



# The Implementation of ISO 9001:2015 in Drainage Project Execution Based on Failure Mode and Effect Analysis (FMEA)

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## ABSTRACT

Urban drainage projects play a strategic role in controlling runoff and mitigating flooding. However, construction quality issues often arise during implementation, leading to channel failure. **This study aims** to analyze the impact of implementing the ISO 9001:2015 Quality Management System on the quality of drainage projects using the Failure Mode and Effect Analysis (FMEA) approach, through a case study of the Rasuna Said drainage channel in Kuningan, Jakarta. The research methodology combines primary and secondary data obtained through field observations, interviews, questionnaires based on ISO 9001:2015 clauses, and project document analysis. **Quality risk identification** is conducted using the FMEA method, with severity, occurrence, and detectability parameters assessed to determine the Risk Priority Number (RPN). **The results show** that the main failure modes with the highest risk levels include mismatched channel elevation and slope, loosely fitting channel element connections, uneven subgrade compaction, and initial sedimentation due to weak work environment controls. These risks are generally related to the field operational stage and the suboptimal application of the risk-based thinking principle in ISO 9001:2015. **The integration of the FMEA method** with ISO 9001:2015 has been proven to identify and prioritize quality risks more systematically and support the development of measurable mitigation actions. **This study concludes** that the implementation of ISO 9001:2015, integrated with FMEA, can improve the effectiveness of quality control, minimize the risk of construction failure, and support the sustainability of urban drainage projects.

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## 1. INTRODUCTION

Drainage systems are essential infrastructure that plays a strategic role in managing surface water, both in urban and rural areas. A well-functioning drainage system helps control rainwater runoff, reduces the risk of waterlogging and flooding, and maintains environmental quality, allowing social and economic activities to proceed optimally. In the context of sustainable development, drainage systems are not only seen as a technical solution for water control, but also as a crucial element in enhancing regional resilience to the impacts of climate change [1, 2].

As the intensity of rainfall and the frequency of extreme rainfall events increase due to global climate

change, the need for reliable and sustainable drainage systems has become more urgent [3]. This situation is further exacerbated by rapid urbanization, which reduces water catchment areas, increases land conversion, and adds to surface runoff loads. Consequently, drainage failures still frequently occur, despite various development and rehabilitation efforts. This indicates that drainage issues are not only related to hydrological planning but also to the quality of construction implementation [4, 5].

Based on existing conditions and various findings from drainage project implementation, it can be identified that the quality of construction results is still suboptimal. This is evident from the persistence of waterlogging and flooding in several locations even though the drainage project has been completed. This condition points to problems not only in the technical planning aspect but also in the implementation and quality control stages of construction work. Additionally, delays in the completion of drainage projects remain a common issue. These delays are generally caused by weak coordination between stakeholders, inconsistencies in the implementation of work procedures, and ineffective monitoring and quality control systems in the field. The impact of these delays affects not only project timelines but also increases costs and reduces public trust in the quality of the infrastructure being built [6].

Another significant problem is the mismatch between planned technical specifications and field implementation, particularly regarding the use of materials and construction methods. This mismatch often leads to rework, increasing project costs and extending the implementation duration [7]. This condition reflects the suboptimal implementation of a comprehensive and consistent quality management system throughout the project cycle. Although some contractors are ISO 9001:2015 certified, the implementation of this quality management system in drainage projects has not been fully effective. The ISO 9001:2015 implementation tends to be administrative and formal, without strong integration into quality control in the field [8, 9, 10]. Moreover, the risk-based approach emphasized in ISO 9001:2015 has not been systematically implemented, often leading to missed identification of potential quality failure risks. The lack of a structured risk analysis method to identify, evaluate, and prioritize quality risks remains a major problem in drainage project management. Without a systematic approach, control measures are often reactive and ineffective [11, 12].

To address these challenges, the integration of the ISO 9001 quality management system with risk analysis methods such as Failure Mode and Effect Analysis (FMEA) is necessary to improve the effectiveness of quality control, minimize the risk of construction failure, and support the achievement of sustainable drainage project quality [13].

## 2. RESEARCH METHODOLOGY

### 2.1. Data Collection

Data collection in this study was conducted through primary and secondary methods to obtain a comprehensive picture of the level of implementation of ISO 9001:2015 and identification of failure risks in drainage projects using the Failure Mode and Effects Analysis (FMEA) approach [14, 15]. Primary data was obtained through direct observation of the Rasuna Said drainage channel to assess the physical condition, potential construction and operational failures, and through structured and semi-structured interviews with contractors, supervisory consultants, and the quality management team to obtain information related to the implementation and constraints of ISO 9001:2015 [16, 17, 18]. In addition, a Likert-scale questionnaire was distributed to project personnel to assess the level of implementation of the standard based on core clauses, as well as the completion of the FMEA form by the technical team to assess each failure mode based on the parameters of Severity, Occurrence, and Detectability to obtain the Risk Priority Number (RPN) value. Secondary data was collected through a review of project documents such as working drawings, technical specifications, quality plans, supervision reports, material test results, and non-conformity records, as well as through a review of scientific literature, technical standards, SNI (*Standar Nasional Indonesia*) or Indonesian National Standard, Ministry of PUPR (*Pekerjaan Umum dan Perumahan Rakyat*) or Ministry of Public Works and Public Housing (MPWPH) guidelines, and hydrological and geotechnical data of the research area as a theoretical basis and supporting analysis, so that the data obtained is complete, accurate, and relevant to evaluate the effect of implementing ISO 9001:2015 on the quality of drainage projects [19, 20].

## 2.2. Data processing

The data processing method in this study was designed to ensure that all primary and secondary data obtained could be analyzed systematically in order to evaluate the impact of ISO 9001:2015 implementation on the quality of FMEA-based drainage projects. The data processing process was carried out through several stages as follows.

- The first stage is processing field observation data, which includes verifying technical records and visual documentation to ensure the consistency and accuracy of findings. Observation data is classified based on the physical condition of the line, potential damage, compliance with technical specifications, and other relevant technical aspects. This classification is used to support failure mode identification and validate FMEA assessment results [21, 22].
- The second stage was the processing of interview and questionnaire data. Interview data were transcribed and analyzed using a thematic analysis approach to identify key patterns related to ISO 9001:2015 implementation, the obstacles encountered, and project implementers' perceptions of the effectiveness of the quality system [23, 24, 25]. Meanwhile, questionnaire data were processed using descriptive statistics to obtain the average value, percentage, and distribution of scores for each ISO 9001:2015 clause indicator. The results of this processing were used to quantitatively assess the level of ISO implementation [26, 27].
- The third stage is FMEA data processing. Each identified failure mode is assigned a Severity (S), Occurrence (O), and Detectability (D) score based on the technical team's assessment. The Risk Priority Number (RPN) is calculated using the formula:

$$RPN = S \times O \times D$$

The RPN values are then analyzed to prioritize risks requiring corrective action [28, 29]. Failure modes with the highest RPN values are categorized as critical risks, potentially significantly impacting project quality [30, 31].

- The fourth stage is processing project document data, which includes material test results, inspection reports, working drawings, technical specifications, and non-conformance records. This data is analyzed to assess the extent to which the drainage work meets technical requirements and quality procedures [32, 33]. Document analysis also serves as cross-verification against primary data.
- The fifth stage is an integrative analysis, which combines the results of ISO 9001:2015 data processing, FMEA, and project quality evaluation to assess the relationship between the level of quality system implementation and drainage technical performance. The analysis was conducted descriptively and comparatively to identify the contribution of ISO 9001:2015 implementation to efforts to reduce the risk of failure and improve construction quality [26, 34]. Through a series of data processing methods, the study produced an objective, systematic, and comprehensive evaluation of the effect of ISO 9001:2015 implementation on drainage project quality based on the FMEA approach [33].

## 2.3. Data Analysis

The data analysis method in this study was designed to evaluate the impact of ISO 9001:2015 implementation on the quality of drainage projects using a Failure Mode and Effects Analysis (FMEA) approach [31, 35]. The analysis was conducted in a step-by-step and systematic manner to produce valid, objective, and scientifically accountable findings.

- The first stage is descriptive analysis, which is used to process and interpret data from observations, interviews, and project documents. This analysis aims to provide a comprehensive overview of the existing condition of the drainage channels, the level of implementation of quality procedures, and the technical characteristics of the work. Data is presented in narrative form, tables, and graphs to facilitate interpretation [36].
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- The second stage is an analysis of the level of ISO 9001:2015 implementation based on the questionnaire results. Quantitative data is processed using descriptive statistics, including calculating the average value, percentage, and distribution of scores for each clause in the ISO 9001:2015 standard. The implementation level scores are then categorized into several levels, such as very high, high, medium, and low. This analysis provides a measurable picture of the effectiveness of the quality management system implementation on the project [37].
- The third stage is the FMEA analysis, which is used to assess the risk level of each failure mode identified in the construction process and operational function of the drainage channel. The assessment is carried out using Severity (S), Occurrence (O), and Detectability (D) scores, which are then calculated to obtain a Risk Priority Number (RPN) value. The RPN value is used to determine risk priority, with the failure mode with the highest value categorized as a critical risk requiring immediate mitigation action [38].
- The fourth stage is a comparative analysis, which is conducted by linking the level of ISO 9001:2015 implementation with the results of the FMEA analysis and project quality data. This analysis aims to assess the extent to which the implementation of quality procedures has reduced risk, increased work conformance to technical specifications, and reduced the potential for construction failure [35]. The results of the comparative analysis help identify causal relationships between ISO implementation and project quality performance [34].
- The fifth stage is integrative analysis, which combines all the previous analysis results to produce comprehensive conclusions. Integrative analysis is conducted by systematically linking qualitative and quantitative data to obtain a comprehensive picture of the effectiveness of ISO 9001:2015 implementation in improving the quality of FMEA-based drainage projects [39].

### 3. RESULT AND DISCUSSION

#### 3.1. Identify Potential Failure Modes

Field observations were conducted directly in the drainage work area in the Rasuna Said area, Kuningan, Jakarta. The main objective of this observation was to obtain an empirical picture of the actual condition of the construction, identify potential failures that may occur, and verify the level of conformity of the work to technical standards and provisions in the ISO 9001:2015 quality management system. Observation activities covered all important stages of the work, from excavation, subgrade compaction, installation of channel elements, elevation and slope control, to evaluation of the final condition after installation.

##### 3.1.1. Observation of Channel Geometry



Figure 1. Elevation Measurement on One of The Channel Segments

Initial observations focused on the channel's geometry, particularly its elevation and longitudinal slope. Measurements using a water level and laser level revealed several points with elevation deviations of 1–3 cm from the planned values [40]. These deviations have the potential to disrupt gravity flow and increase the risk of sedimentation shows in Figure 1. These findings indicate that the set-out and elevation verification processes were not carried out uniformly across the entire track. Furthermore, some sections exhibit inconsistent slopes, particularly in areas with varying terrain contours.

### 3.1.2. Subgrade Compaction Conditions

Subgrade compaction is a critical factor affecting the stability of channel elements. Field observations revealed variations in density at several points, characterized by uneven surfaces, deep heavy equipment ruts, and areas that felt softer during manual testing.



Figure 2. Subgrade Conditions with Uneven Compaction

This Figure 2 discrepancy indicates that the compaction process was not carried out evenly or that the density testing frequency was not up to standard. This condition has the potential to cause differential settlement in the channel.

### 3.1.3. Installation of Drainage Channel Elements



Figure 3. Channel Connection that is not Completely Closed

Observations of the installation of the channel elements indicated that most of the precast elements met the size specifications. However, some minor damage, such as chipping, hairline cracks, and broken corners, was found, likely due to suboptimal handling and transportation. Furthermore, several joints were found to be loosely fitted, with gaps visible in several locations. These gaps have the potential to cause water seepage and internal erosion. Figure 3 shows that the variation in quality of these joints reflects a lack of consistency in installation methods as well as minimal supervision of sealant or gasket use.

### 3.1.4. Work Environment Conditions and Sedimentation Risk

Observations of the work environment indicate a high potential for premature sedimentation. In some locations, the area around the canal is not equipped with temporary erosion control, allowing soil from excavations to easily enter the canal, especially during rain shows in Figure 4 below.



Figure 4. Initial Sedimentation Due to Lack of Work Area Protection

In addition, channel cleaning is not carried out routinely in some segments, causing deposits of soil and debris that can reduce flow capacity.

### 3.1.5. Field Documentation and Quality Control

Evaluation of field inspection documents showed that not all work stages were fully documented. Several critical stages, such as compaction verification, joint checking, and elevation control, did not use standard forms or checklists as required by ISO 9001:2015 (clauses 8.1 and 8.5).



Figure 5. Initial Sedimentation Due to Lack of Work Area Protection

This Figure 5 shows that operational quality control is still not running consistently and comprehensively. Overall, the identification process revealed that potential failure modes in the drainage project fall into four broad categories: technical failures, material failures, operational failures, and quality management system failures. All failure modes were then analyzed to determine their severity, occurrence, and detectability before calculating a Risk Priority Number (RPN). The RPN value is crucial for prioritizing corrective actions, allowing resources to be focused on failure modes with the highest risk and greatest impact on project success.

### 3.2. Quality Risk Factors Based on RPN

The assessment of quality risk factors based on the Risk Priority Number (RPN) value was conducted to determine the priority of risk management that most impacts the quality of the drainage project. The RPN is calculated from the combination of three main parameters in the FMEA, namely severity (S), occurrence (O), and detectability (D). A high RPN value indicates that the risk has a significant impact on quality and requires immediate mitigation action. Based on the results of data processing, both from the respondent questionnaire and the results of field verification, a number of main quality risk factors were obtained with varying RPN levels. These factors illustrate the level of seriousness of quality problems that occurred in the implementation of the Rasuna Said drainage project shows in Table 1.

Table 1. Classification of RPN Value Limits

RPN Value Range	Risk Level	Information
$RPN \geq 200$	Critical Risk	Unacceptable risk. Potential for drainage failure. Corrective and mitigation actions <b>must be done immediately</b> before work continues.
$150 \leq RPN < 200$	High Risk	Significant risks to channel quality and performance. Requires <b>high priority control and corrective actions</b> .
$100 \leq RPN < 150$	Moderate Risk	The risk is still acceptable with control. Requires <b>preventive measures and routine monitoring</b> .
$50 \leq RPN < 100$	Low Risk	Small risk to quality. <b>Routine control</b> is sufficient.
$RPN < 50$	Very Low Risk	The risk is negligible. No special measures are required other than standard monitoring.

Table 2 below shows the risk factor with the highest RPN value is mismatched channel elevation and slope, with the RPN value in the critical category. This risk has a very high severity level because it directly affects the hydraulic function of the drainage system. Elevation deviations of 1–3 cm cause flow disruptions, localized waterlogging, and increased potential for sedimentation. The risk occurrence is quite high because the set-out and elevation verification processes have not been rigorously implemented at each channel installation segment. Detectability is also at a medium to high level because elevation errors are often only identified after the channel is fully installed or after flow testing. The combination of these three factors makes elevation mismatches a top priority for addressing.

Table 2. Drainage Work Quality Risk Analysis

No	Primary Failure Mode	Impact of Failure	S	T	H	E	D	RPN	Category Risk
1	Mismatch of channel elevation and slope	Suboptimal flow, sedimentation, puddles	6	6	6	6	6	216	Very high
2	Uneven compaction of the base soil	Differential settlement, structural cracking	6	5	6	6	6	180	High
3	The connection of the channel elements is not tight	Seepage, internal erosion, land subsidence	5	6	7	7	7	210	Very high
4	Minor damage to precast elements (cracking/chipping)	Decreased structural durability	4	5	5	5	5	100	Currently
5	Initial sedimentation due to weak work environment controls	Reduced flow capacity	5	6	6	6	6	180	High
6	Inconsistent quality documentation and inspection	Failure detected too late	4	5	7	7	7	140	Currently
7	No temporary erosion control	Entry of foreign material into the duct	4	6	6	6	6	144	Currently

The next most important risk factor is suboptimal subgrade compaction, which has an RPN value approaching the critical category. The high RPN is due to very high severity and low detectability. Subgrade that does not reach the required density level can cause differential settlement, structural cracking, and progressive damage to the channel. Although the occurrence varies depending on the soil conditions, this risk remains high because the frequency of density testing has not been consistently performed. Detectability is low because compaction failures are often not immediately visible and only have an impact in the medium term after the structure is loaded. This condition indicates the need for tightened quality control during the compaction stage through field testing and tiered inspections.

The next risk factor with a high RPN is imperfection in inter-channel connections, or joint leakage. This failure mode has a high severity because it can cause groundwater infiltration, internal erosion, and long-term structural damage. Occurrence is moderate but consistent, due to uneven gasket quality and varying installation techniques among workers. The detectability of this risk is also in the medium category because small leaks in joints are not always visible to the naked eye at an early stage. A high RPN value places this risk as the third priority, requiring strengthened installation SOPs and systematic leak testing.

The next risk, which also has a relatively high RPN value, is structural cracks in the walls or base of the channel. Cracks that appear in precast concrete elements can be caused by inconsistent concrete quality, improper curing methods, or subgrade deformation due to poor compaction. The severity of this risk is high because the cracks can widen and potentially cause leaks. Occurrence is in the moderate category, especially in projects that use many precast elements. Detectability is quite high because cracks can be seen through visual inspection, so the detectability value is at a lower level than other failure modes. However, the accumulation of S–O–D parameters still results in a significant RPN.

Risk factors with a medium-high RPN include initial sedimentation and channel blockage due to suboptimal environmental management. Although the severity is not as high as elevation mismatch, this risk has a high occurrence, particularly during the rainy season and in areas with mining activity. Detectability is in the medium category because sedimentation can be seen with routine inspections. A high RPN value for this

risk indicates the need to implement erosion and sedimentation controls in accordance with clause 7.1.4 of ISO 9001:2015 on the work environment.

Other risks with a medium RPN include material specification discrepancies, precast element damage due to handling, uncalibrated measuring instruments, and uneven personnel competency. Although the severity of these risks is not as high as structural failure modes, their suboptimal occurrence and detectability cause the RPN value to remain at a level that requires corrective action. Material specification discrepancies are an indicator of the need to strengthen external supplier controls in accordance with ISO clause 8.4. Meanwhile, precast element damage and measurement errors emphasize the importance of tool maintenance and worker competency as stipulated in clauses 7.2 and 7.1.5.

Table 3. Failure Modes vs ISO 9001:2015

No	Primary Failure Mode	Impact of Failure	Clause
1	Mismatch of channel elevation and slope	Suboptimal flow, sedimentation, puddles	Clause 8.1 (Planning and Control of Operations), Clause 8.5.1 (Control of Production and Service Provision), Clause 9.1 (Monitoring and Measurement)
2	Uneven compaction of the base soil	Differential settlement, structural cracking	Clause 7.2 (Competence), Clause 8.5.1 (Production Control), Clause 9.1 (Performance Evaluation)
3	The connection of the channel elements is not tight	Seepage, internal erosion, land subsidence	Clause 8.5.1 (Production Control), Clause 8.6 (Release of Products and Services), Clause 10.2 (Corrective Action)
4	Minor damage to precast elements (cracking/chipping)	Decreased structural durability	Clause 8.4 (Control of External Providers), Clause 8.7 (Control of Non-Conforming Output)
5	Initial sedimentation due to weak work environment controls	Reduced flow capacity	Clause 7.1.4 (Environment for Process Operation), Clause 8.1 (Operation Planning)
6	Inconsistent quality documentation and inspection	Failure detected too late	Clause 7.5 (Documented Information), Clause 9.2 (Internal Audit), Clause 9.3 (Management Review)
7	No temporary erosion control	Entry of foreign material into the duct	Clause 7.1.4 (Operating Environment), Clause 8.1 (Operational Planning and Control)

The integration of RPN-based risk findings with ISO 9001:2015 clauses provides a systematic and applicable mitigation framework for improving the quality of drainage work in subsequent projects. Based on the analysis results, risks with an RPN value 150 are dominated by failures in the field operational phase. Therefore, mitigation strategies need to focus on strengthening planning, process control, and performance evaluation in accordance with the risk-based thinking principles in ISO 9001:2015.

Table 4. Handling Alternatives

No	Primary Failure Mode	Clause	Handling
1	Mismatch of channel elevation and slope	Clause 8.1 (Planning and Control of Operations), Clause 8.5.1 (Control of Production and Service Provision), Clause 9.1 (Monitoring and Measurement)	Re-establishment of elevation control, use of calibrated measuring instruments, implementation of quality checkpoints on each segment, verification of elevation before and after installation

2	Uneven compaction of the base soil	Clause 7.2 (Competence), Clause 8.5.1 (Production Control), Clause 9.1 (Performance Evaluation)	Establishment of standard compaction methods, increased frequency of density tests, documentation of field test results, and training of heavy equipment operators.
3	The connection of the channel elements is not tight	Clause 8.5.1 (Production Control), Clause 8.6 (Release of Products and Services), Clause 10.2 (Corrective Action)	Standardization of joint installation methods, use of sealants/gaskets according to specifications, visual inspection and leak testing before closing work.
4	Minor damage to precast elements (cracking/chipping)	Clause 8.4 (Control of External Providers), Clause 8.7 (Control of Non-Conforming Output)	Control of material handling and transportation, inspection of incoming materials, minor repairs or rejection of elements that do not meet the criteria.
5	Initial sedimentation due to weak work environment controls	Clause 7.1.4 (Environment for Process Operation), Clause 8.1 (Operation Planning)	Installation of temporary erosion control, routine channel cleaning, work area setup and temporary drainage during construction.
6	Inconsistent quality documentation and inspection	Clause 7.5 (Documented Information), Clause 9.2 (Internal Audit), Clause 9.3 (Management Review)	Development of standard inspection checklists, improvement of internal audits, strengthening of documentation systems and quality control of records.
7	No temporary erosion control	Clause 7.1.4 (Operating Environment), Clause 8.1 (Operational Planning and Control)	Provision of temporary erosion protection, arrangement of excavated materials, monitoring of work areas during rain.

During the operational planning and control phase, very high risk findings, such as inconsistencies in channel elevation and slope, and loose element connections, indicate the need for more consistent application of Clause 8.1 and Clause 8.5.1. For subsequent drainage projects, mitigation can be achieved through the development of a risk-based quality plan, the establishment of quality control points at each channel segment, and the use of calibrated work methods and measuring instruments. This integration ensures that potential technical failures are anticipated from the planning stage and controlled during implementation.

The high risk category findings related to subgrade compaction and initial sedimentation indicate the need to strengthen the work environment and human resource competency, as stipulated in Clause 7.1.4 and Clause 7.2. In subsequent drainage work, mitigation can be carried out through standardization of compaction methods, increased frequency of field testing, personnel training, and the provision of temporary erosion control and drainage systems. This approach not only reduces the occurrence value but also improves the ability to detect risks early.

The moderate risk category related to documentation and quality inspection indicates that the implementation of Clause 7.5 (Documented Information) and Clause 9 (Performance Evaluation) needs to be strengthened. Mitigation for future drainage projects can be achieved through the development of a standard inspection checklist, consistent recording of test results, and regular internal audits. This will allow for faster detection of potential failures, thereby reducing the detection value and preventing the risk from escalating to a higher category.

Furthermore, integrating the RPN findings with Clause 10 (Improvement) encourages the continuous implementation of corrective and preventive actions. Any risk findings from previous drainage projects can serve as lessons learned for improving work procedures, implementation methods, and quality control systems for subsequent projects. This approach ensures that the quality management system is proactive and adaptive to risks, rather than reactive.

Overall, the integration of the RPN findings with ISO 9001:2015 resulted in a structured mitigation strategy, where drainage work quality risks can be controlled through strengthened operational planning, improved competency and work environment, consistent documentation, and ongoing performance evaluation. This framework provides a strong foundation for improving the quality, functional reliability, and sustainability of drainage work in future projects.

#### 4. MANAGERIAL IMPLICATIONS

Managers should adopt an integrated risk management approach combining ISO 9001:2015 and FMEA at every stage of urban drainage projects, enabling proactive risk identification, evaluation of severity, frequency, and failure detection, and prioritization of mitigation measures based on RPN values. Consistent monitoring and inspection of drainage channels must be institutionalized, including routine tasks like cleaning, vegetation management, and structural repairs, to prevent blockages and damage. Effective collaboration between contractors, relevant agencies, and local communities is essential, with public awareness campaigns to reduce blockages caused by waste. A robust data-driven monitoring system should be developed to document risks and RPN periodically, facilitating continuous improvements. Additionally, workforce training focused on ISO 9001:2015 and FMEA methodology will ensure a consistent and effective implementation of quality management and risk mitigation strategies.

#### 5. CONCLUSION


Urban drainage projects face several significant risks, including blockages from waste and sedimentation, physical damage to the channels, such as cracks or collapses, inappropriate slopes or dimensions, incorrect placement of inlets, and poor construction or maintenance controls. These issues lead to flooding, infrastructure damage, operational disruptions, and reduced public satisfaction, highlighting the critical need for effective management and quality control in drainage project execution.


The implementation of ISO 9001:2015 has proven effective in enhancing quality management and risk control in urban drainage projects. However, the approach within ISO 9001:2015 requires integration with FMEA to provide more comprehensive and measurable risk evaluations. By incorporating FMEA, this study found that it allows for root cause identification, impact assessment, and prioritization based on severity, occurrence, and detection, as well as Risk Priority Number (RPN) calculations. This integration ensures continuous improvement and provides a clearer, more systematic framework for identifying and mitigating quality risks in drainage projects.

Ultimately, combining ISO 9001:2015 with FMEA offers significant advantages in managing risks, improving project quality, and ensuring that drainage systems meet both technical standards and user needs. The study concludes that this integrated approach not only enhances quality control but also minimizes construction failures, supporting the long-term sustainability of urban drainage projects.

#### 6. DECLARATIONS

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##### 6.2. Author Contributions

Conceptualization: MW and EK; Methodology: MW and EK; Software: MW; Validation: MW; Formal Analysis: MW and EK; Investigation: MW and EK; Resources: EK; Data Curation: EK; Writing Original Draft Preparation: EK; Writing Review and Editing: EK; Visualization: MW; All authors, MW and EK, have read and agreed to the published version of the manuscript.

##### 6.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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#### 6.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

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