT XYZ has not received the handover of documents from Central company |
| 1E | Details of work methods are not convenient |
| 1F | At the time of project implementation, the HSE account had not been renewed |
| 1G | There is no site survey before creating the project Issued for Construction document |
| 1H | There is too much work that needs to be completed |
| Procurement | |
| 2I | There is no regular 2-way update information from vendors and users |
| 2J | Does not have access to shipping tracking |
| 2K | Shipping goods through needs to go through several stages (from customs to local shipping expeditions) |
| 2L | Special order that is not available on Durag factory standards |
| 2M | There are other projects handled by Project manager vendors |
| 2N | Communication is less effective because they do not know the real conditions in the field |
| 2O | There were no representatives from the Main contractor who took direct measurements on the stack |
| Construction | |
| 3P | The field foreman forgot not to check the work |
| 3Q | Human error |
| 3R | There is no re-checking of materials before they are sent to the location |
| 3S | Differences between existing communication standards and new systems |
| 3T | Sand mixed with water cannot be lifted to the surface |
| 3U | The water volume is not controlled even though it has been drained |
| 3V | The generator is used for other projects |
| 3W | Environmental factors around the project |
| 3X | Drilling tools are used continuously |

The identification step for the engineering phase of the CEMS Hg (Mercury) Unit UBB project identified three main risks: delays in engineering document approval (>1 week), project start delays due to late document handover from procurement, and mismatched drawings during site surveys. Document approval delays stem from design revisions and slow contractor responses, often because project managers juggle multiple projects. Project start delays are linked to administrative hurdles, such as registering contractor accounts on PT XYZ HSE system and managing JSA documents, exacerbated by incomplete document transfers and outdated contractor accounts. Delays in the initial administrative processes of a project can significantly impact the project's overall timeline. When these foundational elements are delayed, it creates a cascading effect, pushing back subsequent phases such as procurement, construction, or implementation. This chain reaction not only extends the project's duration but can also inflate costs and disrupt resource scheduling [15].

While for the procurement phase identified three risks across two stages: delayed gas analyzer delivery and flange size miscommunication during material logistics monitoring, and late arrival of Durag items during field material measurements. Gas analyzer delays were due to lack of routine updates and tracking access issues from the vendor and their partners, with import processes adding to delays. Flange miscommunication arose from ineffective online coordination and poor field survey accuracy by the project manager. Durag item delays resulted from extended fabrication times for custom orders, leading to inaccurate delivery estimates from the contractor.

Besides in construction identified four risks across four stages: incorrect rebar installation during reinforced concrete foundation work, integration failure of the CEMS panel to the DIS during CEMS gateway connectivity, drilling delays during concrete floor demolition, and postponement of Strauss pile drilling and casting for shelter foundation during sloof casting. Rebar installation errors were due to worker negligence and contractor mistakes, including lack of supervision and shipment errors. Drilling delays were caused by limited generator availability and drill malfunctions due to overheating. Strauss pile drilling delays were due to sand and water at a one-meter depth, complicating the excavation process. Lastly, integration issues between the CEMS panel and DIS stemmed from using incompatible existing cables, leading to communication standard discrepancies.

Calculation of Probability and Risk Impact values using the Severity Index formula aims to obtain the average value of the questionnaire results obtained from respondents [10].

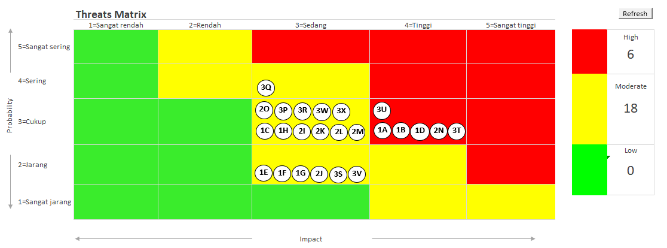
a0=0, a1=1, a2=2, a3=3, a4=4

X0=0, X1=1, X2=3, X3=0, X4=0

With the result:

With a value of 44%, the risk probability falls into the "moderate" category. In risk management, "moderate" within the Severity Index framework represents a middle range of risk probability, indicating that the risk is possible but not frequent. This category suggests that there is a fair chance of the event occurring under specific conditions, but it is not expected to happen regularly. A risk classified as "moderate" necessitates monitoring and possibly some mitigation strategies. While the risk is not highly likely, it still requires attention. The significance of a "moderate" probability can vary based on the risk context, the organization's risk appetite, and the potential consequences of the risk. Applying the Severity Index, risks in the "moderate" category may require interventions such as developing contingency plans, implementing preventive actions, or conducting periodic reviews to ensure control. This categorization helps allocate resources effectively by prioritizing more severe or likely risks while appropriately addressing moderate risks. The SI value, initially issued as a percentage, as shown with the SI result of 44% from risk ID 2L, is then converted into a scale to assess probability, frequency judgments, and impact. The conversion from the percentage of SI to the scale involves mapping specific percentage ranges to numerical values. This allows for a standardized interpretation of the severity index on a 1-5 scale, where 1 represents the lowest severity and 5 the highest.

The multiplication of probability x impact refers to the risk table that was created previously. The following is a visualization of risk categories based on the Probability x Impact Matrix (as shown in **FIGURE 1**). Based on the risk classification results, six dominant risks were identified, each with a score of 12. According to the questionnaire results, these six risks frequently impact the project's timeline, with an impact value of 4 (high). The likelihood of these risks occurring was rated at 3 (moderate), indicating that they may occur occasionally during the project.



**FIGURE. 1.** Risk distribution matrix

The most significant risk identified was the discrepancy in the drawing specifications, which received a score of 12 because accurate drawings are critical for project initiation. If the drawings are not approved by the Design Team, the project cannot commence, affecting the project's timeline. The next significant risk was the submission of incomplete documents for approval, which can delay the project's start. Another major risk involves the procurement documents not being handed over to the Project Integration (PI) team. This is an external risk where projects with a value exceeding 1 billion require direct tendering by the PI. The administrative process from the PI’s Procurement Services is often longer than estimated, necessitating immediate attention as it can impact project execution. Further, ineffective communication due to a lack of understanding of real field conditions can lead to discrepancies between the ordered materials and the on-site requirements, affecting project progress. A notable risk is the inability to remove sand mixed with water from the site, and uncontrolled water volumes during excavation. This issue arises during the foundation pouring process, where water and sand complications were not anticipated. This risk is particularly critical due to the proximity to a water source that was not identified early in the project planning.

The risk classification results yielded five dominating risks, with the following responses in **TABLE 5** to the dominant risks:

**TABLE 5.** Risk response strategy

|  |  |  |
| --- | --- | --- |
| ID Risk | Risk Response Strategy | Planning Response Strategy |
| 1A | Accept | Monitoring document approval periodically by project control |
| 1B | Mitigate | Create Standard Operational Procedures for project administration and submit them at the kick-off meeting |
| 1D | Transfer | Coordination with Procurement Services to add to the tender administration document processing schedule through central company |
| 2N | Mitigate | Place a contractor representative on standby to monitor the project's progress. |
| 3T | Mitigate | Carry out the environmental characterization process (soil inspection) for each supervised project area |
| 3U | Mitigate | The water volume is not controlled even though it has been drained |

This research aligns with previous studies that emphasize how failure to manage risks in the early phases of a project can lead to significant delays [10]. The use of the Severity Index in this study has proven effective in identifying significant risks. However, other research, such as the study by Ulusoy and Hazır (2021), suggests that applying Fault Tree Analysis in conjunction with the Severity Index could provide deeper insights into the root causes of risks, allowing for more precise mitigation measures.

Highlighted by Mohammed and Bello [15], ineffective communication has been shown to be a primary cause of technical errors and procurement delays in construction and procurement phases [15]. Inadequate communication often leads to misunderstandings, incomplete information, and delays in decision-making, which can cause project delays and increased costs. Factors such as unclear communication channels, language barriers, and inconsistent information sharing contribute to inefficiencies and misunderstandings in this project. These issues can lead to rework, project scope changes, and delays in procurement processes as stakeholders struggle to coordinate and align their efforts. Others, delays in the document approval process were one of the primary factors affecting the project timeline. This was worsened by technical errors, such as mismatched drawing specifications, which required revisions and led to extended project delays.

The risk analysis reveals that most risks in the CEMS Hg installation project at PT XYZ were primarily driven by communication issues, inadequate supervision, and poor resource management. The major risks identified include delays in document approvals, mismatched drawing specifications, logistical errors, and human negligence. Risks during the engineering phase were largely due to insufficient site surveys and delayed document revisions. In the procurement phase, lack of coordination between vendors and project managers led to delayed deliveries and material specification errors. Meanwhile, during the construction phase, technical failures and poor equipment management resulted in significant delays. Overall, these findings highlight the need for more effective communication, stricter supervision, and better resource planning to reduce risks in future projects and ensure smoother execution of large-scale engineering projects.

# CONCLUSIONS

This research aims to assess and identify critical risks in the installation project of CEMS Hg (Mercury) Unit, PT XYZ, by using the Severity Index method, particularly those risks expected to occur during the Engineering, Procurement, and Construction phases of the project. The subject of this research therefore encompasses the variables in operational risks, which could happen during these phases, except for financial risks or higher project budget risks. In particular, risks that would involve the timeline of the projects were looked into, which involved delays in document approval, drawing specification mismatch, ineffectiveness in communication, logistic errors, and human mistakes at the construction stage. There were 24 risks the research found, out of which six major ones were related to delays in the approval of documents, poor site surveys, coordination problems among vendors and managers, and technical errors during construction. These findings emphasize the growing need for communication, stringent quality checks, better resource planning, and increased supervision in managing large engineering projects. This study is limited to operational risks occurring during the EPC phases. Future research could consider some other aspects and, such as risks from the contractor's perspective, expand the risk variables to include financial and regulatory factors that may affect the overall project and exploring the impact of digital tools for real-time communication and document approval processes could be another research direction. Future research also could explore the use of integrated risk management frameworks that combine tools such as Fault Tree Analysis (FTA) or Monte Carlo simulations with the Severity Index to provide deeper insights into risk probabilities and impacts.

# references

1. Banholzer, M., et al., How innovative companies leverage tech to outperform. McKinsey and Company, 2023.

2. Greenstone, M., C. Hasenkopf, and K. Lee, Annual Update. Air Quality Life Index.( 30 pages), 2022.

3. Sarumpaet, S., M.L. Nelwan, and D.N. Dewi, The value relevance of environmental performance: evidence from Indonesia. Social Responsibility Journal, 2017. **13**(4): p. 817-827.

4. Srivastava, R.P., S. Kumar, and A. Tiwari, Continuous emission monitoring systems (CEMS) in India: Performance evaluation, policy gaps and financial implications for effective air pollution control. Journal of Environmental Management, 2024. **359**: p. 120584.

5. Triani, M., et al. Development of Emission Factors from Indonesian Coal-Fired Power Plant Using Continuous Emission Monitoring Data. EDP Sciences.

6. Beckers, F., et al., A risk-management approach to a successful infrastructure project. Mckinsey Work. Pap. Risk, 2013. **52**(2013): p. 18.

7. Secundo, G., et al., How machine learning changes Project Risk Management: A structured literature review and insights for organizational innovation. European Journal of Innovation Management, 2023.

8. Al Kokoh, A., ANALISIS SUMBER KEBAKARAN PADA GEDUNG 1 KAMPUS B UNIVERSITAS INTERNASIONAL SEMEN INDONESIA DENGAN METODE (FMEA) FAILURE MODE AND EFFECT ANALYSIS. 2020.

9. Dandage, R.V., et al., Analysis of interactions among barriers in project risk management. Journal of Industrial Engineering International, 2018. **14**: p. 153-169.

10. Febryan, D.F. and H.T. Tjendani, Analisis Tingkat Risiko pada Proyek Pembangunan Perumahan Grand Eastern Surabaya dengan Metode Severity Index. Jurnal Teknik Industri Terintegrasi (JUTIN), 2024. **7**(2): p. 1093-1106.

11. Ulusoy, G., et al., Introduction to Project Modeling and Planning. 2021: Springer.

12. Hunziker, S., et al., Literature review research design. Research Design in Business and Management: A Practical Guide for Students and Researchers, 2021: p. 235-251.

13. Rahman, P., Analisa Resiko Pada Proyek Pembangunan Instalasi Pengolahan Air Limbah Di Kota Pekanbaru. 2020.

14. Balasubramaniam, V.C., Focus group discussions, in Methodological issues in management research: Advances, challenges, and the way ahead. 2019, Emerald Publishing Limited. p. 93-108.

15. Mohammed, Z. and U. Bello, Causes of Delay in construction projects: A systematic review. International Journal of Engineering Research, 2022. **11**(03): p. 63-71.