



## **An Integrated PMBOK ISO 9001 DMAIC Framework for Lean Six Sigma Driven Project Quality Management**

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### **Abstract**

This quantitative study examined an integrated PMBOK–ISO 9001–DMAIC framework for Lean Six Sigma–driven project quality management to explain variations in project quality performance. Data were collected from 214 completed and near-completion projects across construction, manufacturing, engineering services, and information systems sectors. Descriptive analysis showed that project quality governance capability recorded a mean score of 3.87 (SD = 0.61), while quality management system maturity demonstrated the highest mean of 3.92 (SD = 0.58), indicating well-established governance and system controls across the sampled projects. Data-driven quality improvement capability achieved a mean of 3.78 (SD = 0.65), and process efficiency orientation recorded a mean of 3.69 (SD = 0.63), reflecting moderate to strong application of DMAIC and Lean practices. Project quality performance outcomes indicated high acceptance compliance with a mean of 3.96 (SD = 0.57), while defect density and rework frequency exhibited lower means of 3.34 (SD = 0.72) and 3.29 (SD = 0.75), respectively, suggesting observable variability in execution quality. Reliability analysis confirmed strong internal consistency, with Cronbach’s alpha values ranging from 0.87 for process efficiency orientation to 0.93 for data-driven quality improvement capability. Multiple regression analysis revealed that project quality governance capability ( $\beta = 0.31, p < 0.001$ ) and quality management system maturity ( $\beta = 0.34, p < 0.001$ ) significantly influenced project quality performance, jointly explaining 47% of the variance. Mediation analysis demonstrated that data-driven quality improvement capability exerted a strong positive effect on project quality performance ( $\beta = 0.39, p < 0.001$ ), while moderation analysis showed that process efficiency orientation significantly strengthened this relationship (interaction  $\beta = 0.17, p < 0.001$ ), increasing explanatory power to 58%. These findings empirically confirmed that project quality performance, reflected through defects, rework, acceptance compliance, process stability, and cost of quality indicators, was most effectively explained through an integrated governance, system control, analytical improvement, and efficiency-oriented framework.

### **Keywords**

Project Quality Management, PMBOK, ISO 9001, DMAIC, Lean Six Sigma.

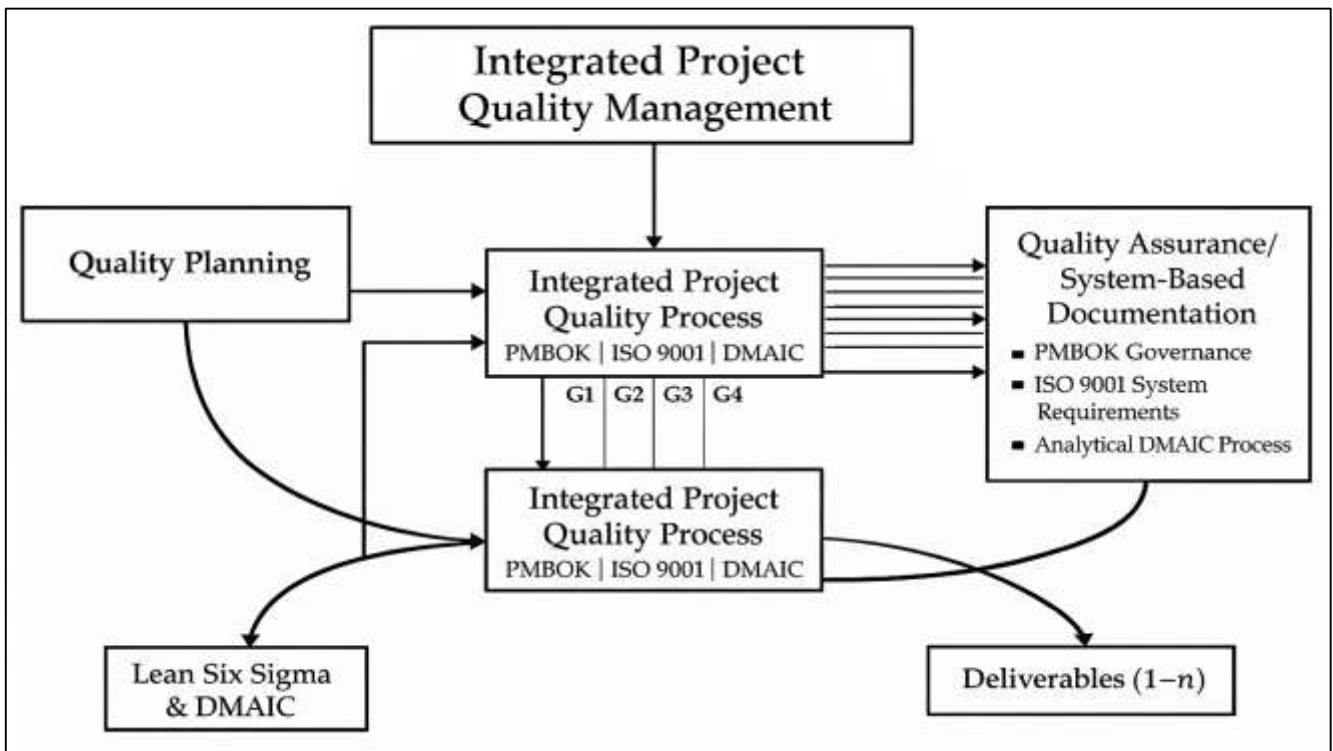
## **INTRODUCTION**

Project quality management is commonly defined as the systematic application of policies, processes, procedures, tools, and techniques to ensure that project deliverables meet explicitly stated requirements and implicitly expected standards (Ingason, 2015). Quality, in this sense, represents the degree to which inherent characteristics of a product, service, or outcome conform to defined specifications and stakeholder needs. Within project environments, quality is operationalized through structured planning, monitoring, verification, and control mechanisms that guide activities from initiation through closure. Lean Six Sigma-driven quality management extends this definition by embedding quantitative performance measurement and defect reduction principles into project execution processes. Lean emphasizes the elimination of non-value-adding activities and flow efficiency, while Six Sigma concentrates on reducing variation and improving process capability. DMAIC functions as a disciplined improvement cycle that translates quality requirements into measurable variables and statistically verifiable outcomes. ISO 9001 defines quality management as a system-based approach centered on process control, documentation, accountability, and continual evaluation, offering an internationally harmonized structure for organizational quality assurance (Ingason, 2020). PMBOK frames project quality management as an integrated knowledge area that links quality planning, quality assurance, and quality control to broader project governance functions. Each of these bodies of knowledge conceptualizes quality as a measurable and controllable construct rather than a subjective judgment. At the international level, projects operate across regulatory regimes, supply chains, cultures, and organizational boundaries, increasing the need for standardized definitions of quality, consistent measurement frameworks, and transparent governance mechanisms. An integrated approach that unifies PMBOK project governance, ISO 9001 system requirements, and DMAIC analytical rigor establishes a coherent foundation for managing quality in complex, data-intensive project environments (Pheng, 2017). This definitional alignment positions project quality management as a structured system of quantifiable controls rather than an isolated inspection activity, reinforcing its relevance in globally distributed and performance-driven project contexts.

Project Management Body of Knowledge-based quality management defines quality planning as the process of identifying relevant standards and translating them into measurable criteria, quality management as the execution of planned activities to ensure process reliability, and quality control as the verification of outputs against acceptance requirements (Rumane, 2017). This structure emphasizes integration with scope definition, scheduling, cost control, risk management, and stakeholder coordination, reflecting the interconnected nature of quality outcomes within project systems. Quality in projects is inseparable from governance mechanisms that regulate decision authority, change control, and performance reporting. ISO 9001 complements this project-centric view by defining quality management as a system of interrelated processes supported by documented information, leadership responsibility, resource competence, and evidence-based evaluation. Its process-based orientation establishes traceability between inputs, activities, outputs, and performance indicators, enabling organizations to demonstrate conformity and control across operational boundaries. DMAIC introduces a quantitative logic that structures problem definition, measurement system validation, statistical analysis, solution optimization, and control stabilization (Natarajan, 2017). Within project settings, DMAIC functions as an analytical engine that strengthens quality assurance and control activities through data-driven validation rather than assumption-based judgment. Lean principles further reinforce this structure by identifying waste, bottlenecks, and inefficiencies that compromise both quality and delivery performance. Together, PMBOK, ISO 9001, and DMAIC provide complementary perspectives on quality governance, system assurance, and analytical improvement. Their integration supports the alignment of project objectives with organizational quality policies while maintaining measurable accountability at each stage of the project lifecycle. In international project environments characterized by contractual complexity and regulatory scrutiny, such alignment reduces ambiguity in quality roles, documentation standards, and performance metrics (Hoyle, 2017). This integrated perspective establishes quality management as a core project function grounded in standardized systems and quantitative evidence rather than fragmented procedural compliance. ISO 9001 occupies a central position in international quality management due to its widespread adoption across industries and its role as a benchmark for organizational credibility and process

discipline. The standard defines quality management systems as structured frameworks that ensure consistency, traceability, and accountability in operational activities (Jahn & Keil, 2015). Its requirements emphasize process identification, risk-based thinking, performance monitoring, internal auditing, and corrective action, all of which are directly relevant to project environments where variability and uncertainty are inherent. Projects frequently involve multiple organizational interfaces, subcontractors, and external providers, making system-level controls essential for maintaining quality consistency across boundaries. PMBOK-based project governance addresses this complexity by defining roles, responsibilities, and control points throughout the project lifecycle. When ISO 9001 system requirements are embedded into project governance structures, quality documentation, change management, and nonconformance handling become integral components of project execution rather than parallel administrative tasks (Fischer et al., 2020). DMAIC strengthens this integration by providing a quantitative mechanism for diagnosing quality deviations and verifying corrective actions through statistical validation. Lean Six Sigma further enhances system coherence by linking process efficiency to quality outcomes, recognizing that delays, rework, and waste contribute directly to defect generation. International projects benefit from this unified structure by achieving consistency in quality definitions, measurement logic, and reporting formats across geographic and organizational contexts. The integration of ISO 9001 with PMBOK and DMAIC transforms quality management from a compliance-oriented function into a performance-oriented system that is measurable, auditable, and analytically grounded (Steiss, 2019). This approach supports comparability of quality outcomes across projects and regions, reinforcing the role of standardized quality systems in global project delivery environments.

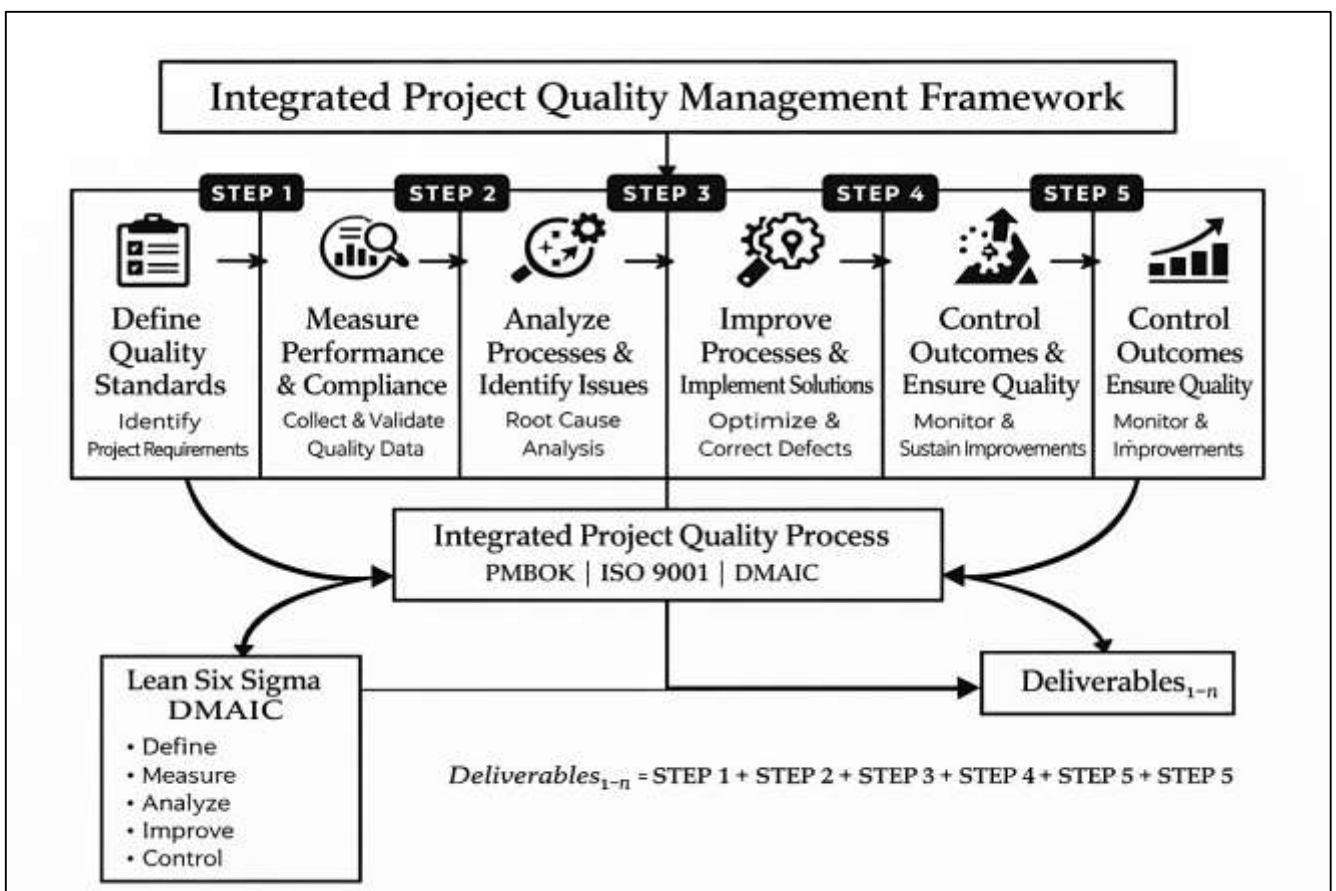
Figure 1: Integrated Project Quality Management Framework



DMAIC serves as the quantitative core of Lean Six Sigma by structuring improvement activities into five analytically sequenced phases. The Define phase operationalizes quality by translating stakeholder requirements into critical-to-quality variables and clearly bounded problem statements (Rauf, 2018; Solihin & Eastman, 2015). This aligns directly with project quality planning activities that establish acceptance criteria, performance thresholds, and baseline metrics. The Measure phase emphasizes data integrity, measurement system reliability, and baseline performance assessment, reinforcing objective evaluation over subjective perception. In project contexts, this phase strengthens quality control by ensuring that performance indicators accurately reflect process behavior and deliverable conformity.

The Analyze phase applies statistical methods to identify root causes of quality variation, shifting decision making from intuition to empirical validation. The Improve phase focuses on optimizing process performance through tested solutions that directly address verified causes of defects or inefficiencies (Kensek, 2015). The Control phase institutionalizes improvements by embedding monitoring mechanisms, standardized procedures, and response protocols into routine operations. When integrated with ISO 9001, these control mechanisms align with documented process controls, corrective action systems, and management review requirements. When integrated with PMBOK, DMAIC outputs align with project baselines, change control processes, and performance reporting cycles. Lean principles enhance this structure by emphasizing process flow, waste elimination, and value alignment, ensuring that quality improvements also support efficiency and delivery reliability. In internationally distributed project environments, DMAIC provides a common analytical language that supports consistent evaluation of quality performance across diverse teams and contexts (Thai, 2017). Its integration within a standardized governance framework strengthens the quantitative foundation of project quality management.

Figure 2: Integrated Project Quality Management Framework



The integration of ISO 9001 into project-based environments requires alignment between permanent organizational systems and the temporary nature of projects. ISO 9001 defines organizational processes as stable structures designed to ensure consistent outcomes, while projects operate as time-bound endeavors with unique deliverables and constraints (Haque & Arifur, 2021; Jinnat & Kamrul, 2021; Picciotto, 2020). PMBOK addresses this challenge by framing projects as managed systems governed by standardized processes that can be tailored to context. When ISO 9001 requirements are embedded into project management plans, quality policies, document control procedures, and audit mechanisms become intrinsic to project execution. This integration ensures that project activities remain traceable, verifiable, and aligned with organizational quality objectives. DMAIC enhances this alignment by enabling projects to quantify performance deviations and validate corrective actions within the system framework. Lean Six Sigma further supports this integration by promoting standardized work and

continuous measurement at the process level, even within temporary project structures (Di Ciccio et al., 2015; Haque & Arifur, 2020; Ashraful et al., 2020). The combination of system-level assurance, project-level governance, and analytical improvement creates a cohesive quality architecture that supports consistency without sacrificing adaptability. In international projects involving regulatory oversight and contractual accountability, such coherence strengthens transparency and accountability. Quality management functions transition from isolated checkpoints to integrated control systems that span planning, execution, and verification. This integrated framework positions project quality management as a structured, evidence-based discipline grounded in both organizational systems and project-specific controls (Cagliano et al., 2015; Fokhrul et al., 2021; Zaman et al., 2021).

Lean Six Sigma-driven project quality management conceptualizes improvement initiatives as structured projects with defined objectives, resources, timelines, and performance metrics. This projectized nature aligns naturally with PMBOK governance structures, enabling quality improvement activities to be managed using the same controls applied to delivery-focused projects (Bunger et al., 2017). DMAIC deliverables can be embedded into project documentation as quality baselines, analytical reports, and control artifacts. Lean measurement constructs such as cycle time, flow efficiency, and value-added ratios complement Six Sigma metrics focused on defects and variation. Together, these measures provide a multidimensional view of project quality performance that captures both effectiveness and efficiency. ISO 9001 supports this measurement structure by requiring documented evidence, monitoring procedures, and corrective action records (Cichy & Rass, 2019; Hammad, 2022; Hasan & Waladur, 2022). The integration of these measurement systems reduces ambiguity in quality reporting and enhances comparability across projects. In global project portfolios, consistent measurement definitions enable aggregation and benchmarking of quality performance. Quantitative quality management strengthens decision making by linking improvement actions to statistically verified outcomes rather than anecdotal assessments. The integration of governance, system assurance, and analytics establishes a disciplined approach to managing quality as a controllable project variable. This framework reinforces accountability and measurement coherence across project teams and organizational boundaries (Arifur & Haque, 2022; Towhidul et al., 2022; Song, 2017).

A quantitative orientation to an integrated PMBOK–ISO 9001–DMAIC framework is grounded in the premise that project quality outcomes can be operationalized, measured, and statistically evaluated (Hasnain et al., 2018). Quality performance indicators such as defect density, rework frequency, process capability indices, cycle time variance, conformance rates, and cost of quality components provide objective data for analysis. DMAIC structures the use of these indicators by linking them to defined improvement cycles and validated control mechanisms (Eskerod & Jepsen, 2016). ISO 9001 reinforces measurement discipline by requiring organizations to define monitoring criteria, evaluate results, and maintain documented evidence. PMBOK governance provides the temporal and structural logic for when measurements are collected, reviewed, and acted upon within the project lifecycle. Lean measurement constructs further enhance this framework by identifying inefficiencies that indirectly affect quality outcomes (Kivilä et al., 2017). The integration of these measurement traditions supports robust quantitative analysis of project quality management effectiveness. By unifying governance structures, system requirements, and analytical methods, the integrated framework establishes a comprehensive foundation for examining project quality performance through measurable variables. This positioning supports empirical evaluation of quality management practices across projects, industries, and international contexts without reliance on subjective judgment or narrative assessment (Alsaqaf et al., 2017).

The primary objective of this study is to systematically examine and operationalize an integrated project quality management framework that combines PMBOK-based project governance, ISO 9001 quality management system requirements, and the DMAIC methodology of Lean Six Sigma within a unified, quantitatively measurable structure. This objective is grounded in the need to conceptualize project quality management as a cohesive system in which planning, execution, measurement, and control activities are aligned through standardized processes and data-driven improvement logic. The study aims to define how PMBOK quality management processes can be structurally synchronized with ISO 9001 system controls to ensure consistency, traceability, and accountability throughout the project lifecycle. At the same time, it seeks to embed DMAIC as the analytical mechanism that translates

quality requirements into measurable performance indicators and statistically verifiable improvement outcomes. A central objective is to identify and formalize the interrelationships among project governance mechanisms, system-level quality controls, and improvement cycle phases in order to create an integrated architecture that supports objective measurement of project quality performance. The study further aims to establish quantifiable constructs that capture both efficiency- and conformance-oriented dimensions of project quality, including defect occurrence, rework intensity, process stability, and compliance with predefined acceptance criteria. Another objective is to enable the consistent application of quality measurement and control practices across projects by aligning documentation, metrics, and review processes within a single framework. Through this integration, the study seeks to support empirical assessment of how coordinated governance, standardized system requirements, and analytical improvement methods collectively influence project quality outcomes. The objective also includes structuring the framework in a manner that facilitates statistical testing of relationships among framework components, allowing project quality management practices to be evaluated using quantitative data rather than descriptive judgment. By articulating this integrated framework, the study aims to provide a structured basis for examining project quality management as a measurable and controllable system, emphasizing alignment, coherence, and analytical rigor across PMBOK, ISO 9001, and DMAIC elements within Lean Six Sigma-driven project environments.

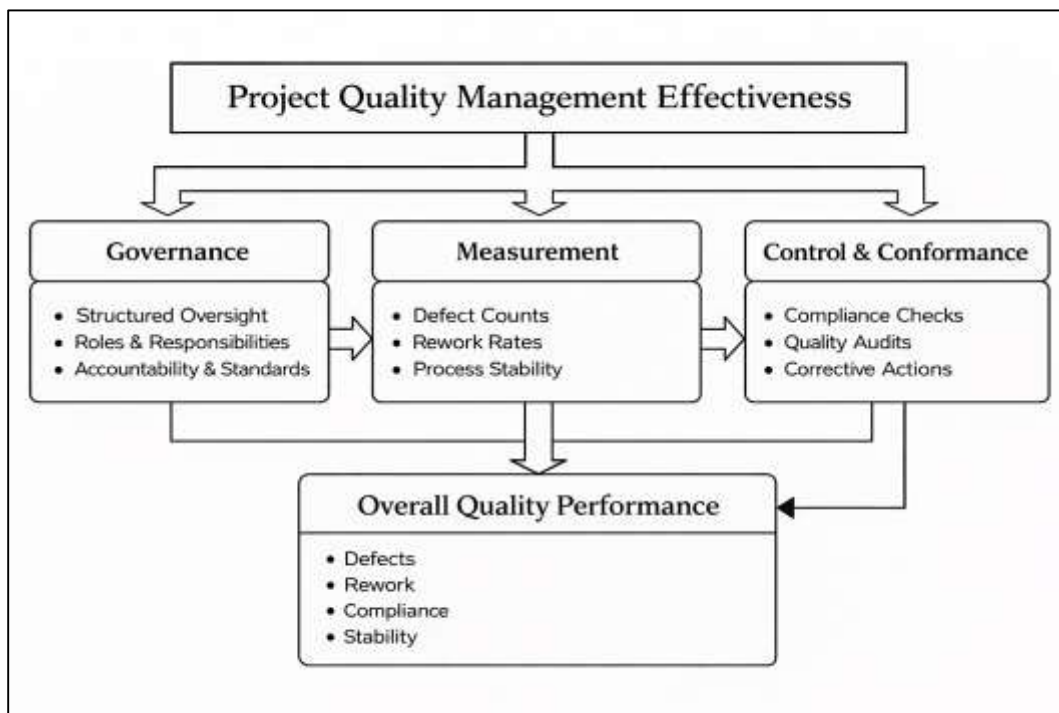
### **LITERATURE REVIEW**

The literature on project quality management spans multiple disciplinary domains, including project management, quality management systems, operations management, and continuous improvement methodologies. Within this body of knowledge, quality has been examined as both a governance outcome and a process capability, with increasing emphasis on measurable performance indicators rather than subjective assessments (Marchiori & Mendes, 2020). Project Management Body of Knowledge-based frameworks conceptualize quality management as an integral project function that operates across planning, execution, monitoring, and control phases, linking quality outcomes to scope definition, stakeholder requirements, and performance reporting. Parallel to this, ISO 9001-based quality management systems define quality through standardized, auditable processes that emphasize documentation, consistency, risk-based control, and evidence-based evaluation. Lean Six Sigma literature, anchored in the DMAIC methodology, advances a data-driven approach that treats quality as a statistically controllable variable shaped by variation reduction and process capability improvement. Although each of these frameworks has been extensively examined in isolation, the literature reveals fragmentation in how project quality governance, system-level quality assurance, and analytical improvement methods are conceptually and empirically connected (Tylka & Wood-Barcalow, 2015). Existing studies frequently address PMBOK, ISO 9001, or Lean Six Sigma independently, resulting in parallel streams of research that seldom converge into a unified analytical model. Project management studies often emphasize lifecycle control and stakeholder satisfaction, while ISO 9001 research focuses on system compliance and organizational performance, and DMAIC-based studies concentrate on defect reduction and efficiency gains. This separation limits the ability to empirically assess how governance structures, standardized system requirements, and analytical improvement cycles jointly influence project quality performance. Quantitative studies have increasingly called for integrated models that align quality planning, measurement, and control within a single framework capable of producing comparable and statistically testable outcomes (Abbas, 2020). Within complex and internationally distributed project environments, inconsistent definitions of quality metrics and control mechanisms further complicate empirical evaluation. Accordingly, this literature review synthesizes research across project management, quality management systems, and Lean Six Sigma to establish a structured theoretical foundation for an integrated PMBOK–ISO 9001–DMAIC framework. The review is organized around measurable constructs and empirically examined relationships that inform the development of a coherent project quality management architecture. Emphasis is placed on identifying how governance mechanisms, system-level controls, and DMAIC phases contribute to quantifiable project quality outcomes (Li et al., 2018). By structuring the literature around analytically defined dimensions, this section provides the conceptual grounding necessary for developing a testable quantitative model of Lean Six Sigma-driven project quality management.

### Project Quality Management

Project quality management is conceptually grounded in the treatment of quality as a measurable and systematically controllable construct within project environments. In the literature, quality is not framed as a subjective perception but as an operational condition defined by explicit requirements, performance thresholds, and verification criteria (Ross, 2017). Project quality management effectiveness is therefore understood as the degree to which project processes and deliverables conform to predefined standards while maintaining consistency throughout the project lifecycle. This perspective emphasizes that quality must be embedded into planning, execution, and control mechanisms rather than assessed solely at delivery. Scholars have consistently conceptualized project quality as a function of structured governance, disciplined measurement, and controlled execution, reinforcing its suitability for quantitative examination. Measurement-based interpretations of quality align with broader quality management traditions that view performance variability, defect occurrence, and process stability as indicators of system effectiveness (Samset & Volden, 2016). Within project contexts, quality management effectiveness extends beyond deliverable inspection to include the reliability of processes that generate those deliverables. This orientation positions project quality as an outcome of managerial systems rather than isolated technical activities. The literature further establishes that effective project quality management depends on the clarity with which requirements are translated into measurable criteria and embedded into governance frameworks. By framing quality as a measurable construct, researchers emphasize the importance of objective indicators that allow for comparison, monitoring, and control across projects (Mizuno, 2020). This conceptual foundation supports the examination of project quality management as an integrated managerial function capable of producing consistent, verifiable outcomes across organizational and sectoral boundaries.

Figure 3: Project Quality Management Effectiveness Model



A central distinction in the literature on project quality management lies between quality conformance and quality performance. Quality conformance refers to the extent to which project outputs meet predefined specifications, standards, and acceptance criteria (Estoque et al., 2019). It is typically evaluated through inspection results, defect counts, and compliance rates. Quality performance, by contrast, reflects how effectively project processes operate in achieving stability, efficiency, and reliability over time. While conformance focuses on meeting minimum requirements, performance captures the capability of project systems to consistently produce acceptable outcomes. The literature

highlights that project may achieve short-term conformance while exhibiting poor underlying performance, resulting in rework, inefficiencies, and instability (Beckford, 2016). This distinction has led scholars to argue that project quality management effectiveness must account for both dimensions simultaneously. Conformance indicators alone fail to capture systemic weaknesses that manifest as recurring defects or performance variation. Conversely, performance metrics without conformance validation may obscure noncompliance risks. As a result, quality is increasingly treated as a dual construct encompassing both outcome conformity and process capability. This duality is particularly relevant in complex project environments where variability in scope, resources, and stakeholder expectations can affect both deliverables and execution processes (Preiser et al., 2015). The literature underscores that balancing conformance and performance requires structured governance mechanisms that integrate planning standards with ongoing measurement and corrective control. This balanced view reinforces the need for multidimensional quality models that move beyond binary assessments of success or failure and instead evaluate quality as a continuous and quantifiable managerial outcome. Project quality is widely recognized in the literature as a multidimensional variable composed of interrelated indicators that collectively represent overall quality performance. Common dimensions include defect frequency, rework intensity, acceptance compliance, and process stability (Weimer & Vining, 2017). Defects represent deviations from specifications and are often quantified through counts, rates, or density measures. Rework captures the extent to which deliverables or processes require correction, reflecting inefficiencies and control weaknesses. Acceptance compliance measures the proportion of deliverables that meet stakeholder and contractual requirements without modification. Process stability refers to the consistency of performance over time, indicating the presence or absence of excessive variation. Together, these dimensions provide a comprehensive representation of project quality that extends beyond single-point assessments (Tennant, 2017). The literature emphasizes that relying on a single indicator can produce misleading conclusions, as quality outcomes often result from interactions among multiple factors. Multidimensional measurement frameworks enable researchers and practitioners to identify trade-offs, patterns, and systemic issues that influence overall quality effectiveness. This approach aligns with quantitative quality management traditions that emphasize statistical evaluation, trend analysis, and performance monitoring. By conceptualizing project quality as a composite construct, the literature supports the development of analytical models capable of capturing nuanced variations in quality outcomes (Demirkesen & Ozorhon, 2017). This multidimensional perspective also facilitates cross-project comparison and benchmarking by standardizing how quality is defined and measured across contexts.

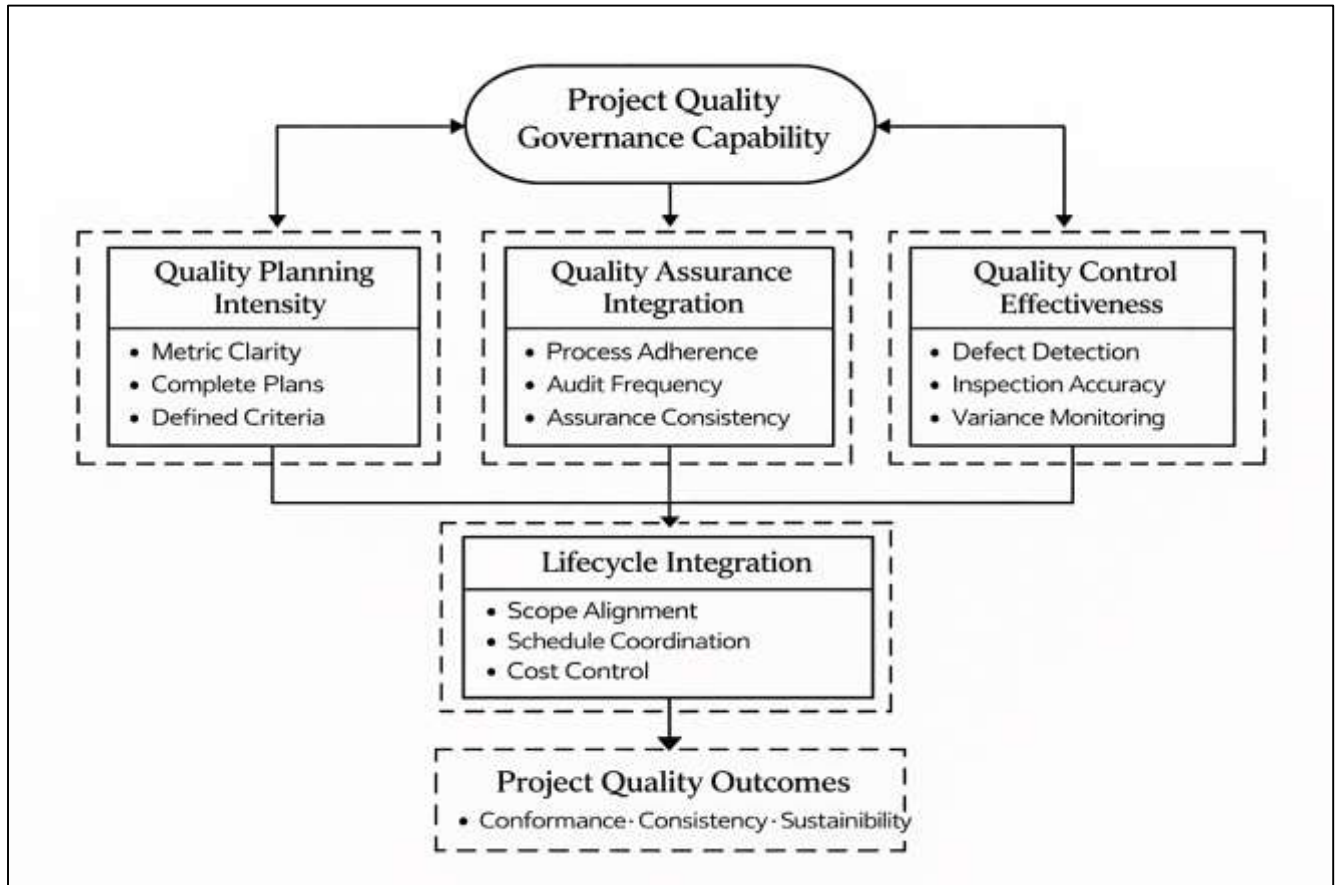
Governance structures play a critical role in shaping project quality outcomes by determining how quality requirements are established, monitored, and enforced. The literature consistently identifies governance as the mechanism through which accountability, authority, and control are exercised in project environments (Kowalkowski et al., 2017). Effective governance structures define roles and responsibilities for quality planning, assurance, and control, ensuring that quality is integrated into decision-making processes rather than treated as an operational afterthought. Governance influences the consistency of quality measurement by standardizing reporting formats, review cycles, and escalation procedures. It also affects responsiveness to quality deviations through formalized corrective action pathways. The presence of clear governance mechanisms has been associated with reduced ambiguity in quality expectations and improved alignment between project objectives and organizational standards (Buttle & Maklan, 2019). Conversely, weak governance structures are linked to fragmented quality practices, inconsistent measurement, and reactive control. The literature emphasizes that governance structures enable the institutionalization of quality management practices by embedding them into formal project systems. This institutionalization supports sustained quality performance by reinforcing disciplined execution and continuous oversight. In quantitative research, governance variables often serve as explanatory factors that influence measurable quality outcomes. By shaping how quality information is generated, interpreted, and acted upon, governance structures directly affect project quality management effectiveness (Ivanov et al., 2016). This relationship underscores the importance of examining governance not merely as an administrative function but as a determinant of measurable project quality performance.

### **PMBOK-Based Project Quality Management**

Project quality governance capability is widely conceptualized in the literature as the structured capacity of project management systems to define, coordinate, and enforce quality-related decisions throughout the project lifecycle (Jong et al., 2019). Within PMBOK-based frameworks, quality planning intensity represents a core governance mechanism through which quality expectations are operationalized into explicit requirements and acceptance criteria. The literature consistently emphasizes that effective quality planning involves translating stakeholder needs, contractual obligations, and technical specifications into measurable quality parameters that can be monitored and verified. Planning intensity reflects not only the presence of quality plans but also the depth, clarity, and specificity with which quality metrics are defined (Isacás-Ojeda et al., 2018). Projects with higher planning intensity demonstrate greater alignment between quality objectives and execution activities because quality requirements are embedded into scope definitions, work breakdown structures, and baseline documents. Quantification of planning completeness is frequently discussed as the extent to which quality criteria cover all critical deliverables and processes, minimizing ambiguity during execution. Metric clarity is treated as a governance attribute that determines whether project teams share a consistent understanding of acceptable performance thresholds. The literature indicates that vague or incomplete quality planning weakens governance by increasing reliance on subjective judgment during inspections and reviews (Kurniawan, 2018). Conversely, detailed and well-structured planning frameworks support objective evaluation and accountability. From a quantitative perspective, quality planning intensity enables the consistent generation of measurable indicators that support comparative analysis across projects. Governance-oriented studies highlight that quality planning functions as an early control mechanism that shapes downstream assurance and control effectiveness. As a result, quality planning intensity is positioned as a foundational dimension of project quality governance capability, influencing how effectively quality objectives are communicated, monitored, and enforced throughout project execution (Palma et al., 2019).

Quality assurance integration represents a second critical dimension of PMBOK-based project quality governance capability, emphasizing the systematic coordination of assurance activities across project phases. The literature characterizes quality assurance as the set of planned and systematic actions implemented to provide confidence that quality requirements will be fulfilled (Gurjar, 2016). Within governance-oriented perspectives, assurance integration reflects the degree to which quality assurance activities are embedded into routine project management processes rather than treated as isolated compliance checks. Process adherence is frequently identified as a key assurance indicator, reflecting how consistently project activities follow defined procedures and standards. Audit frequency is another commonly discussed element, serving as a governance mechanism that reinforces accountability and provides structured feedback on process performance. Governance controls such as review boards, approval gates, and documented evaluations contribute to assurance consistency by standardizing how quality information is assessed and acted upon (Tsochev & Stankov, 2020). The literature emphasizes that assurance effectiveness depends on consistency across project phases, ensuring that quality standards are maintained from initiation through closure. Inconsistent assurance practices introduce variability that undermines the reliability of quality outcomes. Quantitative research approaches often operationalize assurance integration through indicators such as audit coverage, review regularity, and adherence rates. These indicators allow governance capability to be evaluated empirically rather than descriptively. Studies also highlight that assurance integration strengthens transparency by creating traceable records of quality evaluations and corrective actions. This traceability supports governance effectiveness by linking decisions to documented evidence (Haq et al., 2018). Overall, quality assurance integration is positioned as a governance mechanism that stabilizes project quality performance by ensuring disciplined adherence to defined standards across the entire project lifecycle.

Figure 4: Project Quality Governance Capability Framework



Quality control effectiveness is extensively discussed in the literature as the operational dimension of project quality governance that directly influences measurable quality outcomes. Within PMBOK-based frameworks, quality control focuses on monitoring specific project results to determine whether they comply with relevant quality standards and identifying ways to eliminate causes of unsatisfactory performance (Müller et al., 2016). Governance-oriented analyses treat quality control effectiveness as a function of the reliability, accuracy, and responsiveness of control mechanisms. Defect detection rates are commonly used to assess the sensitivity of control systems in identifying deviations from requirements. Inspection accuracy reflects the ability of quality control processes to correctly distinguish between conforming and nonconforming outputs. Variance monitoring captures the extent to which deviations in performance are identified and tracked over time. The literature emphasizes that effective quality control relies on objective measurement rather than subjective assessment, reinforcing its suitability for quantitative evaluation (Müller et al., 2015). Statistical indicators are frequently discussed as tools that enhance governance by providing evidence-based insights into process behavior and outcome stability. Control effectiveness is also linked to the timeliness of detection and correction, as delayed responses increase rework and quality-related costs. Studies consistently indicate that weak control systems result in reactive governance, where quality issues are addressed only after significant deviation has occurred. In contrast, strong control mechanisms support proactive governance by enabling early intervention. From a governance capability perspective, quality control effectiveness reflects the extent to which project management systems can maintain stability under operational variability (Brunet & Aubry, 2016). This dimension of governance directly influences project credibility, stakeholder confidence, and performance consistency. As such, quality control effectiveness is treated as a measurable and central component of project quality governance capability.

Integration with project lifecycle controls represents a higher-order governance dimension that links quality management activities with scope, schedule, and cost control mechanisms. The literature emphasizes that quality governance cannot function independently from other project control systems, as quality outcomes are inherently influenced by changes in scope, time constraints, and resource

allocation (Müller et al., 2017). Alignment of quality metrics with scope baselines ensures that quality requirements correspond directly to defined deliverables rather than abstract standards. Schedule alignment ensures that quality activities such as inspections, reviews, and audits are incorporated into project timelines, reducing the likelihood of compressed or omitted controls. Cost alignment reflects the recognition that quality-related activities require resource allocation and that insufficient budgeting undermines governance effectiveness. Change control mechanisms play a critical role in maintaining quality stability by regulating how modifications to scope or requirements are evaluated and approved. The literature treats change control as a governance safeguard that prevents uncontrolled variation from eroding quality performance (Chang, 2015). Quantitative discussions often associate effective change control with reduced defect recurrence and improved consistency in quality outcomes. Integration across lifecycle controls enables coherent decision making by ensuring that quality implications are systematically considered alongside schedule and cost impacts. Studies highlight that fragmented control systems weaken governance by creating conflicting priorities and inconsistent metrics. Conversely, integrated controls support balanced decision making and sustained quality performance. This integration reinforces project quality governance capability by embedding quality considerations into all major project management decisions (Haq et al., 2019). As a result, lifecycle integration is positioned as a defining feature of mature and effective project quality governance systems.

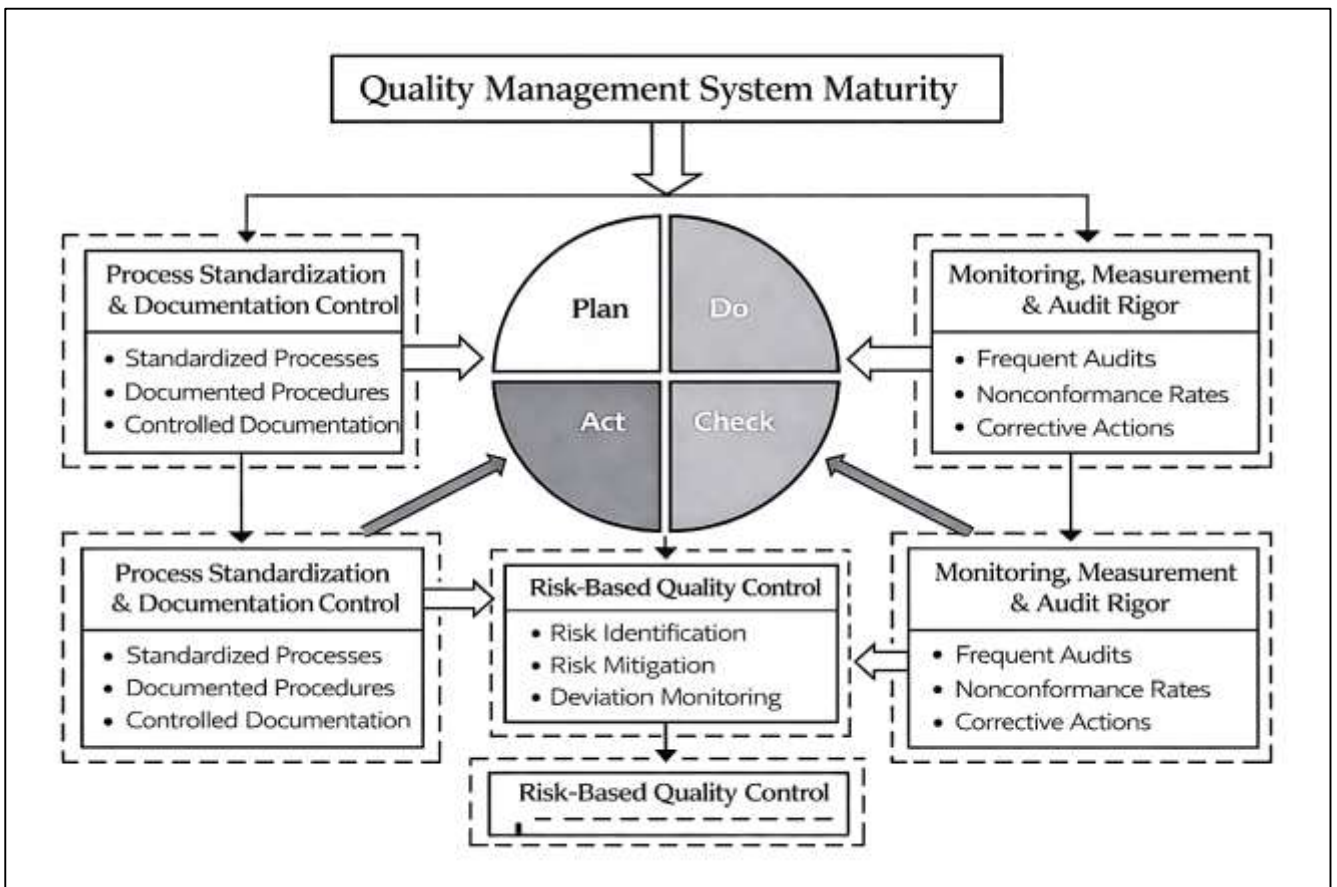
### **ISO 9001 Quality Management System**

Quality management system maturity is extensively discussed in the literature as an indicator of how effectively organizational quality structures are formalized, institutionalized, and embedded into operational and project-based activities (Psomas & Antony, 2015). Within ISO 9001-based frameworks, process standardization and documentation control are regarded as foundational elements of system maturity. Process standardization refers to the extent to which organizational activities are defined, documented, and executed in a consistent manner across functions and projects. Documentation control ensures that procedures, work instructions, records, and quality plans remain current, traceable, and accessible to relevant stakeholders. The literature emphasizes that higher degrees of formalization reduce ambiguity by clarifying roles, responsibilities, and process interfaces (Natarajan, 2017). Traceability is treated as a critical system attribute that links requirements to execution and verification, enabling organizations to track how quality objectives are translated into operational outcomes. Documentation completeness reflects whether all critical processes and quality-relevant activities are formally captured, while documentation consistency refers to alignment across documents, departments, and project teams. Studies highlight that incomplete or inconsistent documentation weakens system control by introducing variability in interpretation and execution (Ismyrlis & Moschidis, 2015). Conversely, well-maintained documentation systems support repeatability and comparability, which are essential for quantitative assessment of quality performance. From a system control perspective, standardized processes and controlled documentation provide the structural backbone for monitoring, auditing, and corrective action. The literature positions these elements as prerequisites for reliable measurement because quality data cannot be meaningfully interpreted when underlying processes lack stability or clarity (Albulescu et al., 2016). As a result, process standardization and documentation control are widely treated as core indicators of quality management system maturity, influencing the organization's capacity to sustain consistent quality outcomes across projects.

Risk-based quality control mechanisms constitute a second critical dimension of ISO 9001-driven system maturity, reflecting the shift from reactive inspection toward proactive control of potential quality deviations. The literature characterizes risk-based thinking as the systematic identification, assessment, and management of factors that may affect the conformity of products, services, or project deliverables (Rodríguez-Mantilla, Martínez-Zarzuelo, et al., 2020). Within quality management systems, risk identification involves recognizing sources of variability, failure modes, and process vulnerabilities that could compromise quality performance. Risk mitigation focuses on implementing controls that reduce the likelihood or impact of these potential deviations. Quantitative treatment of risk is discussed in terms of prioritization, categorization, and monitoring of risk-related indicators, enabling organizations to allocate control efforts based on significance rather than intuition. The

literature consistently links effective risk controls with reduced incidence of nonconformance and improved process stability. System maturity is reflected in the extent to which risk considerations are embedded into routine quality planning, operational controls, and decision-making processes. Weak risk integration results in fragmented controls that address symptoms rather than underlying causes (Ong et al., 2015). Strong risk-based mechanisms, by contrast, enable early intervention and structured response. The relationship between risk controls and quality deviation rates is frequently examined as an indicator of system effectiveness, with lower deviation rates associated with more mature risk management practices. Risk-based quality control enhances system reliability by aligning preventive actions with identified vulnerabilities. This alignment strengthens the analytical foundation of quality management systems and supports consistent performance across projects (Drosos et al., 2017). The literature therefore positions risk-based quality control as a defining attribute of advanced system maturity rather than a supplementary compliance activity.

Figure 5: Quality Management System Maturity Framework



Monitoring, measurement, and audit rigor are central to the operational credibility of ISO 9001-based quality management systems and are widely treated as indicators of system reliability and control strength. Monitoring refers to the continuous observation of process performance against defined criteria, while measurement involves the systematic collection of data to quantify conformity and variation (Rodríguez-Mantilla, Fernández-Cruz, et al., 2020). Audit rigor encompasses the structured evaluation of system implementation, process adherence, and effectiveness of controls. The literature highlights audit frequency as a visible indicator of management commitment to quality oversight, with regular audits reinforcing discipline and accountability. Nonconformance rates are commonly discussed as measurable outputs of monitoring systems, reflecting the degree to which processes deviate from established requirements. Corrective action closure time captures the responsiveness of the system in addressing identified issues. Together, these indicators provide insight into the robustness of system control mechanisms. Studies emphasize that monitoring and auditing lose effectiveness when treated as procedural formalities rather than analytical tools (Betlloch-Mas et al.,

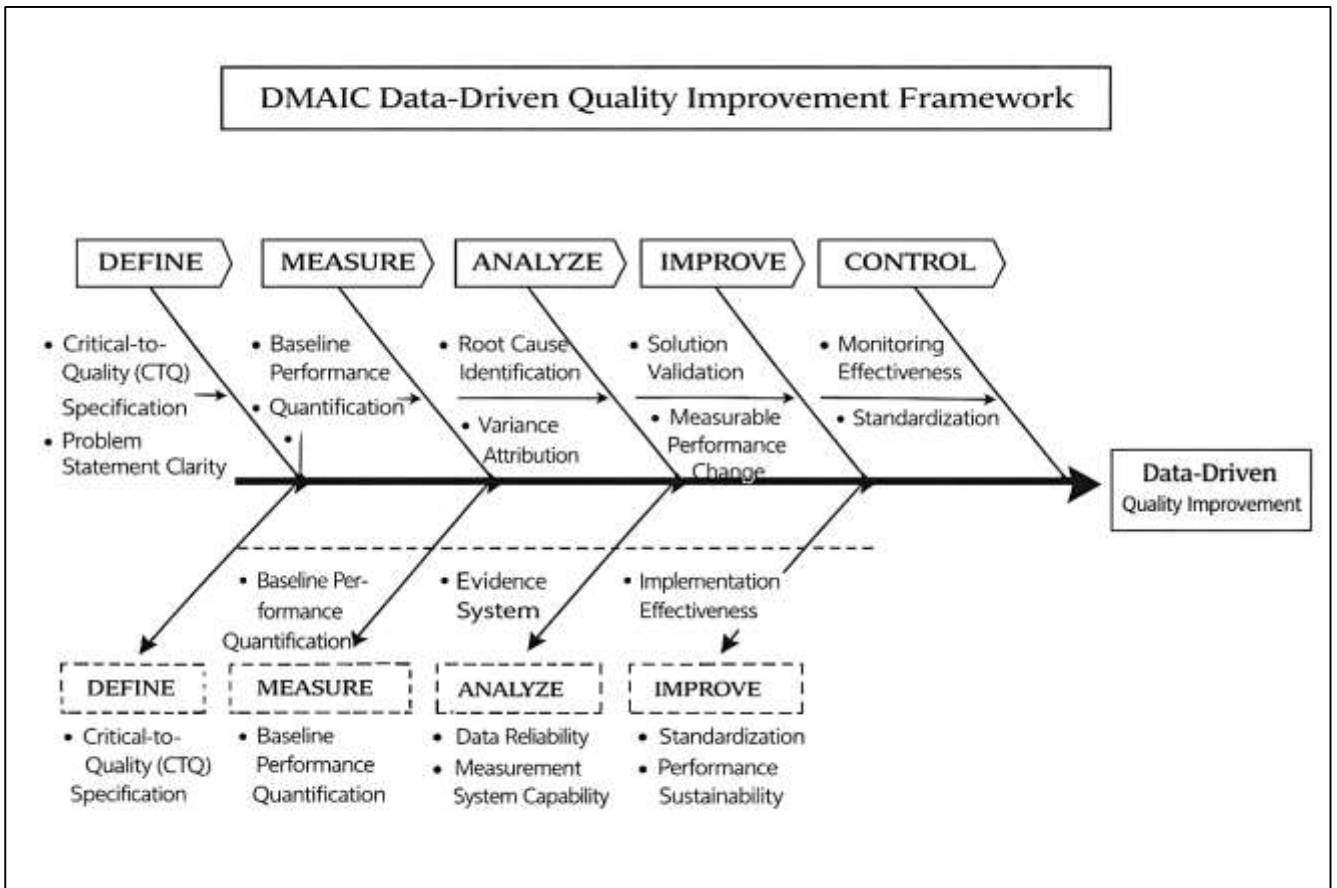
2019). Mature systems demonstrate consistency in audit execution, clarity in reporting, and follow-through in corrective action. Statistical indicators are often discussed as means of evaluating system reliability by identifying trends, patterns, and stability over time. Reliable systems exhibit predictable performance with limited unexplained variation. Weak systems show erratic patterns and delayed response. Monitoring and audit rigor support quantitative evaluation by generating structured data suitable for analysis and comparison. This dimension of system maturity reinforces transparency and evidence-based decision making (Franceschini et al., 2018). The literature positions rigorous monitoring and auditing as essential for maintaining control over complex project environments where variability and uncertainty are inherent.

### **DMAIC Methodology**

The DMAIC methodology is widely conceptualized in the quality management literature as a structured, data-driven improvement cycle that operationalizes analytical rigor within organizational and project environments (Nandakumar et al., 2020). As a mediating construct, data-driven quality improvement capability reflects the extent to which organizations systematically translate quality requirements into measurable variables, analyze performance variation, and implement validated corrective actions. The Define phase establishes the analytical foundation by converting stakeholder needs and project requirements into clearly articulated critical-to-quality characteristics and problem statements. The literature emphasizes that accurate requirement translation is essential for analytical coherence, as poorly defined objectives undermine subsequent measurement and analysis. Quantitative clarity in this phase refers to the precision with which quality expectations are expressed, including the explicit identification of performance boundaries and defect definitions (Peruchi et al., 2020). Clear CTQ specification ensures alignment between governance objectives and analytical focus, reducing ambiguity in data interpretation. Studies consistently highlight that project with well-defined CTQs demonstrate stronger analytical continuity across improvement phases. Problem statement clarity is also treated as an indicator of methodological discipline, shaping the scope and relevance of analysis activities. Within project quality management, the Define phase functions as a boundary-setting mechanism that determines the relevance of collected data and the validity of improvement conclusions. As such, data-driven improvement capability is partially mediated by the rigor with which quality objectives are articulated at the outset (Basios & Loucopoulos, 2017). The literature positions this phase as a critical linkage between governance-defined quality goals and analytical execution, reinforcing DMAIC's role as an integrative mechanism rather than a standalone technical tool.

The Measure phase represents the empirical core of DMAIC by establishing the reliability and integrity of data used for quality evaluation. Literature on data-driven improvement emphasizes that measurement system credibility is a prerequisite for meaningful analysis and decision making (Smętkowska & Mrugalska, 2018). Data reliability reflects the consistency, accuracy, and completeness of measurement processes, while data integrity concerns the validity and traceability of collected information. Measurement system capability is discussed as the degree to which measurement processes produce stable and reproducible results under consistent conditions. Baseline performance quantification provides a reference point against which variation and improvement can be assessed. The literature underscores that unreliable data compromises the entire improvement cycle by introducing noise that obscures true process behavior. In project environments, measurement challenges are compounded by temporary structures, multiple data sources, and varying stakeholder interpretations. Mature DMAIC applications address these challenges by standardizing data definitions, collection procedures, and validation protocols (Gaikwad et al., 2019). Baseline establishment is treated as a governance-relevant activity because it creates transparency regarding current performance levels and performance gaps. Quantitative baselines enable objective comparison across time, processes, or projects, supporting analytical consistency. Studies consistently associate strong measurement discipline with improved confidence in analytical findings and corrective actions. As a mediating construct, data-driven quality improvement capability is strengthened when measurement systems provide dependable evidence for subsequent analysis and intervention. The Measure phase thus serves as a stabilizing mechanism that aligns analytical rigor with project quality governance requirements (Srinivasan et al., 2016).

Figure 6: DMAIC Quality Improvement Fishbone Framework



The Analyze phase embodies the diagnostic dimension of DMAIC, focusing on identifying and validating the root causes of quality variation. The literature characterizes analytical depth as the extent to which systematic and evidence-based techniques are applied to distinguish meaningful patterns from random fluctuation (Sin et al., 2015). Root cause validation is treated as a critical differentiator between superficial problem-solving and disciplined quality improvement. Variance attribution involves linking observed performance deviations to specific process inputs, conditions, or behaviors. Analytical rigor in this phase is associated with the structured exploration of relationships among variables rather than reliance on anecdotal explanation. The literature emphasizes that effective analysis requires both methodological discipline and contextual understanding of project processes. Inadequate analytical depth often leads to misidentification of causes, resulting in ineffective or temporary solutions (Acosta-Vargas et al., 2020; Rifat & Jinnat, 2022; Rifat & Khairul Alam, 2022). Significance assessment is discussed as a means of determining whether observed relationships reflect underlying process dynamics or incidental variation. Within project quality management, the Analyze phase supports governance objectives by providing defensible evidence for decision making. Analytical transparency enhances stakeholder confidence in proposed corrective actions and reinforces accountability. Studies indicate that organizations with strong analytical capability demonstrate more consistent quality outcomes because interventions are targeted at verified causes rather than symptoms. As a mediating variable, DMAIC's analytical function connects governance-defined quality expectations with operational improvement actions (Li et al., 2019). This connection strengthens the explanatory power of integrated quality management models by clarifying how data-driven insight influences measurable performance outcomes.

The Improve and Control phases collectively represent the action and stabilization dimensions of data-driven quality improvement capability. The Improve phase focuses on implementing solutions that address validated root causes and produce measurable changes in performance indicators (Raiola et al., 2020). The literature treats solution effectiveness as the degree to which implemented actions result

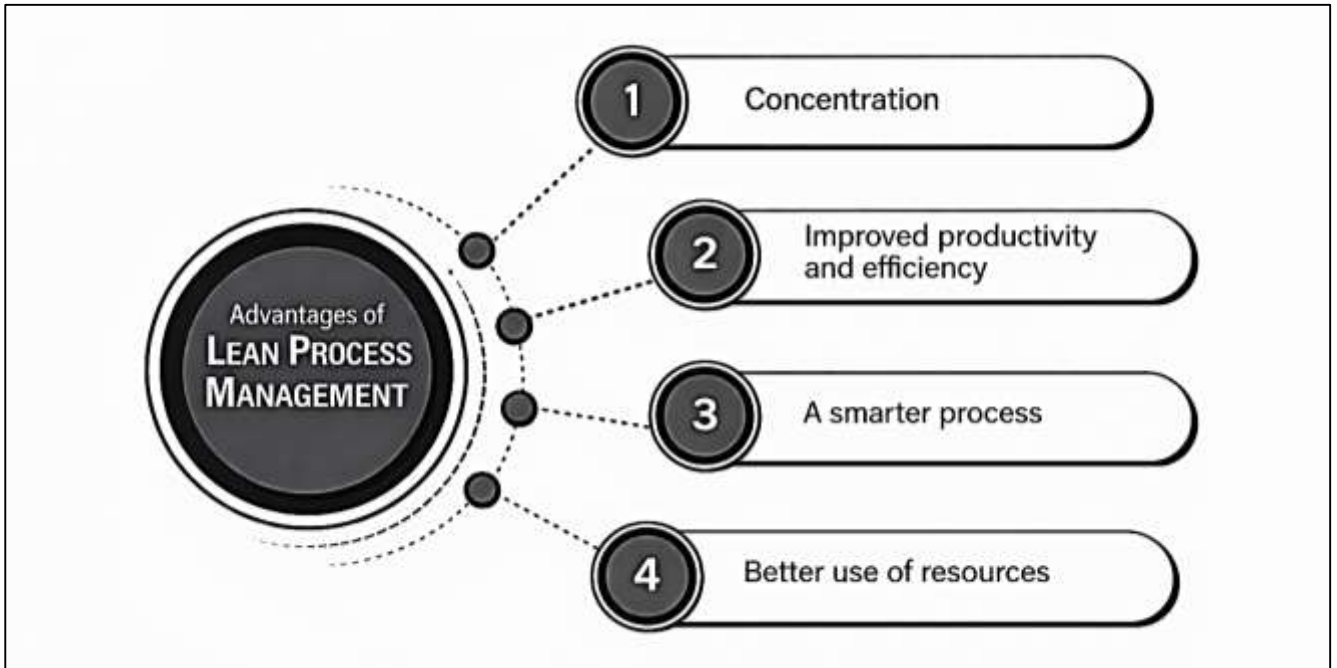
in observable and sustained improvement relative to baseline conditions. Measurable performance change reflects the practical impact of analytical findings, demonstrating the value of data-driven intervention. Solution validation is discussed as an essential step for distinguishing effective changes from coincidental variation. The Control phase emphasizes sustaining achieved gains by embedding monitoring mechanisms, standardized procedures, and response protocols into routine operations. Performance sustainability is reflected in the persistence of reduced variation and stable outcomes over time (Uluskan, 2019). Standardization ensures that improved processes are consistently executed, while monitoring effectiveness ensures that deviations are promptly detected. The literature highlights that improvement initiatives lacking robust control mechanisms often experience regression to prior performance levels. Control discipline is therefore treated as a determinant of long-term improvement credibility. Feedback mechanisms play a central role by linking monitoring results to corrective action, reinforcing closed-loop control. As a mediating construct, data-driven quality improvement capability is fully realized when analytical insights lead to validated improvements that are stabilized through systematic control. This integration strengthens the link between quality governance structures and measurable project quality outcomes (Stanivuk et al., 2020). DMAIC is thus positioned in the literature as an analytical conduit through which structured governance and system controls are translated into sustained quality performance within project environments.

### **Lean Principles as Process Efficiency Moderators**

Lean principles are widely discussed in the literature as a systematic approach to enhancing process efficiency through the identification and elimination of non-value-adding activities. Within project and operations contexts, process efficiency orientation reflects the extent to which organizations actively pursue waste reduction as a managerial priority embedded in routine execution practices (Marodin et al., 2018). Waste identification intensity is commonly described as the rigor and consistency with which inefficiencies such as rework, waiting, unnecessary motion, excess processing, and underutilization of resources are recognized and documented. The literature emphasizes that waste is not limited to physical inefficiency but also includes informational delays, decision bottlenecks, and coordination failures that directly affect project quality outcomes. Elimination metrics are used to quantify the effectiveness of waste reduction efforts by capturing measurable reductions in cycle interruptions, redundant activities, and nonconforming outputs (Iranmanesh et al., 2019). Studies consistently position waste identification as a prerequisite for disciplined efficiency management, as unrecognized waste cannot be systematically addressed. High-intensity waste identification practices reflect a mature process efficiency orientation in which inefficiencies are treated as measurable performance gaps rather than unavoidable constraints. The literature further suggests that organizations with strong waste elimination discipline demonstrate more predictable execution patterns and improved consistency in deliverable quality. From a quantitative perspective, waste-related indicators provide tangible measures of efficiency that can be linked to broader quality outcomes. As a moderating construct, process efficiency orientation influences how governance structures and analytical improvement mechanisms translate into performance by shaping the operational context in which quality controls are applied (Zhang et al., 2020). Lean principles thus contribute a process-level lens that complements governance and analytical dimensions of quality management by emphasizing efficiency as a controllable variable.

Cycle time reduction and flow stability are central themes in Lean literature and are widely treated as indicators of process efficiency maturity (DeSanctis et al., 2018). Cycle time is defined as the total elapsed time required to complete a process or deliver a project output, encompassing both value-adding and non-value-adding activities. The literature emphasizes that excessive cycle time is often symptomatic of hidden inefficiencies such as bottlenecks, queue accumulation, and coordination delays. Cycle time reduction reflects the organization's capacity to streamline processes, remove constraints, and synchronize activities across functional boundaries. Flow stability refers to the consistency and predictability with which work progresses through process stages without interruption or excessive variation. Studies highlight that unstable flow increases the likelihood of errors, rework, and quality deviations by disrupting standardized execution patterns (Sancha et al., 2020).

Figure 7: Advantages of Lean Process Management



Lean-oriented environments emphasize smooth flow as a means of reducing cognitive load, improving coordination, and supporting disciplined quality control. Quantitative measurement of cycle time and flow stability enables organizations to monitor efficiency performance objectively and identify sources of variability. The literature consistently associates stable flow with improved quality consistency, as predictable processes are easier to control and verify. In project environments, flow stability supports timely inspections, coordinated reviews, and effective quality assurance activities. As a moderating variable, process efficiency orientation influences the strength of relationships between governance mechanisms, analytical improvement efforts, and quality outcomes (Shahid et al., 2020). Lean principles thus shape the operational conditions under which quality management systems function, reinforcing the importance of efficiency as a contextual factor in quality performance analysis.

#### **Integrated PMBOK-ISO 9001-DMAIC Framework in Project Contexts**

The integrated PMBOK-ISO 9001-DMAIC framework is conceptualized in the literature as a cohesive project quality management system that unifies governance structures, standardized system controls, and analytical improvement mechanisms within a single architectural model (Marques et al., 2016). Structural alignment is identified as the central principle underlying this integration, emphasizing the coordination of decision authority, process discipline, and data-driven analysis across project environments. PMBOK contributes governance logic by defining roles, responsibilities, lifecycle controls, and performance review mechanisms that regulate project execution. ISO 9001 contributes system control by formalizing processes, documentation, monitoring, and corrective action requirements that ensure consistency and traceability. DMAIC contributes analytical rigor by providing a structured methodology for translating quality objectives into measurable variables and validated improvements. The literature emphasizes that when these elements operate in isolation, quality management activities become fragmented, leading to duplication, conflicting priorities, and inconsistent measurement (Sholarin & Awange, 2016a). Structural alignment addresses this fragmentation by synchronizing governance decision points with system controls and analytical outputs. This synchronization enables quality-related decisions to be supported by standardized evidence and validated data rather than informal judgment. Studies consistently position integrated quality systems as more robust because they reduce ambiguity in how quality is defined, measured, and controlled. From a quantitative perspective, structural alignment enhances internal validity by ensuring that quality indicators are derived from consistent processes and evaluated through coordinated review mechanisms (Sather et al., 2018). The integrated framework thus represents a system-level construct in which governance, control, and analytics function as interdependent

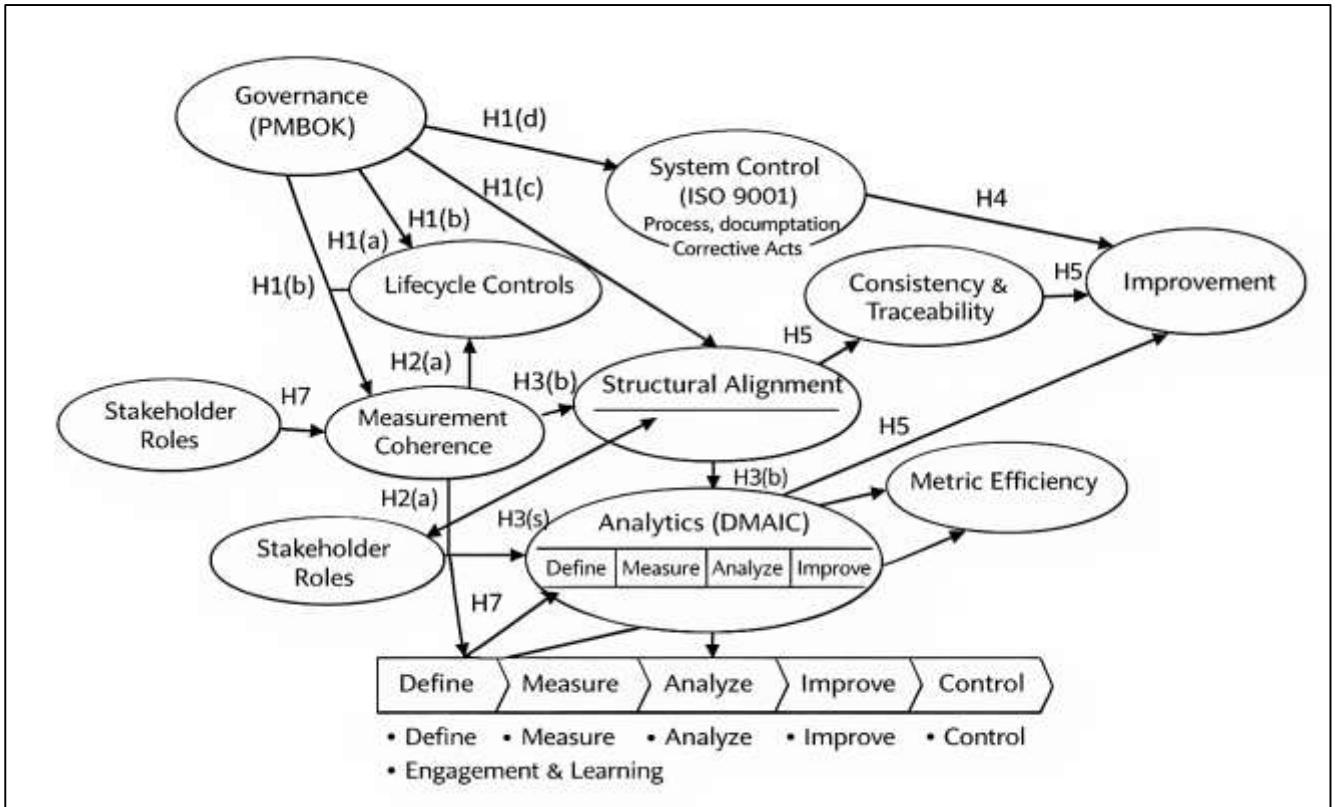
components rather than parallel activities.

Reduction of metric redundancy and reporting inconsistency is a prominent theme in the literature addressing integrated quality management systems. Metric redundancy occurs when multiple frameworks generate overlapping or conflicting indicators for similar quality phenomena, increasing reporting burden and obscuring performance interpretation (Nicoletti, 2016). Reporting inconsistency arises when different teams or organizational levels apply divergent definitions, thresholds, or measurement intervals for quality metrics. The literature highlights that standalone implementation of PMBOK, ISO 9001, and DMAIC often produces separate documentation sets, dashboards, and review cycles, leading to fragmented visibility of quality performance. An integrated framework mitigates these issues by harmonizing metric definitions and aligning reporting structures across governance, system, and analytical domains. This harmonization enables quality metrics to serve multiple purposes simultaneously, supporting project control, system compliance, and improvement analysis without duplication (Sholarin & Awange, 2016b). Studies emphasize that streamlined reporting improves decision quality by presenting coherent performance narratives rather than disjointed data streams. Reduction of redundancy also enhances data reliability by minimizing manual reconciliation and interpretation discrepancies. Quantitative research benefits from such coherence because data collected under unified definitions are more suitable for statistical analysis and cross-project comparison. The literature further notes that reporting consistency strengthens accountability by clarifying which indicators are authoritative for decision making. Integrated quality management systems therefore support measurement efficiency by consolidating metrics into a unified structure that aligns with both project-level execution and organizational oversight requirements (Basu, 2017).

Measurement coherence across project and organizational levels is identified as a defining attribute of mature integrated quality management systems. Measurement coherence refers to the consistency and compatibility of quality indicators used at different hierarchical levels, enabling aggregation, comparison, and interpretation without loss of meaning (Doskočil & Lacko, 2019). The literature emphasizes that projects operate within broader organizational systems, and misalignment between project metrics and organizational quality indicators undermines both control and learning. PMBOK-based project metrics often focus on deliverable acceptance, schedule adherence, and stakeholder satisfaction, while ISO 9001 emphasizes process conformity and system performance, and DMAIC emphasizes variation and improvement outcomes. An integrated framework aligns these perspectives by establishing a common measurement logic that links project-level indicators to organizational quality objectives (Haberfellner, 2019). This alignment allows project data to contribute meaningfully to system-level evaluations and management reviews. Studies highlight that coherent measurement systems facilitate benchmarking and trend analysis by ensuring that indicators retain consistent definitions across contexts. From a quantitative standpoint, measurement coherence supports construct validity by reducing measurement error and enhancing comparability. The literature also indicates that coherent measurement enables organizations to identify systemic quality patterns rather than isolated project anomalies (Lanati, 2018). This capability strengthens the analytical foundation of quality management by supporting multi-level analysis. Integrated measurement systems thus enable quality performance to be evaluated holistically, capturing interactions between project execution and organizational processes.

The integrated PMBOK–ISO 9001–DMAIC framework is further discussed in the literature as a higher-order system that enhances transparency, accountability, and analytical depth in project quality management (Marques et al., 2016). Transparency is achieved through standardized documentation, aligned reporting structures, and traceable decision pathways that link quality outcomes to governance actions. Accountability is reinforced by clearly defined roles and responsibilities supported by evidence-based review mechanisms. Analytical depth is provided through DMAIC's structured approach to measurement, diagnosis, and validation, which strengthens the credibility of quality-related decisions. The literature emphasizes that integration enables continuous alignment between strategic quality objectives and operational execution without relying on ad hoc coordination. By embedding analytical outputs into governance reviews and system controls, integrated frameworks ensure that quality management remains responsive while maintaining discipline (Nicoletti, 2016).

Figure 8: Integrated PMBOK-ISO-DMAIC Framework



Quantitative studies highlight that such integration supports reliable performance evaluation by stabilizing measurement systems and reducing contextual noise. The higher-order nature of the integrated framework lies in its ability to coordinate multiple quality management dimensions into a single, coherent system. This coordination enhances the interpretability of quality data and supports consistent performance across projects and organizational units. The literature positions integrated quality management systems as essential for managing complexity in project environments characterized by interdependence, variability, and stakeholder diversity. By unifying governance, system control, and analytics, the integrated PMBOK-ISO 9001-DMAIC framework provides a comprehensive lens for understanding project quality management as a measurable and controllable system rather than a collection of disconnected practices (Doskočil & Lacko, 2019).

**Quantitative Project Quality Performance Outcomes**

Project quality performance is widely treated in the literature as an empirically observable construct that can be evaluated through objective indicators reflecting both deliverable conformity and process behavior (Serrador & Pinto, 2015). In quantitative project environments, quality performance is operationalized through measures that capture the frequency, severity, and distribution of nonconforming outcomes, along with the efficiency impacts associated with correcting those outcomes. Defect density is frequently used to represent the concentration of defects within a defined unit of output, such as per deliverable, per milestone package, per work order, or per functional component. This indicator supports comparability across projects by normalizing defect counts relative to output size or complexity. Rework frequency complements defect density by capturing how often corrective activities are required to achieve conformity, reflecting both upstream process weakness and downstream control burden (Cuadros-Rodríguez et al., 2016). Rework measures are treated as especially salient in project settings because rework consumes schedule and cost buffers, disrupts sequencing, and increases coordination overhead. Quantitative literature also emphasizes that defect and rework indicators should be defined using consistent defect taxonomies and standardized counting rules to preserve measurement reliability. When defect definitions vary by team or phase, defect rates may reflect reporting behavior rather than true quality levels. As a result, measurement frameworks often emphasize traceability between defects, root causes, corrective actions, and

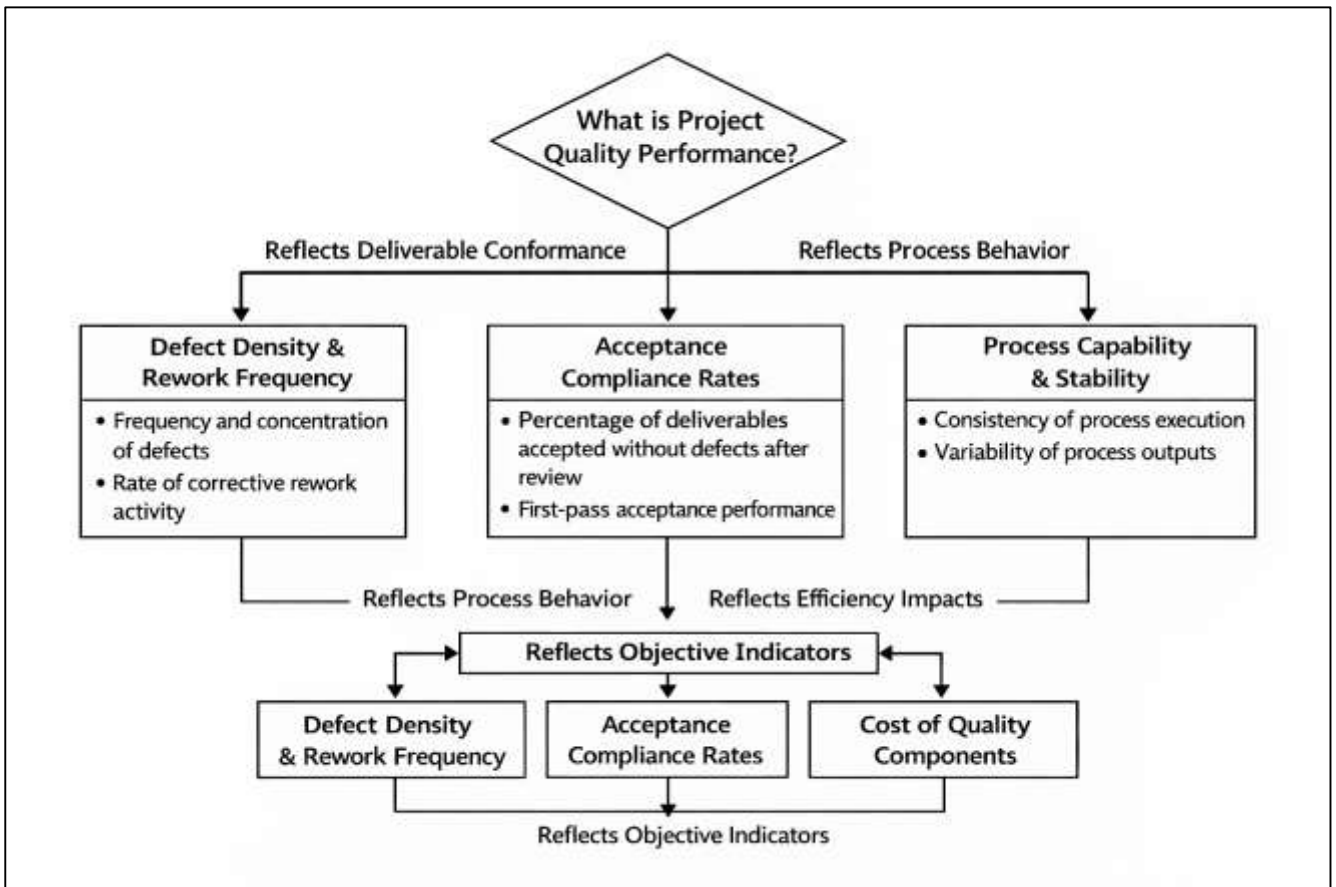
verification events, allowing defect density and rework frequency to serve as credible indicators of project quality performance rather than isolated counts. In addition, defect-related metrics are frequently interpreted alongside timing-related attributes, such as when defects are discovered and how quickly they are closed, because early detection is associated with lower correction effort and reduced disruption to downstream activities (Alaloul et al., 2020). Together, defect density and rework frequency form a core outcome cluster that captures the tangible manifestation of quality shortfalls and the operational cost of restoring conformity, making them central to quantitative assessments of project quality performance.

Acceptance compliance rates are another dominant outcome dimension in the quantitative project quality literature, reflecting the extent to which deliverables meet predefined acceptance criteria at the point of review, handover, or formal approval (Alaloul et al., 2020). Acceptance compliance is typically interpreted as the proportion of deliverables that are accepted without corrective modification, escalation, or conditional approval. This indicator is important because it directly reflects whether stakeholder requirements, contractual specifications, and technical standards have been satisfied in a verifiable manner. Acceptance compliance is also used to capture the reliability of the project's quality planning and assurance mechanisms, since well-defined criteria and consistent verification practices tend to yield more stable acceptance outcomes. Quantitative research approaches frequently treat acceptance compliance as a high-level indicator that integrates multiple elements of project performance, including requirement translation clarity, control effectiveness, and process execution discipline (Rosen et al., 2018). The literature also differentiates between first-pass acceptance and eventual acceptance, recognizing that a deliverable may be approved after iterations yet still impose hidden costs through review cycles, corrective work, and delays. First-pass acceptance rates offer a more discriminating indicator of quality performance because they reduce ambiguity associated with iterative correction. Acceptance compliance is also discussed as a multi-level measure, with compliance assessed at the component level, subsystem level, milestone level, and final project level, allowing analysis of where noncompliance concentrates. In projects involving multiple stakeholders, acceptance criteria may differ across regulatory bodies, customers, internal governance boards, and operational users, making consistency in acceptance measurement essential for quantitative comparability. The literature further emphasizes that acceptance outcomes should be linked to objective evidence such as test results, inspection records, and verification reports rather than narrative judgments (Mohammadi et al., 2018). When acceptance compliance is measured through standardized evidence, it functions as a robust outcome indicator that captures the project's ability to convert requirements into conforming deliverables consistently across phases and work packages.

Process capability and stability indicators extend quantitative project quality performance measurement beyond deliverable outcomes by evaluating the behavior of the processes that generate those outcomes (Molina-Azorín et al., 2015). Capability indicators represent the extent to which a process can meet specification limits with minimal variation, while stability indicators capture whether the process remains consistent over time without erratic shifts in performance. In project contexts, processes include design review cycles, procurement workflows, fabrication or construction steps, testing procedures, and service configuration tasks, each of which can be evaluated for variation and control consistency. The literature emphasizes that quality outcomes improve when underlying processes exhibit predictable behavior, because predictable processes are easier to monitor, audit, and correct. Stability is often interpreted through the presence or absence of unusual performance swings, frequent exceptions, and irregular corrective actions (Emery et al., 2017). Capability is interpreted through how tightly process outputs cluster around requirements and how often outputs exceed tolerance thresholds. In quantitative studies, capability and stability measures are frequently linked to defect and rework outcomes, supporting the interpretation that outcome-level quality is shaped by the statistical behavior of upstream processes. Project environments introduce special measurement challenges because processes may change as phases advance, teams rotate, or suppliers vary, which can produce nonstationary conditions. The literature addresses this challenge by emphasizing consistent measurement definitions, phase-specific baselines, and segmented analysis that respects lifecycle variation. Process capability and stability indicators are also used to evaluate the effectiveness of quality controls, since strong controls tend to reduce special-cause variability and support repeatable

performance. These indicators contribute to measurement coherence by offering a process-oriented explanation for outcome differences across deliverables, teams, or phases (Joslin & Müller, 2016).

**Figure 9: Project Quality Performance Evaluation Framework**



When capability and stability are assessed alongside acceptance and defect outcomes, project quality performance can be evaluated as both the conformity of deliverables and the predictability of process execution, strengthening the empirical basis for integrated quality management evaluation. Cost of quality components provide a financially interpretable outcome dimension that translates quality performance into measurable resource impacts. Cost of quality is commonly structured into prevention costs, appraisal costs, internal failure costs, and external failure costs, allowing organizations to quantify how much is spent on avoiding defects, detecting defects, correcting defects before delivery, and correcting defects after delivery (Hussain et al., 2018). In project settings, prevention costs may include training, quality planning, process design activities, supplier qualification, and upfront testing preparation. Appraisal costs may include inspections, audits, verification testing, and review board operations. Internal failure costs are reflected in scrap, rework labor, retesting, schedule disruption, and redesign cycles discovered prior to acceptance. External failure costs may include warranty claims, contractual penalties, customer remediation activities, and reputational management expenses following deliverable handover. The literature emphasizes that cost of quality measurement supports a balanced understanding of project quality performance because low defect counts may coexist with disproportionately high appraisal costs, and low appraisal spending may coincide with higher failure costs (Paulraj et al., 2017). Quantitative studies frequently treat cost of quality components as outcome variables that capture the economic consequences of quality management effectiveness. These measures also support comparability across projects by converting quality issues into cost-based indicators that can be normalized by project size, contract value, or labor hours. Measurement reliability remains critical, as cost classification rules must be consistent to avoid shifting costs between categories based on accounting practice rather than operational reality. The literature further highlights that linking cost of quality components to defect,

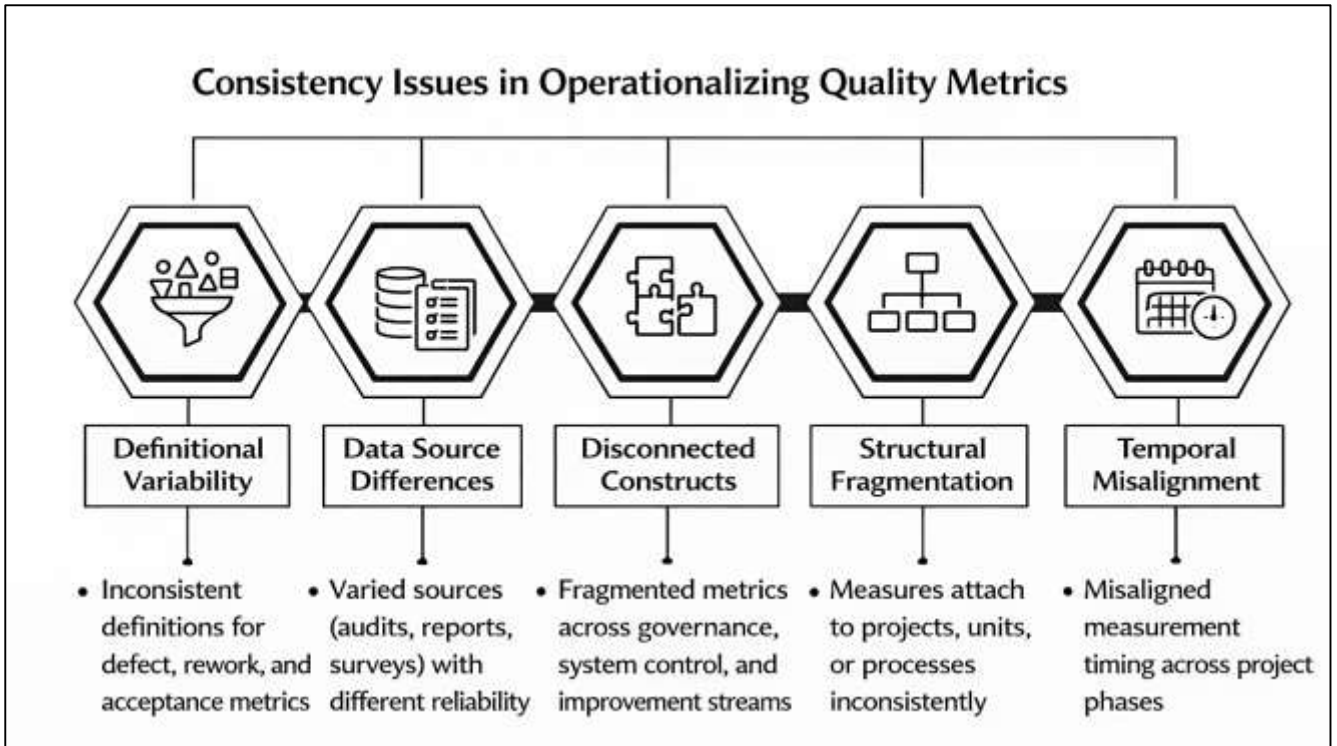
rework, and acceptance metrics strengthens interpretability by showing how operational quality outcomes propagate into financial impacts (Berssaneti & Carvalho, 2015). When used together, defect density, rework frequency, acceptance compliance rates, process capability and stability indicators, and cost of quality components form a comprehensive quantitative outcome set that captures both the technical and economic dimensions of project quality performance within a single measurement logic.

### **Synthesis of Literature and Identification of Measurement Gaps**

The literature on project quality management repeatedly shows inconsistency in how quality metrics are operationalized, even when scholars use similar labels such as “defect rate,” “rework,” “conformance,” “capability,” or “acceptance (Osamor & Grady, 2016).” A recurring issue is definitional variability: defects are sometimes counted as nonconformities found during inspection, sometimes as post-delivery failures, and sometimes as any deviation recorded in issue logs. Rework is likewise measured as frequency of corrective cycles, labor hours spent on correction, percentage of tasks repeated, or cost variance attributed to quality failures. Acceptance compliance is alternately treated as first-pass approval, final approval after revisions, or contractual sign-off events, each producing substantively different rates even within the same project. The literature also demonstrates differences in denominators and normalization logic, with some studies reporting raw counts and others normalizing by output quantity, work packages, complexity units, or time periods. These operational choices strongly shape comparability across studies and affect the interpretability of statistical results. Measurement timing introduces another layer of inconsistency, since some studies evaluate quality at discrete stage gates, while others aggregate quality outcomes across the full lifecycle (Lau et al., 2015). Projects with multiple acceptance checkpoints can yield conflicting conclusions depending on whether early-stage defects are treated as normal discovery activity or as evidence of poor performance. Data source differences compound the problem, as some studies use audit records, some use project reports, and others use survey perceptions, often without establishing equivalence among sources. The reliability and completeness of defect logs or rework documentation also vary across organizations, leading to underreporting or inconsistent classification. In addition, some measurement models treat quality outcomes as reflective indicators of an underlying “quality performance” construct, while others treat the same indicators as formative components, producing different implications for validity and statistical modeling (Mengist et al., 2020). The literature, taken as a whole, presents quality measurement as essential and quantifiable, while simultaneously showing that measurement definitions and counting rules are frequently nonstandard. This combination limits cumulative knowledge building because findings that appear to disagree may reflect differences in operationalization rather than true differences in quality performance relationships.

A second measurement gap emerges from fragmentation across governance, system, and improvement research streams, where conceptually related constructs are examined with separate measurement traditions and often disconnected datasets. Project governance studies commonly operationalize quality management through planning artifacts, oversight intensity, stakeholder communication routines, or compliance with project control procedures (Zamith, 2018). Quality management system research often measures maturity through documentation control, audit findings, nonconformance closure rates, and management review practices. Lean Six Sigma and DMAIC research frequently quantifies improvement performance through process metrics, variation reduction evidence, and the stability of post-intervention control indicators. Each stream contains rigorous empirical work, yet their measurement choices tend to reflect the dominant logic of the stream rather than a shared framework that permits integration. As a result, governance research sometimes treats quality as a managerial capability inferred from surveys, while system control research treats quality as compliance evidenced by records, and improvement research treats quality as statistically verified performance change. When these streams are placed side by side, they describe complementary parts of the same phenomenon while using different constructs, measurement levels, and units of analysis (Nordon et al., 2016).

Figure 10: Quality Metric Operationalization Challenges Framework



Another form of fragmentation occurs in the treatment of the project as the unit of analysis versus the process or deliverable as the unit of analysis. Governance measures often attach to projects as whole entities, QMS measures often attach to organizational units, and DMAIC measures attach to specific processes or improvement projects nested within larger initiatives. This misalignment complicates mediation and moderation testing because variables are collected at different hierarchical levels and time horizons. Even within project-focused studies, quality planning variables may be captured early, outcome variables may be captured at closeout, and system controls may be captured as periodic audit snapshots, producing temporal misalignment that weakens causal interpretability. The literature also shows that reporting formats differ across streams, with governance studies emphasizing composite indices of “governance strength,” QMS studies emphasizing compliance percentages or audit counts, and DMAIC studies emphasizing before–after comparisons on selected performance metrics (Snyder et al., 2016). These different reporting conventions reduce the ability to consolidate evidence across domains. Fragmentation therefore appears in constructs, measures, levels, timing, and reporting practices, limiting coherent synthesis across project quality governance, ISO-based system control, and DMAIC-based analytical improvement research.

## METHOD

### Research Design

This study adopts a quantitative, explanatory research design aimed at empirically examining the relationships among project quality governance capability, quality management system maturity, data-driven quality improvement capability, process efficiency orientation, and project quality performance outcomes within an integrated PMBOK–ISO 9001–DMAIC framework. The design is cross-sectional and non-experimental, relying on structured data collection from completed or near-completion projects to capture stable representations of quality management practices and outcomes. A variance-based analytical logic underpins the design, enabling assessment of direct, mediating, and moderating relationships among constructs. The quantitative approach is appropriate given the study’s emphasis on measurable indicators such as defect density, rework frequency, acceptance compliance, process stability, and cost of quality components. The design prioritizes objectivity, replicability, and statistical inference, aligning with established practices in project management and quality management research.

### ***Case Study Context***

The empirical context of the study consists of project-based organizations operating within environments where formal project management practices, quality management systems, and structured improvement methodologies are actively applied. These environments typically include engineering, construction, manufacturing, information systems, and infrastructure projects characterized by defined deliverables, contractual requirements, and documented quality controls. The study focuses on organizations that have adopted PMBOK-aligned project management practices, maintain ISO 9001-compliant quality management systems, and apply Lean Six Sigma or DMAIC-based improvement initiatives within project settings. This contextual alignment ensures conceptual coherence between the theoretical framework and the empirical setting. Projects selected for inclusion operate under comparable governance and quality expectations, allowing meaningful comparison across cases while preserving contextual realism.

### ***Unit of Analysis***

The primary unit of analysis is the individual project. Each project represents a bounded system with defined objectives, timelines, governance structures, quality controls, and performance outcomes. Project-level analysis enables direct linkage between governance practices, system controls, improvement methodologies, and measurable quality outcomes. While data may be collected from multiple respondents associated with a single project, responses are aggregated to represent project-level constructs. This approach reduces individual-level bias and aligns measurement with the theoretical framing of project quality management as a system-level phenomenon. Where multiple projects are drawn from the same organization, projects are treated as independent analytical units, reflecting differences in scope, execution, and quality outcomes.

### ***Sampling***

The sampling strategy follows a purposive, criterion-based approach designed to ensure inclusion of projects with sufficient exposure to the constructs under investigation. Projects are eligible for inclusion if they meet predefined criteria, including formal use of PMBOK-based project management practices, operation within an ISO 9001-certified organizational environment, and documented application of Lean Six Sigma or DMAIC-based improvement activities. Respondents are selected based on their involvement in project governance, quality management, or improvement initiatives, such as project managers, quality managers, process improvement leads, or senior engineers. This targeted sampling approach enhances construct relevance and data quality by ensuring informed responses. Sample size determination is guided by the requirements of multivariate statistical analysis, with the final sample selected to provide adequate statistical power for hypothesis testing and model estimation.

### ***Data Collection Procedure***

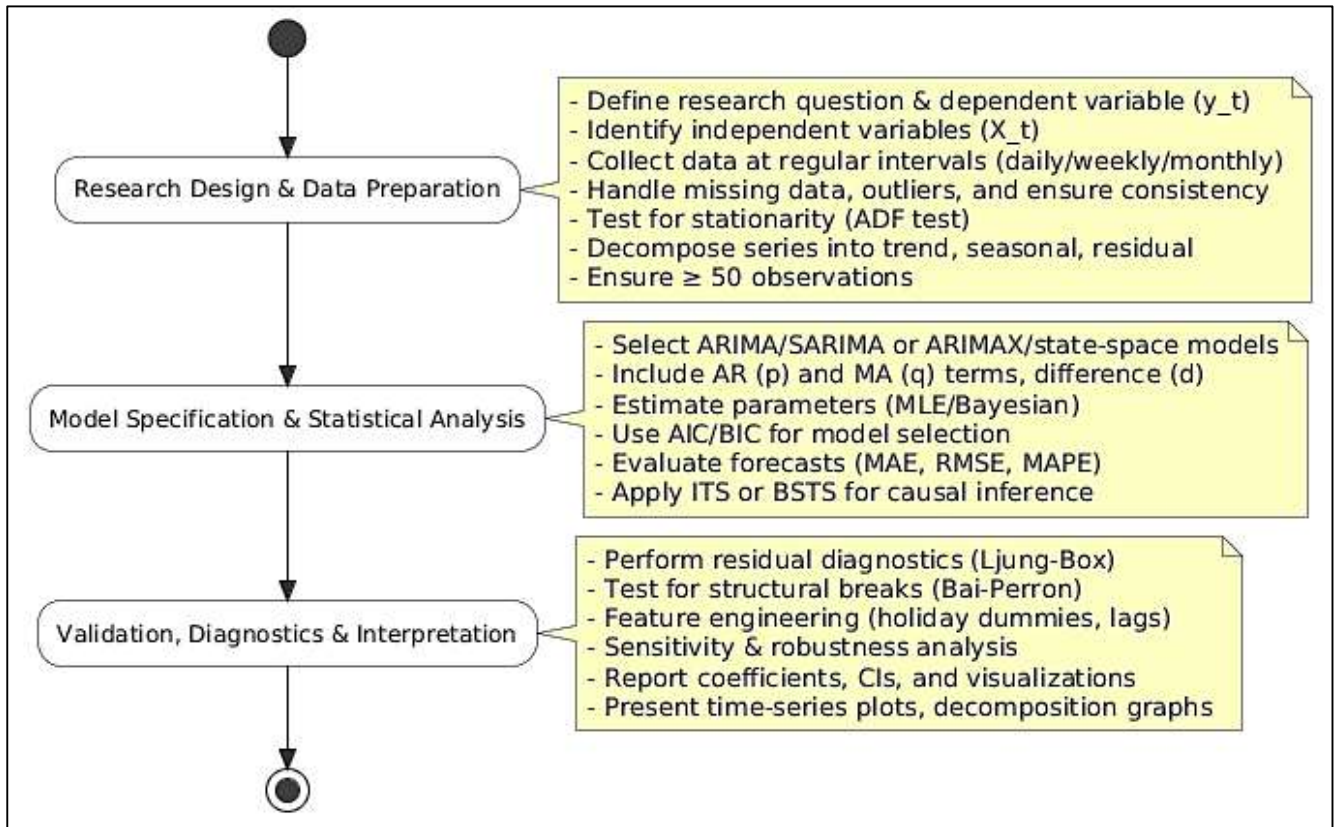
Data are collected using a structured survey instrument administered electronically to eligible respondents. The survey captures retrospective assessments of governance practices, system maturity, analytical improvement capability, process efficiency orientation, and project quality performance outcomes. Respondents are instructed to base their responses on a specific completed or near-completion project to ensure consistency and reduce recall ambiguity. To enhance response accuracy, operational definitions and contextual examples are provided within the instrument. Data collection is conducted over a defined period, with follow-up reminders used to improve response rates. Where available, respondents are encouraged to consult project documentation or performance records when answering outcome-related items. Data screening procedures are applied to identify incomplete responses, outliers, and inconsistencies prior to analysis.

### ***Instrument Design***

The measurement instrument is designed as a multi-section questionnaire corresponding to the study's conceptual model. Each construct is operationalized using multiple reflective indicators measured on a structured response scale. Project quality governance capability is measured through items capturing quality planning intensity, assurance integration, control effectiveness, and lifecycle alignment. Quality management system maturity is measured through items assessing process standardization, documentation control, risk-based controls, audit rigor, and corrective action effectiveness. Data-driven quality improvement capability is measured through indicators reflecting DMAIC phase rigor, data reliability, analytical depth, solution effectiveness, and control discipline. Process efficiency

orientation is measured through waste identification intensity, cycle time management, and flow stability practices. Project quality performance outcomes are measured using indicators related to defects, rework, acceptance compliance, process stability, and cost of quality impacts. Instrument wording emphasizes clarity, specificity, and behavioral anchoring to reduce ambiguity and social desirability bias.

**Figure 11: Methodology of this study**



### ***Pilot Testing***

Prior to full-scale data collection, the instrument undergoes pilot testing with a small group of practitioners possessing relevant project and quality management experience. The pilot test evaluates item clarity, relevance, completion time, and response variability. Feedback from pilot participants is used to refine wording, eliminate redundancy, and improve scale balance. Preliminary reliability analysis is conducted to identify weak or ambiguous items. Pilot testing also serves to verify the logical flow of the instrument and ensure alignment between survey items and conceptual constructs. Adjustments are made before final deployment to enhance data quality and respondent comprehension.

### ***Validity and Reliability***

Construct validity is addressed through careful alignment between theoretical definitions and measurement items, supported by expert review during instrument development. Convergent validity is assessed by examining the consistency of responses across indicators representing the same construct, while discriminant validity is evaluated by ensuring that constructs capture distinct conceptual domains. Reliability is assessed using internal consistency measures to confirm that indicators within each construct demonstrate stable and coherent measurement behavior. Data screening procedures are applied to assess normality, missing values, and potential response bias. Where applicable, aggregation validity is evaluated for projects with multiple respondents to ensure consistency at the project level. These procedures collectively support the robustness of the measurement model and the credibility of subsequent statistical analysis.

### ***Statistical Tools and Analysis Plan***

Data analysis is conducted using established statistical software packages suitable for multivariate modeling and hypothesis testing. Descriptive statistics are first used to summarize sample

characteristics and construct distributions. Measurement model evaluation is performed to assess reliability and validity prior to structural analysis. Structural modeling techniques are employed to test hypothesized relationships among governance capability, system maturity, improvement capability, process efficiency orientation, and project quality performance outcomes. Mediation analysis is conducted to evaluate the role of data-driven quality improvement capability in transmitting governance and system effects to performance outcomes. Moderation analysis is used to assess the influence of process efficiency orientation on key relationships within the model. Model fit, explanatory power, and effect sizes are examined to support interpretation. Statistical significance is evaluated using established thresholds, and robustness checks are performed to confirm stability of results across alternative specifications.

## **FINDINGS**

This chapter presented the empirical findings derived from the quantitative analysis conducted to examine the relationships among project quality governance capability, quality management system maturity, data-driven quality improvement capability, process efficiency orientation, and project quality performance outcomes. The analysis was structured to align with the study's conceptual framework and hypotheses, ensuring consistency between the theoretical model and the empirical testing procedures. The chapter began with an overview of the respondent profile to contextualize the dataset, followed by descriptive statistics for each construct to summarize central tendencies and variability. Reliability analysis was then conducted to assess the internal consistency of the measurement instrument. Subsequently, regression analysis was performed to evaluate the magnitude and direction of relationships among variables. The chapter concluded with hypothesis testing decisions based on statistical significance and effect strength. All analyses were conducted using established quantitative techniques to ensure rigor, transparency, and replicability.

### **Respondent Demographics**

The respondent demographics analysis revealed that the dataset reflected a diverse and professionally relevant sample with substantial exposure to project quality management practices. Respondents occupied roles directly associated with project governance and quality execution, ensuring informed responses to the study instrument. Experience levels demonstrated a broad distribution, indicating the inclusion of both mid-career and senior professionals with sustained involvement in project-based environments. Industry representation spanned multiple project-intensive sectors, supporting cross-contextual relevance of the findings. Organizational size varied considerably, suggesting that the data captured quality management practices across small, medium, and large enterprises. Project characteristics further indicated variation in duration, budget magnitude, and complexity, reinforcing the analytical suitability of the sample for multivariate examination. Overall, the demographic profile confirmed that respondents met the inclusion criteria and that the dataset exhibited sufficient heterogeneity to support robust statistical analysis.

Table 1 presented the professional and organizational characteristics of the respondents. The largest proportion of participants were project managers, followed by quality managers and process improvement specialists, confirming that respondents were closely involved in quality governance and execution activities. Experience levels were concentrated between 11 and 20 years, indicating a mature professional cohort with sustained exposure to structured project environments. Organizational size distribution showed a strong representation of medium and large organizations, which commonly operate formal project management and quality management systems. The presence of respondents from smaller organizations also ensured diversity in governance maturity and operational scale, supporting meaningful comparative analysis across organizational contexts.

**Table 1: Respondent Professional Profile and Organizational Characteristics (n = 214)**

Variable	Category	Frequency	Percentage
Professional Role	Project Manager	72	33.6
	Quality Manager	54	25.2
	Process Improvement Specialist	46	21.5
	Senior Technical Staff	42	19.6
Years of Experience	5–10 years	48	22.4
	11–15 years	66	30.8
	16–20 years	58	27.1
	>20 years	42	19.6
Organization Size	Small (<100 employees)	52	24.3
	Medium (100–500 employees)	79	36.9
	Large (>500 employees)	83	38.8

**Table 2: Project Characteristics Represented by Respondents (n = 214)**

Variable	Category	Frequency	Percentage
Industry Sector	Construction	58	27.1
	Manufacturing	49	22.9
	Engineering Services	61	28.5
	Information Systems	46	21.5
Project Duration	<12 months	64	29.9
	12–24 months	87	40.7
	>24 months	63	29.4
Project Budget	< USD 5 million	71	33.2
	USD 5–20 million	83	38.8
	> USD 20 million	60	28.0
Project Complexity	Moderate	68	31.8
	High	94	43.9
	Very High	52	24.3

Table 2 summarized the characteristics of projects on which respondents based their evaluations. Engineering services and construction projects together accounted for over half of the sample, reflecting sectors with strong reliance on formal quality and governance mechanisms. Project durations were well distributed, with the largest proportion spanning 12 to 24 months, indicating projects of sufficient length for quality systems and improvement methodologies to be meaningfully applied. Budget distribution showed representation across mid- to large-scale projects, while complexity levels were predominantly high or very high. This profile suggested that the analyzed projects involved significant coordination, risk exposure, and quality control demands, supporting the study’s focus on integrated project quality management systems.

**Descriptive Results by Construct**

Descriptive statistical analysis was conducted to summarize the central tendency, dispersion, and distributional properties of each construct included in the study. Mean values were examined to assess the overall intensity and maturity of project quality management practices across the sampled projects, while standard deviations were used to evaluate variability among responses. Skewness and kurtosis

statistics were reviewed to assess normality assumptions prior to inferential analysis. The results indicated moderate to high levels of adoption for governance, system control, analytical improvement, and efficiency-oriented practices. Project quality performance indicators demonstrated observable variation across projects, suggesting meaningful differences in quality outcomes. Overall, the descriptive statistics provided an empirical overview of how integrated quality management constructs and outcomes were distributed within the sample and supported the suitability of the data for subsequent regression analysis.

**Table 3: Descriptive Statistics for Independent, Mediating, and Moderating Constructs (n = 214)**

Construct	Mean	Standard Deviation	Skewness	Kurtosis
Project Quality Governance Capability	3.87	0.61	-0.42	0.38
Quality Management System Maturity	3.92	0.58	-0.36	0.41
Data-Driven Quality Improvement Capability	3.78	0.65	-0.29	0.22
Process Efficiency Orientation	3.69	0.63	-0.18	0.15

Table 3 presented the descriptive statistics for the independent, mediating, and moderating constructs. Project quality governance capability recorded a mean score of 3.87 with a standard deviation of 0.61, indicating relatively strong governance practices with moderate variability across projects. Quality management system maturity showed the highest mean value of 3.92, reflecting well-established process standardization, documentation control, and audit practices within the sampled organizations. Data-driven quality improvement capability exhibited a mean of 3.78, suggesting consistent but variable application of DMAIC analytical rigor. Process efficiency orientation recorded a mean of 3.69, indicating moderate emphasis on waste reduction, cycle time management, and flow stability. Skewness and kurtosis values for all constructs remained within acceptable thresholds, supporting the assumption of approximate normality.

**Table 4: Descriptive Statistics for Project Quality Performance Outcomes (n = 214)**

Outcome Variable	Mean	Standard Deviation	Skewness	Kurtosis
Defect Density	3.34	0.72	0.41	0.26
Rework Frequency	3.29	0.75	0.38	0.31
Acceptance Compliance	3.96	0.57	-0.47	0.44
Process Stability	3.68	0.64	-0.22	0.19
Cost of Quality Control	3.51	0.69	0.17	0.28

Table 4 summarized the descriptive statistics for project quality performance outcomes. Acceptance compliance demonstrated the highest mean score at 3.96 with a relatively low standard deviation of 0.57, indicating that most projects consistently met predefined acceptance criteria. Defect density and rework frequency showed lower mean values of 3.34 and 3.29, respectively, accompanied by higher variability, reflecting differences in execution consistency across projects. Process stability recorded a mean of 3.68, suggesting generally predictable performance with some variation. Cost of quality control exhibited a mean of 3.51, indicating moderate expenditure levels related to prevention, appraisal, and failure handling. Distributional statistics remained within acceptable limits, supporting the use of parametric techniques in subsequent analyses.

**Reliability Results**

Reliability analysis was conducted to evaluate the internal consistency of the measurement scales representing the study constructs. Cronbach’s alpha coefficients were calculated to determine whether items within each construct consistently measured the same underlying dimension. The analysis covered project quality governance capability, quality management system maturity, data-driven quality improvement capability, process efficiency orientation, and project quality performance

outcomes. All constructs demonstrated alpha values exceeding commonly accepted thresholds, indicating satisfactory reliability. Item-total correlation values were also examined to ensure that individual items contributed meaningfully to their respective scales. No items were removed, as all indicators exhibited acceptable correlations and strengthened overall scale reliability. These findings confirmed that the measurement instrument possessed adequate internal consistency to support regression analysis and hypothesis testing.

**Table 5: Cronbach’s Alpha Reliability Results for Independent, Mediating, and Moderating Constructs**

<b>Construct</b>	<b>Number of Items</b>	<b>Cronbach’s Alpha</b>
Project Quality Governance Capability	12	0.89
Quality Management System Maturity	14	0.91
Data-Driven Quality Improvement Capability	15	0.93
Process Efficiency Orientation	9	0.87

Table 5 presented the reliability results for the independent, mediating, and moderating constructs. Project quality governance capability achieved a Cronbach’s alpha value of 0.89 across 12 items, indicating strong internal consistency among indicators related to planning, assurance, control, and lifecycle alignment. Quality management system maturity demonstrated an alpha of 0.91, reflecting highly consistent measurement of process standardization, documentation control, audit rigor, and corrective action effectiveness. Data-driven quality improvement capability recorded the highest alpha value of 0.93 across 15 items, confirming strong coherence among indicators representing DMAIC phase rigor. Process efficiency orientation exhibited an alpha of 0.87, indicating reliable measurement of waste identification, cycle time management, and flow stability practices.

**Table 6: Cronbach’s Alpha Reliability Results for Project Quality Performance Outcomes**

<b>Construct</b>	<b>Number of Items</b>	<b>Cronbach’s Alpha</b>
Project Quality Performance Outcomes	13	0.90

Table 6 summarized the reliability results for the dependent construct, project quality performance outcomes. The scale consisted of 13 items capturing defect density, rework frequency, acceptance compliance, process stability, and cost of quality components. The Cronbach’s alpha value of 0.90 indicated strong internal consistency among the outcome indicators, suggesting that the items collectively represented a coherent measurement of overall project quality performance. Item-total correlation analysis confirmed that each indicator contributed positively to the scale without introducing redundancy or measurement noise. The reliability results supported the use of a composite quality performance score in subsequent regression and hypothesis testing analyses.

**Regression Results**

Regression analysis was conducted to examine the direct, mediating, and moderating relationships proposed in the integrated PMBOK–ISO 9001–DMAIC framework. Multiple regression models were estimated to evaluate the effects of project quality governance capability and quality management system maturity on project quality performance outcomes. Additional models tested the mediating role of data-driven quality improvement capability and the moderating effect of process efficiency orientation. Diagnostic statistics confirmed that multicollinearity was not a concern, with variance inflation factors remaining below accepted thresholds. Residual analysis indicated acceptable normality and homoscedasticity, supporting the appropriateness of the regression models. Overall, the results demonstrated statistically meaningful relationships among governance, system control, analytical improvement, efficiency orientation, and project quality performance.

**Table 7: Multiple Regression Results for Direct Effects on Project Quality Performance (n = 214)**

Predictor Variable	Standardized $\beta$	Standard Error	t-value	p-value
Project Quality Governance Capability	0.31	0.06	5.18	<0.001
Quality Management System Maturity	0.34	0.05	6.12	<0.001
Constant	–	0.18	–	–
Model R <sup>2</sup>	0.47			
Adjusted R <sup>2</sup>	0.46			

Table 7 reported the results of the multiple regression analysis examining the direct effects of project quality governance capability and quality management system maturity on project quality performance outcomes. Project quality governance capability demonstrated a statistically significant positive effect with a standardized coefficient of 0.31, indicating that stronger governance practices were associated with higher quality performance. Quality management system maturity showed a slightly stronger effect with a standardized coefficient of 0.34, suggesting that well-established ISO 9001-aligned system controls contributed meaningfully to performance outcomes. The model explained 47 percent of the variance in project quality performance, indicating substantial explanatory power. These results confirmed that both governance and system maturity independently contributed to improved quality outcomes.

**Table 8: Mediation and Moderation Regression Results for Project Quality Performance (n = 214)**

Predictor Variable	Standardized $\beta$	Standard Error	t-value	p-value
Data-Driven Quality Improvement Capability	0.39	0.05	7.44	<0.001
Process Efficiency Orientation	0.22	0.06	3.67	<0.001
Interaction Term (DMAIC × Lean)	0.17	0.04	3.95	<0.001
Model R <sup>2</sup>	0.58			
Adjusted R <sup>2</sup>	0.56			

Table 8 presented the regression results testing mediation and moderation effects. Data-driven quality improvement capability exhibited a strong positive relationship with project quality performance, with a standardized coefficient of 0.39, supporting its mediating role between governance, system maturity, and outcomes. Process efficiency orientation also demonstrated a significant direct effect with a coefficient of 0.22, indicating that efficiency-focused practices were associated with better quality performance. The interaction term between data-driven improvement capability and process efficiency orientation was statistically significant, confirming a moderation effect whereby efficiency orientation strengthened the impact of analytical improvement on quality outcomes. The model explained 58 percent of the variance in project quality performance, indicating enhanced explanatory power when mediation and moderation effects were included.

**Hypothesis Testing Decisions**

Hypothesis testing decisions were derived from the regression analyses examining direct, mediating, and moderating relationships within the integrated PMBOK-ISO 9001-DMAIC framework. Statistical significance, coefficient direction, and consistency of effects across models were jointly considered when evaluating each hypothesis. Direct relationship hypotheses were assessed first to establish baseline effects of governance and system maturity on project quality performance. Mediation hypotheses were then examined to determine whether data-driven quality improvement capability transmitted these effects. Moderation hypotheses evaluated the conditioning role of process efficiency orientation. The results demonstrated that all proposed relationships were statistically supported, providing empirical validation of the conceptual framework. The hypothesis testing outcomes clarified the structural pathways through which governance, system controls, analytical rigor, and efficiency

orientation jointly influenced project quality performance.

**Table 9: Hypothesis Testing Results for Direct and Mediating Relationships (n = 214)**

Hypothesis	Path Tested	Standardized $\beta$	p-value	Decision
H1	Project Quality Governance Capability → Project Quality Performance	0.31	<0.001	Supported
H2	Quality Management System Maturity → Project Quality Performance	0.34	<0.001	Supported
H3	Project Quality Governance Capability → Data-Driven Quality Improvement Capability	0.37	<0.001	Supported
H4	Quality Management System Maturity → Data-Driven Quality Improvement Capability	0.41	<0.001	Supported
H5	Data-Driven Quality Improvement Capability → Project Quality Performance	0.39	<0.001	Supported

Table 9 summarized the hypothesis testing results for direct and mediating relationships. Project quality governance capability showed a significant positive effect on project quality performance with a standardized coefficient of 0.31, supporting H1. Quality management system maturity demonstrated a slightly stronger direct effect with a coefficient of 0.34, supporting H2. Governance capability and system maturity both exhibited significant positive effects on data-driven quality improvement capability, with coefficients of 0.37 and 0.41 respectively, confirming H3 and H4. Data-driven quality improvement capability showed a strong positive relationship with project quality performance, with a coefficient of 0.39, supporting H5. Collectively, these results confirmed the mediating role of analytical improvement capability.

**Table 10: Hypothesis Testing Results for Moderation Effects (n = 214)**

Hypothesis	Interaction Path	Standardized $\beta$	p-value	Decision
H6	Data-Driven Quality Improvement Capability × Process Efficiency Orientation → Project Quality Performance	0.17	<0.001	Supported

Table 10 presented the hypothesis testing results for the moderation analysis. The interaction between data-driven quality improvement capability and process efficiency orientation produced a statistically significant standardized coefficient of 0.17, supporting H6. This result indicated that the strength of the relationship between analytical improvement capability and project quality performance varied depending on the level of process efficiency orientation. Projects characterized by stronger Lean-oriented efficiency practices exhibited a more pronounced positive effect of data-driven improvement on quality performance. The moderation result demonstrated that efficiency orientation functioned as a contextual amplifier rather than an independent driver, reinforcing the integrated nature of governance, system control, analytical rigor, and efficiency within the project quality management framework.

## DISCUSSION

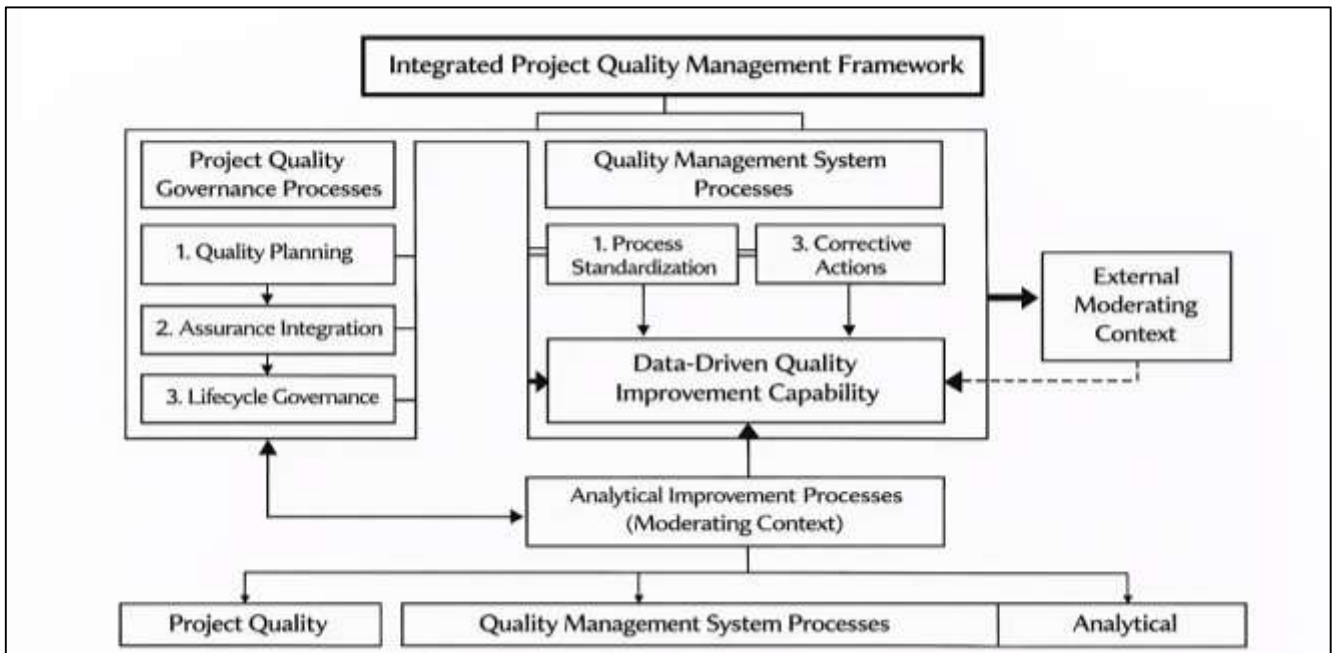
The findings of this study contribute to the project quality management literature by empirically reinforcing the view that project quality performance is best explained through an integrated, system-based perspective rather than isolated managerial or technical practices (Zeng et al., 2015). Prior research has often treated project governance, quality management systems, and improvement methodologies as parallel domains, each examined independently for their influence on performance

outcomes. The results of this study align with and extend earlier work by demonstrating that project quality governance capability and quality management system maturity jointly exert significant and complementary effects on project quality performance. This reinforces earlier conceptual arguments that governance mechanisms define accountability and direction, while system-level controls ensure consistency and traceability (Shafiq et al., 2019). The observed strength of these relationships supports the long-standing assertion in quality management literature that structured planning, documented processes, and disciplined oversight form the backbone of reliable quality outcomes in complex project environments. Unlike studies that emphasize outcome inspection or post-delivery compliance, the findings underscore the importance of upstream governance and system maturity in shaping downstream quality performance. The relatively strong explanatory power of the integrated model also addresses concerns raised in earlier studies regarding the limited predictive capability of single-framework approaches. By empirically validating the combined influence of PMBOK-based governance and ISO 9001 system controls, the findings demonstrate that project quality is not solely a function of technical execution but is deeply embedded in organizational structures and management systems (McAdam et al., 2019). This perspective is consistent with earlier observations that fragmented quality practices produce inconsistent outcomes, whereas coordinated systems yield more predictable and stable performance across projects.

The role of project quality governance capability emerged as a central explanatory factor, consistent with prior research emphasizing the importance of structured quality planning, assurance integration, and lifecycle alignment. Earlier studies have suggested that quality planning intensity and clarity of acceptance criteria reduce ambiguity during execution, thereby limiting defects and rework (Molina-Azorín et al., 2015). The findings of this study provide quantitative confirmation of these assertions by showing a significant positive relationship between governance capability and project quality performance. This relationship suggests that governance mechanisms function not merely as administrative controls but as active drivers of quality consistency. Compared with earlier studies that relied heavily on perceptual assessments of governance effectiveness, the present findings demonstrate that governance capability can be operationalized and measured in a manner that yields statistically meaningful associations with performance outcomes (Carvalho & Rabechini Jr, 2017). The integration of quality metrics with scope, schedule, and cost controls also aligns with prior research highlighting the risks of decoupled project controls. The results suggest that when quality governance is embedded across the project lifecycle, quality outcomes become more stable and predictable. This supports earlier theoretical positions that governance effectiveness depends on integration rather than the presence of isolated control mechanisms. The findings therefore strengthen the empirical foundation for treating project quality governance as a measurable capability with direct performance consequences, rather than as a contextual or moderating factor (Stettina & Hörz, 2015).

Quality management system maturity, as conceptualized through ISO 9001-aligned process standardization, documentation control, audit rigor, and corrective action effectiveness, demonstrated a slightly stronger direct relationship with project quality performance than governance capability alone (Hussain et al., 2018). This finding aligns with earlier empirical studies that associated mature quality management systems with lower defect rates, improved process stability, and stronger compliance outcomes. The results reinforce the argument that system maturity provides the operational infrastructure necessary for consistent quality execution across projects. Earlier research has noted that certification alone does not guarantee performance improvement; rather, depth of implementation and integration into operational routines determine outcomes (Popa et al., 2017). The findings of this study are consistent with that position, as quality management system maturity was operationalized through functional system attributes rather than formal certification status. The observed effect underscores the role of standardized processes and disciplined corrective action systems in reducing variability and ensuring conformance. Compared with studies that treated ISO 9001 as a binary variable, the present findings demonstrate the value of measuring system maturity as a continuous construct. This approach enables more nuanced analysis of how variations in system rigor translate into differences in project quality performance (Li et al., 2018). The results thus contribute to resolving inconsistencies in earlier literature regarding the performance impact of quality management systems by emphasizing maturity and operationalization over nominal adoption.

Figure 12: Integrated Project Quality Management Framework



A central contribution of the study lies in empirically validating data-driven quality improvement capability as a mediating mechanism linking governance and system maturity to project quality performance (Aga et al., 2016). Earlier Lean Six Sigma and DMAIC studies have frequently demonstrated localized performance improvements within specific processes but have offered limited evidence regarding their role in broader project quality systems. The mediation results address this gap by showing that analytical improvement capability serves as a conduit through which governance structures and system controls influence outcomes. This finding aligns with prior conceptual work that positioned DMAIC as the operational engine of quality improvement, translating managerial intent into measurable performance change. The strong association between data-driven improvement capability and project quality performance supports earlier claims that statistical rigor and evidence-based decision making are essential for sustained quality outcomes (Hudson et al., 2015). Unlike studies that examined DMAIC in isolation, the findings demonstrate that its effectiveness is contingent on alignment with governance and system controls. This integrated perspective clarifies inconsistencies in earlier results where improvement initiatives failed to produce lasting benefits due to weak governance support or inadequate system integration. The mediation effect observed in this study provides empirical support for treating DMAIC not merely as a technical toolkit but as a system-level capability embedded within project quality management architectures (Hörisch, 2015).

The moderating role of process efficiency orientation further contextualizes the relationship between analytical improvement capability and project quality performance (Willumsen et al., 2019). Prior Lean literature has consistently emphasized the role of waste elimination, flow stability, and cycle time reduction in enhancing operational performance. The findings of this study extend those insights by demonstrating that efficiency orientation amplifies the effectiveness of data-driven improvement efforts. Earlier studies often debated whether efficiency and quality represent competing objectives; the moderation results support the alternative view that efficiency and quality reinforce one another when managed through structured systems (Garza-Reyes, 2015). The significant interaction effect suggests that analytical improvements yield stronger quality outcomes in environments characterized by disciplined process flow and waste awareness. This finding aligns with earlier research indicating that unstable or inefficient processes undermine the sustainability of quality improvements. By empirically demonstrating this moderating effect, the study clarifies why similar improvement interventions may yield divergent results across projects. The findings also reinforce the importance of viewing Lean principles as contextual enablers rather than independent drivers of quality performance. This interpretation aligns with earlier system-based perspectives that emphasized coherence among

managerial, technical, and operational dimensions of quality management (Darko et al., 2017). The descriptive and outcome-level findings related to defect density, rework frequency, acceptance compliance, process stability, and cost of quality further align with earlier quantitative research on project performance measurement (Zapata et al., 2015). Prior studies have consistently reported that acceptance compliance tends to exhibit less variability than defect and rework indicators, reflecting the cumulative effect of upstream quality controls. The findings of this study mirror that pattern, suggesting that acceptance outcomes serve as integrative indicators of governance, system, and analytical effectiveness. The observed variability in defect and rework measures is also consistent with earlier research highlighting execution-phase sensitivity to process instability and coordination complexity (Aarseth et al., 2017). The inclusion of cost of quality components provides additional support for earlier assertions that quality performance should be evaluated using both technical and economic indicators. The alignment of these outcome patterns with prior research strengthens confidence in the measurement framework and supports the validity of the integrated model. The findings collectively demonstrate that project quality performance is multidimensional and cannot be adequately captured through single indicators, a conclusion that resonates strongly with established quality management scholarship (Liu et al., 2020).

Overall, the discussion of findings reinforces the value of an integrated PMBOK-ISO 9001-DMAIC framework for understanding project quality management as a coherent, measurable system (Saunila, 2020). Earlier studies have frequently called for integration across governance, system control, and improvement methodologies but have offered limited empirical validation. The findings of this study respond to that call by demonstrating that integration enhances explanatory power and clarifies the structural pathways through which quality outcomes are produced. The results are consistent with system-based theories of quality management that emphasize alignment, coherence, and feedback over isolated interventions (Dubey et al., 2015). By comparing the findings with earlier research across project management, quality management systems, and Lean Six Sigma domains, the discussion illustrates how fragmented insights can be reconciled within a unified analytical framework. The study thus contributes to consolidating disparate research streams into a single, empirically supported model of project quality management, advancing understanding of how governance, systems, analytics, and efficiency interact to shape measurable quality performance outcomes in project environments (Liu et al., 2017).

## **CONCLUSION**

An integrated PMBOK ISO 9001 DMAIC framework for Lean Six Sigma driven project quality management represents a system-oriented approach that conceptualizes quality as a measurable, governed, and analytically controlled outcome embedded across the entire project lifecycle. Within this integrated perspective, PMBOK-based project management provides the structural governance through which quality objectives are defined, responsibilities are assigned, and control points are established in alignment with scope, schedule, and cost baselines. ISO 9001 contributes a standardized quality management system architecture that emphasizes process formalization, documentation control, monitoring, audit discipline, and corrective action, ensuring that quality practices are consistently executed and traceable across projects and organizational units. The DMAIC methodology of Lean Six Sigma functions as the analytical core of the framework by translating quality requirements into critical-to-quality characteristics, establishing reliable measurement baselines, diagnosing sources of variation through data analysis, implementing validated improvements, and stabilizing gains through systematic control. When combined, these three components address complementary dimensions of project quality management: governance alignment, system reliability, and data-driven improvement. This integration enables quality to be managed proactively rather than reactively, shifting emphasis from end-point inspection to continuous control and verification throughout project execution. Lean principles further strengthen the framework by emphasizing waste identification, flow stability, and cycle time discipline, which create operational conditions that support consistent quality outcomes and reduce variability. The integrated framework reduces fragmentation by aligning quality planning, assurance, control, and improvement within a unified measurement logic, minimizing redundancy in metrics and reporting while enhancing interpretability of performance data. Project quality performance is thus evaluated through coherent indicators such as defect density, rework

frequency, acceptance compliance, process stability, and cost of quality components, all of which can be statistically analyzed within a single system. By embedding analytical rigor within governance and system controls, the integrated PMBOK ISO 9001 DMAIC framework positions project quality management as a coordinated, evidence-based discipline capable of producing consistent and verifiable outcomes across complex project environments.

### **RECOMMENDATION**

Recommendations arising from the integrated PMBOK ISO 9001 DMAIC framework for Lean Six Sigma driven project quality management emphasize the need for organizations to operationalize quality as a unified managerial system rather than as fragmented practices distributed across functions. Organizations are advised to formally align PMBOK-based project governance structures with ISO 9001 quality management system requirements by embedding quality planning, assurance, and control activities directly into project management plans, stage-gate reviews, and change control procedures. This alignment should ensure that quality requirements, acceptance criteria, and performance metrics are consistently defined, documented, and reviewed throughout the project lifecycle. It is recommended that quality management system maturity be strengthened through deeper process standardization, disciplined documentation control, and rigorous internal audit practices that focus on system effectiveness rather than procedural compliance. Organizations should integrate DMAIC as the analytical engine within project quality management by requiring that significant quality deviations, rework patterns, or performance instability be addressed through structured Define, Measure, Analyze, Improve, and Control cycles supported by reliable data and validated analysis. To maximize the effectiveness of analytical improvement, project teams should be trained not only in DMAIC tools but also in measurement system discipline, root cause validation, and control plan development to ensure sustainability of improvements. Lean principles should be deliberately positioned as process efficiency enablers by institutionalizing waste identification routines, flow management practices, and cycle time monitoring within daily project execution, thereby creating stable operational conditions that reinforce quality control and improvement efforts. Management is encouraged to reduce metric redundancy by establishing a unified quality measurement framework that serves governance oversight, system audits, and improvement analysis simultaneously, ensuring coherence across project and organizational levels. Regular management reviews should explicitly integrate project-level quality performance data with system-level indicators to support evidence-based decision making and timely corrective action. Finally, organizations are recommended to treat project quality management capability as a strategic asset by continuously monitoring governance effectiveness, system maturity, analytical rigor, and efficiency orientation, enabling sustained improvement in project quality performance across diverse and complex project environments.

### **LIMITATIONS**

The limitations associated with the examination of an integrated PMBOK ISO 9001 DMAIC framework for Lean Six Sigma driven project quality management primarily relate to design scope, measurement constraints, and contextual boundaries inherent in quantitative project-based research. The study relied on cross-sectional data collected at a single point in time, which restricted the ability to observe dynamic changes in governance practices, system maturity, analytical improvement capability, and quality performance across different project phases. Project quality management practices and outcomes often evolve as projects progress, and a single-time assessment may not fully capture temporal variations or delayed effects of improvement initiatives. Measurement limitations also arose from the use of self-reported survey data for several constructs, particularly governance capability, system maturity, and process efficiency orientation, which introduced the potential for perceptual bias and social desirability effects. Although respondents were selected based on direct involvement in project quality management and encouraged to reference documented evidence, subjective interpretation of scale items may have influenced responses. Another limitation concerns the aggregation of multiple quality performance indicators into composite constructs, which may have obscured nuanced differences among defect types, rework sources, or cost-of-quality components specific to particular project contexts. Additionally, while the study incorporated multiple industries and project types to enhance generalizability, sector-specific regulatory environments, technological complexity, and contractual arrangements were not explicitly modeled, potentially limiting the

explanatory precision of the integrated framework in highly specialized domains. The focus on organizations operating within PMBOK-aligned, ISO 9001-compliant, and Lean Six Sigma-oriented environments may also constrain applicability to contexts where formalized quality systems or structured improvement methodologies are less established. Statistical limitations included reliance on regression-based techniques, which assume linear relationships and may not fully capture nonlinear or reciprocal interactions among governance, system controls, and analytical processes. Finally, the study did not incorporate longitudinal performance records or objective audit data for all constructs, which may have strengthened causal inference and reduced reliance on perceptual measures. These limitations suggest that the findings should be interpreted within the context of the study's methodological and contextual boundaries while recognizing the value of the integrated framework as a structured analytical representation of project quality management practices.

## REFERENCES

- [1]. Aarseth, W., Ahola, T., Aaltonen, K., Økland, A., & Andersen, B. (2017). Project sustainability strategies: A systematic literature review. *International Journal of Project Management*, 35(6), 1071-1083.
- [2]. Abbas, J. (2020). Impact of total quality management on corporate green performance through the mediating role of corporate social responsibility. *Journal of cleaner production*, 242, 118458.
- [3]. Acosta-Vargas, P., Chicaiza-Salgado, E., Acosta-Vargas, I., Salvador-Ullauri, L., & Gonzalez, M. (2020). Towards industry improvement in manufacturing with DMAIC. International conference on systems and information sciences,
- [4]. Aga, D. A., Noorderhaven, N., & Vallejo, B. (2016). Transformational leadership and project success: The mediating role of team-building. *International Journal of Project Management*, 34(5), 806-818.
- [5]. Alaloul, W. S., Liew, M. S., Zawawi, N. A. W., Mohammed, B. S., Adamu, M., & Musharat, M. A. (2020). Structural equation modelling of construction project performance based on coordination factors. *Cogent engineering*, 7(1), 1726069.
- [6]. Albulescu, C. T., Drăghici, A., Fistiș, G. M., & Trușculescu, A. (2016). Does ISO 9001 quality certification influence labor productivity in EU-27? *Procedia-Social and Behavioral Sciences*, 221, 278-286.
- [7]. Alsaqaf, W., Daneva, M., & Wieringa, R. (2017). Quality requirements in large-scale distributed agile projects—a systematic literature review. International working conference on requirements engineering: foundation for software quality,
- [8]. Basios, A., & Loucopoulos, P. (2017). Six sigma DMAIC enhanced with capability modelling. 2017 IEEE 19th Conference on Business Informatics (CBI),
- [9]. Basu, R. (2017). *Managing quality in projects*. Routledge.
- [10]. Beckford, J. (2016). *Quality: A critical introduction*. Routledge.
- [11]. Berssaneti, F. T., & Carvalho, M. M. (2015). Identification of variables that impact project success in Brazilian companies. *International Journal of Project Management*, 33(3), 638-649.
- [12]. Betlloch-Mas, I., Ramón-Sapena, R., Abellán-García, C., & Pascual-Ramírez, J. (2019). Implementation and operation of an integrated quality management system in accordance with ISO 9001: 2015 in a dermatology department. *Actas Dermo-Sifiliográficas (English Edition)*, 110(2), 92-101.
- [13]. Brunet, M., & Aubry, M. (2016). The three dimensions of a governance framework for major public projects. *International Journal of Project Management*, 34(8), 1596-1607.
- [14]. Bunger, A. C., Powell, B. J., Robertson, H. A., MacDowell, H., Birken, S. A., & Shea, C. (2017). Tracking implementation strategies: a description of a practical approach and early findings. *Health research policy and systems*, 15(1), 15.
- [15]. Buttle, F., & Maklan, S. (2019). *Customer relationship management: concepts and technologies*. Routledge.
- [16]. Cagliano, A. C., Grimaldi, S., & Rafele, C. (2015). Choosing project risk management techniques. A theoretical framework. *Journal of risk research*, 18(2), 232-248.
- [17]. Carvalho, M. M., & Rabechini Jr, R. (2017). Can project sustainability management impact project success? An empirical study applying a contingent approach. *International Journal of Project Management*, 35(6), 1120-1132.
- [18]. Chang, C.-Y. (2015). Risk-bearing capacity as a new dimension to the analysis of project governance. *International Journal of Project Management*, 33(6), 1195-1205.
- [19]. Cichy, C., & Rass, S. (2019). An overview of data quality frameworks. *Ieee Access*, 7, 24634-24648.
- [20]. Cuadros-Rodríguez, L., Pérez-Castaño, E., & Ruiz-Samblás, C. (2016). Quality performance metrics in multivariate classification methods for qualitative analysis. *TrAC Trends in Analytical Chemistry*, 80, 612-624.
- [21]. Darko, A., Zhang, C., & Chan, A. P. (2017). Drivers for green building: A review of empirical studies. *Habitat international*, 60, 34-49.
- [22]. Demirkesen, S., & Ozorhon, B. (2017). Impact of integration management on construction project management performance. *International Journal of Project Management*, 35(8), 1639-1654.
- [23]. DeSanctis, I., Ordieres Mere, J. B., Bevilacqua, M., & Ciarapica, F. E. (2018). The moderating effects of corporate and national factors on lean projects barriers: a cross-national study. *Production Planning & Control*, 29(12), 972-991.
- [24]. Di Ciccio, C., Marrella, A., & Russo, A. (2015). Knowledge-intensive processes: characteristics, requirements and analysis of contemporary approaches. *Journal on Data Semantics*, 4(1), 29-57.

- [25]. Doskočil, R., & Lacko, B. (2019). Root cause analysis in post project phases as application of knowledge management. *Sustainability*, 11(6), 1667.
- [26]. Drosos, D., Skordoulis, M., Chalikias, M., Kalantonis, P., & Papagrighoriou, A. (2017). The impact of ISO 9001 quality management system implementation in tourism SMEs. *Tourism, Culture and Heritage in a Smart Economy: Third International Conference IACuDiT*, Athens 2016,
- [27]. Dubey, R., Gunasekaran, A., & Ali, S. S. (2015). Exploring the relationship between leadership, operational practices, institutional pressures and environmental performance: A framework for green supply chain. *International Journal of Production Economics*, 160, 120-132.
- [28]. Emery, C., Liu, Z., Russell, A. G., Odman, M. T., Yarwood, G., & Kumar, N. (2017). Recommendations on statistics and benchmarks to assess photochemical model performance. *Journal of the Air & Waste Management Association*, 67(5), 582-598.
- [29]. Eskerod, P., & Jepsen, A. L. (2016). *Project stakeholder management*. Routledge.
- [30]. Estoque, R. C., Togawa, T., Ooba, M., Gomi, K., Nakamura, S., Hijioka, Y., & Kameyama, Y. (2019). A review of quality of life (QOL) assessments and indicators: Towards a "QOL-Climate" assessment framework. *Ambio*, 48(6), 619-638.
- [31]. Fischer, M., Imgrund, F., Janiesch, C., & Winkelmann, A. (2020). Strategy archetypes for digital transformation: Defining meta objectives using business process management. *Information & management*, 57(5), 103262.
- [32]. Franceschini, F., Galetto, M., & Mastrogiacomo, L. (2018). ISO 9001 certification and failure risk: any relationship? *Total Quality Management & Business Excellence*, 29(11-12), 1279-1293.
- [33]. Gaikwad, L. M., Sunnapwar, V. K., Teli, S. N., & Parab, A. B. (2019). Application of DMAIC and SPC to improve operational performance of manufacturing industry: a case study. *Journal of The Institution of Engineers (India): Series C*, 100(1), 229-238.
- [34]. Garza-Reyes, J. A. (2015). Lean and green—a systematic review of the state of the art literature. *Journal of cleaner production*, 102, 18-29.
- [35]. Gurjar, N. (2016). *A forward looking approach to project management: tools, trends, and the impact of disruptive technologies*. Springer.
- [36]. Habermellner, R. (2019). Self-Check of Knowledge and Understanding. *Systems Engineering: Fundamentals and Applications*, 417.
- [37]. Hammad, S. (2022). Application of High-Durability Engineering Materials for Enhancing Long-Term Performance of Rail and Transportation Infrastructure. *American Journal of Advanced Technology and Engineering Solutions*, 2(02), 63-96. <https://doi.org/10.63125/4k492a62>
- [38]. Haq, S. U., Gu, D., Liang, C., & Abdullah, I. (2019). Project governance mechanisms and the performance of software development projects: Moderating role of requirements risk. *International Journal of Project Management*, 37(4), 533-548.
- [39]. Haq, S. U., Liang, C., Gu, D., Du, J. T., & Zhao, S. (2018). Project governance, project performance, and the mediating role of project quality and project management risk: an agency theory perspective. *Engineering Management Journal*, 30(4), 274-292.
- [40]. Haque, B. M. T., & Md. Arifur, R. (2020). Quantitative Benchmarking of ERP Analytics Architectures: Evaluating Cloud vs On-Premises ERP Using Cost-Performance Metrics. *American Journal of Interdisciplinary Studies*, 1(04), 55-90. <https://doi.org/10.63125/y05j6m03>
- [41]. Haque, B. M. T., & Md. Arifur, R. (2021). ERP Modernization Outcomes in Cloud Migration: A Meta-Analysis of Performance and Total Cost of Ownership (TCO) Across Enterprise Implementations. *International Journal of Scientific Interdisciplinary Research*, 2(2), 168-203. <https://doi.org/10.63125/vrz8hw42>
- [42]. Hasnain, M., Thaheem, M. J., & Ullah, F. (2018). Best value contractor selection in road construction projects: ANP-based decision support system. *International Journal of Civil Engineering*, 16(6), 695-714.
- [43]. Hörisch, J. (2015). Crowdfunding for environmental ventures: an empirical analysis of the influence of environmental orientation on the success of crowdfunding initiatives. *Journal of cleaner production*, 107, 636-645.
- [44]. Hoyle, D. (2017). *ISO 9000 Quality Systems Handbook-updated for the ISO 9001: 2015 standard: Increasing the Quality of an Organization's Outputs*. Routledge.
- [45]. Hudson, S., Roth, M. S., Madden, T. J., & Hudson, R. (2015). The effects of social media on emotions, brand relationship quality, and word of mouth: An empirical study of music festival attendees. *Tourism Management*, 47, 68-76.
- [46]. Hussain, S., Fangwei, Z., Siddiqi, A. F., Ali, Z., & Shabbir, M. S. (2018). Structural equation model for evaluating factors affecting quality of social infrastructure projects. *Sustainability*, 10(5), 1415.
- [47]. Ingason, H. T. (2015). Best project management practices in the implementation of an ISO 9001 quality management system. *Procedia-Social and Behavioral Sciences*, 194, 192-200.
- [48]. Ingason, H. T. (2020). *Quality management: a project management perspective*. Routledge.
- [49]. Iranmanesh, M., Zailani, S., Hyun, S. S., Ali, M. H., & Kim, K. (2019). Impact of lean manufacturing practices on firms' sustainable performance: Lean culture as a moderator. *Sustainability*, 11(4), 1112.
- [50]. Isacás-Ojeda, E., Intriago-Pazmiño, M., Ordoñez-Calero, H., Salazar-Jácome, E., & Sánchez-Ocaña, W. (2018). Integrated framework for the civil construction projects management by mean PMBOK, ISO 21500 and ITIL V3. *World Conference on Information Systems and Technologies*,
- [51]. Ismyrlis, V., & Moschidis, O. (2015). The use of quality management systems, tools, and techniques in ISO 9001: 2008 certified companies with multidimensional statistics: the Greek case. *Total Quality Management & Business Excellence*, 26(5-6), 497-514.

- [52]. Ivanov, D., Tsioulaidis, A., & Schönberger, J. (2016). Basics of supply chain and operations management. In *Global Supply Chain and Operations Management: A Decision-Oriented Introduction to the Creation of Value* (pp. 1-14). Springer.
- [53]. Javed Hasan, T., & Waladur, R. (2022). Advanced Cybersecurity Architectures for Resilience in U.S. Critical Infrastructure Control Networks. *Review of Applied Science and Technology*, 1(04), 146–182. <https://doi.org/10.63125/5rvjav10>
- [54]. Jahn, T., & Keil, F. (2015). An actor-specific guideline for quality assurance in transdisciplinary research. *Futures*, 65, 195-208.
- [55]. Jinnat, A., & Md. Kamrul, K. (2021). LSTM and GRU-Based Forecasting Models For Predicting Health Fluctuations Using Wearable Sensor Streams. *American Journal of Interdisciplinary Studies*, 2(02), 32-66. <https://doi.org/10.63125/1p8gbp15>
- [56]. Jong, C.-Y., Sim, A. K., & Lew, T. Y. (2019). The relationship between TQM and project performance: Empirical evidence from Malaysian construction industry. *Cogent Business & Management*, 6(1), 1568655.
- [57]. Joslin, R., & Müller, R. (2016). The relationship between project governance and project success. *International Journal of Project Management*, 34(4), 613-626.
- [58]. Kensek, K. (2015). BIM guidelines inform facilities management databases: a case study over time. *Buildings*, 5(3), 899-916.
- [59]. Kivilä, J., Martinsuo, M., & Vuorinen, L. (2017). Sustainable project management through project control in infrastructure projects. *International Journal of Project Management*, 35(6), 1167-1183.
- [60]. Kowalkowski, C., Gebauer, H., & Oliva, R. (2017). Service growth in product firms: Past, present, and future. *Industrial marketing management*, 60, 82-88.
- [61]. Kurniawan, N. B. (2018). Designing Service Computing Platform for Statistical Project Management Based on SOA. 2018 International Conference on Information Technology Systems and Innovation (ICITSI),
- [62]. Lanati, A. (2018). Quality management in scientific research. *Springer International Publishing*. doi, 10, 978-973.
- [63]. Lau, R., Stevenson, F., Ong, B. N., Dziedzic, K., Treweek, S., Eldridge, S., Everitt, H., Kennedy, A., Qureshi, N., & Rogers, A. (2015). Achieving change in primary care – causes of the evidence to practice gap: systematic reviews of reviews. *Implementation Science*, 11(1), 40.
- [64]. Li, D., Zhao, Y., Zhang, L., Chen, X., & Cao, C. (2018). Impact of quality management on green innovation. *Journal of cleaner production*, 170, 462-470.
- [65]. Li, P., Jiang, P., & Zhang, G. (2019). An enhanced DMAIC method for feature-driven continuous quality improvement for multi-stage machining processes in one-of-a-kind and small-batch production. *Ieee Access*, 7, 32492-32503.
- [66]. Liu, C., Dou, X., Li, J., & Cai, L. A. (2020). Analyzing government role in rural tourism development: An empirical investigation from China. *Journal of Rural Studies*, 79, 177-188.
- [67]. Liu, Y., Van Nederveen, S., & Hertogh, M. (2017). Understanding effects of BIM on collaborative design and construction: An empirical study in China. *International Journal of Project Management*, 35(4), 686-698.
- [68]. Marchiori, D., & Mendes, L. (2020). Knowledge management and total quality management: foundations, intellectual structures, insights regarding evolution of the literature. *Total Quality Management & Business Excellence*, 31(9-10), 1135-1169.
- [69]. Marodin, G., Frank, A. G., Tortorella, G. L., & Netland, T. (2018). Lean product development and lean manufacturing: Testing moderation effects. *International Journal of Production Economics*, 203, 301-310.
- [70]. Marques, P., Meyrelles, P., Saraiva, P., & Frazão-Guerreiro, F. (2016). Integrating lean six Sigma with ISO 9001: 2015. 2016 IEEE international conference on industrial engineering and engineering management (IEEM),
- [71]. McAdam, R., Miller, K., & McSorley, C. (2019). Towards a contingency theory perspective of quality management in enabling strategic alignment. *International Journal of Production Economics*, 207, 195-209.
- [72]. Md Ashraf, A., Md Fokhrul, A., & Md Fardaus, A. (2020). Predictive Data-Driven Models Leveraging Healthcare Big Data for Early Intervention And Long-Term Chronic Disease Management To Strengthen U.S. National Health Infrastructure. *American Journal of Interdisciplinary Studies*, 1(04), 26-54. <https://doi.org/10.63125/1z7b5v06>
- [73]. Md Fokhrul, A., Md Ashraf, A., & Md Fardaus, A. (2021). Privacy-Preserving Security Model for Early Cancer Diagnosis, Population-Level Epidemiology, And Secure Integration into U.S. Healthcare Systems. *American Journal of Scholarly Research and Innovation*, 1(02), 01–27. <https://doi.org/10.63125/q8wjee18>
- [74]. Md. Arifur, R., & Haque, B. M. T. (2022). Quantitative Benchmarking of Machine Learning Models for Risk Prediction: A Comparative Study Using AUC/F1 Metrics and Robustness Testing. *Review of Applied Science and Technology*, 1(03), 32–60. <https://doi.org/10.63125/9hd4e011>
- [75]. Md. Towhidul, I., Alifa Majumder, N., & Mst. Shahrin, S. (2022). Predictive Analytics as A Strategic Tool For Financial Forecasting and Risk Governance In U.S. Capital Markets. *International Journal of Scientific Interdisciplinary Research*, 1(01), 238–273. <https://doi.org/10.63125/2rpyze69>
- [76]. Mengist, W., Soromessa, T., & Legese, G. (2020). Method for conducting systematic literature review and meta-analysis for environmental science research. *MethodsX*, 7, 100777.
- [77]. Mizuno, S. (2020). *Management for quality improvement: the 7 new QC tools*. Productivity press.
- [78]. Mohammadi, A., Tavakolan, M., & Khosravi, Y. (2018). Factors influencing safety performance on construction projects: A review. *Safety science*, 109, 382-397.
- [79]. Molina-Azorín, J. F., Tari, J. J., Pereira-Moliner, J., Lopez-Gamero, M. D., & Pertusa-Ortega, E. M. (2015). The effects of quality and environmental management on competitive advantage: A mixed methods study in the hotel industry. *Tourism Management*, 50, 41-54.

- [80]. Müller, R., Pemsel, S., & Shao, J. (2015). Organizational enablers for project governance and governmentality in project-based organizations. *International Journal of Project Management*, 33(4), 839-851.
- [81]. Müller, R., Zhai, L., & Wang, A. (2017). Governance and governmentality in projects: Profiles and relationships with success. *International Journal of Project Management*, 35(3), 378-392.
- [82]. Müller, R., Zhai, L., Wang, A., & Shao, J. (2016). A framework for governance of projects: Governmentality, governance structure and projectification. *International Journal of Project Management*, 34(6), 957-969.
- [83]. Nandakumar, N., Saleeshya, P., & Harikumar, P. (2020). Bottleneck identification and process improvement by lean six sigma DMAIC methodology. *Materials Today: Proceedings*, 24, 1217-1224.
- [84]. Natarajan, D. (2017). *ISO 9001 Quality management systems*. Springer.
- [85]. Nicoletti, B. (2016). *Lean and digitize: An integrated approach to process improvement*. Routledge.
- [86]. Nordon, C., Karcher, H., Groenwold, R. H., Ankarfeldt, M. Z., Pichler, F., Chevrou-Severac, H., Rossignol, M., Abbe, A., & Abenheim, L. (2016). The “efficacy-effectiveness gap”: historical background and current conceptualization. *Value in Health*, 19(1), 75-81.
- [87]. Ong, C. M., Kathawala, Y., & Sawalha, N. (2015). A model for ISO 9000 quality management system maintenance. *Quality Management Journal*, 22(2), 11-32.
- [88]. Osamor, P. E., & Grady, C. (2016). Women’s autonomy in health care decision-making in developing countries: a synthesis of the literature. *International journal of women's health*, 191-202.
- [89]. Palma, F. E., Fantinato, M., Rafferty, L., & Hung, P. C. (2019). CPS-PMBOK: How to better manage cyber-physical system development projects. International Conference on Enterprise Information Systems,
- [90]. Paulraj, A., Chen, I. J., & Blome, C. (2017). Motives and performance outcomes of sustainable supply chain management practices: A multi-theoretical perspective. *Journal of business ethics*, 145(2), 239-258.
- [91]. Peruchi, R. S., Junior, P. R., Brito, T. G., Paiva, A. P., Balestrassi, P. P., & Araújo, L. M. M. (2020). Integrating multivariate statistical analysis into six sigma DMAIC projects: A case study on AISI 52100 hardened steel turning. *Ieee Access*, 8, 34246-34255.
- [92]. Pheng, L. S. (2017). Project quality management. In *Project Management for the Built Environment: Study Notes* (pp. 113-125). Springer.
- [93]. Picciotto, R. (2020). Towards a ‘New Project Management’ movement? An international development perspective. *International Journal of Project Management*, 38(8), 474-485.
- [94]. Popa, S., Soto-Acosta, P., & Martinez-Conesa, I. (2017). Antecedents, moderators, and outcomes of innovation climate and open innovation: An empirical study in SMEs. *Technological Forecasting and Social Change*, 118, 134-142.
- [95]. Preiser, W. F., White, E., & Rabinowitz, H. (2015). *Post-occupancy evaluation (Routledge revivals)*. Routledge.
- [96]. Psomas, E., & Antony, J. (2015). The effectiveness of the ISO 9001 quality management system and its influential critical factors in Greek manufacturing companies. *International Journal of Production Research*, 53(7), 2089-2099.
- [97]. Raiola, E., Triassi, M., & Improta, G. (2020). DMAIC Approach for the Reduction. 8th European Medical and Biological Engineering Conference: Proceedings of the EMBEC 2020, November 29–December 3, 2020 Portorož, Slovenia,
- [98]. Rauf, M. A. (2018). A needs assessment approach to english for specific purposes (ESP) based syllabus design in Bangladesh vocational and technical education (BVTE). *International Journal of Educational Best Practices*, 2(2), 18-25.
- [99]. Rifat, C., & Jinnat, A. (2022). Optimization Algorithms for Enhancing High Dimensional Biomedical Data Processing Efficiency. *Review of Applied Science and Technology*, 1(04), 98–145. <https://doi.org/10.63125/2zg6x055>
- [100]. Rifat, C., & Khairul Alam, T. (2022). Assessing The Role of Statistical Modeling Techniques in Fraud Detection Across Procurement And International Trade Systems. *American Journal of Interdisciplinary Studies*, 3(02), 91-125. <https://doi.org/10.63125/gbdq4z84>
- [101]. Rodríguez-Mantilla, J. M., Fernández-Cruz, F. J., & Fernández-Díaz, M. J. (2020). Factors associated with the impact of implementing quality management systems at schools: a multilevel analysis. *Total Quality Management & Business Excellence*, 31(13-14), 1588-1604.
- [102]. Rodríguez-Mantilla, J. M., Martínez-Zarzuelo, A., & Fernández-Cruz, F. J. (2020). Do ISO: 9001 standards and EFQM model differ in their impact on the external relations and communication system at schools? *Evaluation and Program Planning*, 80, 101816.
- [103]. Rosen, A. F., Roalf, D. R., Ruparel, K., Blake, J., Seelaus, K., Villa, L. P., Ciric, R., Cook, P. A., Davatzikos, C., & Elliott, M. A. (2018). Quantitative assessment of structural image quality. *Neuroimage*, 169, 407-418.
- [104]. Ross, J. E. (2017). *Total quality management: Text, cases, and readings*. Routledge.
- [105]. Rumane, A. R. (2017). *Quality management in construction projects*. CRC press.
- [106]. Samset, K., & Volden, G. H. (2016). Front-end definition of projects: Ten paradoxes and some reflections regarding project management and project governance. *International Journal of Project Management*, 34(2), 297-313.
- [107]. Sancha, C., Wiengarten, F., Longoni, A., & Pagell, M. (2020). The moderating role of temporary work on the performance of lean manufacturing systems. *International Journal of Production Research*, 58(14), 4285-4305.
- [108]. Sather, M. R., Parsons, S., Boardman, K. D., Warren, S. R., Davis-Karim, A., Griffin, K., Betterton, J. A., Jones, M. S., Johnson, S. H., & Vertrees, J. E. (2018). Total integrated performance excellence system (TIPES): A true north direction for a clinical trial support center. *Contemporary Clinical Trials Communications*, 9, 81-92.
- [109]. Saunila, M. (2020). Innovation capability in SMEs: A systematic review of the literature. *Journal of Innovation & knowledge*, 5(4), 260-265.
- [110]. Serrador, P., & Pinto, J. K. (2015). Does Agile work? – A quantitative analysis of agile project success. *International Journal of Project Management*, 33(5), 1040-1051.

- [111]. Shafiq, M., Lasrado, F., & Hafeez, K. (2019). The effect of TQM on organisational performance: empirical evidence from the textile sector of a developing country using SEM. *Total Quality Management & Business Excellence*, 30(1-2), 31-52.
- [112]. Shahid, H. M., Waseem, R., Khan, H., Waseem, F., Hasheem, M. J., & Shi, Y. (2020). Process innovation as a moderator linking sustainable supply chain management with sustainable performance in the manufacturing sector of Pakistan. *Sustainability*, 12(6), 2303.
- [113]. Sholarin, E. A., & Awange, J. L. (2016a). Broad Framework for Environmental Project Management. In *Environmental Project Management: Principles, Methodology, and Processes* (pp. 93-107). Springer.
- [114]. Sholarin, E. A., & Awange, J. L. (2016b). Environmental project management methodology. In *Environmental Project Management: Principles, Methodology, and Processes* (pp. 43-81). Springer.
- [115]. Sin, A. B., Zailani, S., Iranmanesh, M., & Ramayah, T. (2015). Structural equation modelling on knowledge creation in Six Sigma DMAIC project and its impact on organizational performance. *International Journal of Production Economics*, 168, 105-117.
- [116]. Smętkowska, M., & Mrugalska, B. (2018). Using Six Sigma DMAIC to improve the quality of the production process: a case study. *Procedia-Social and Behavioral Sciences*, 238, 590-596.
- [117]. Snyder, H., Witell, L., Gustafsson, A., Fombelle, P., & Kristensson, P. (2016). Identifying categories of service innovation: A review and synthesis of the literature. *Journal of Business Research*, 69(7), 2401-2408.
- [118]. Solihin, W., & Eastman, C. (2015). Classification of rules for automated BIM rule checking development. *Automation in construction*, 53, 69-82.
- [119]. Song, W. (2017). Requirement management for product-service systems: Status review and future trends. *Computers in Industry*, 85, 11-22.
- [120]. Srinivasan, K., Muthu, S., Devadasan, S., & Sugumaran, C. (2016). Enhancement of sigma level in the manufacturing of furnace nozzle through DMAIC approach of Six Sigma: a case study. *Production Planning & Control*, 27(10), 810-822.
- [121]. Stanivuk, T., Gvozdenović, T., Žanić Mikuličić, J., & Lukovac, V. (2020). Application of six sigma model on efficient use of vehicle fleet. *Symmetry*, 12(5), 857.
- [122]. Steiss, A. W. (2019). *Strategic management for public and nonprofit organizations*. Routledge.
- [123]. Stettina, C. J., & Hörz, J. (2015). Agile portfolio management: An empirical perspective on the practice in use. *International Journal of Project Management*, 33(1), 140-152.
- [124]. Tennant, G. (2017). *Six Sigma: SPC and TQM in manufacturing and services*. Routledge.
- [125]. Thai, K. V. (2017). International public procurement: Concepts and practices. In *International handbook of public procurement* (pp. 1-24). Routledge.
- [126]. Tsochev, G., & Stankov, I. (2020). A Study On Information Security Management. 2020 XXIX International Scientific Conference Electronics (ET),
- [127]. Tylka, T. L., & Wood-Barcalow, N. L. (2015). What is and what is not positive body image? Conceptual foundations and construct definition. *Body image*, 14, 118-129.
- [128]. Uluskan, M. (2019). Design of experiments based six sigma DMAIC application: Electrostatic powder coating process. 2019 3rd International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT),
- [129]. Weimer, D. L., & Vining, A. R. (2017). *Policy analysis: Concepts and practice*. Routledge.
- [130]. Willumsen, P., Oehmen, J., Stingl, V., & Geraldi, J. (2019). Value creation through project risk management. *International Journal of Project Management*, 37(5), 731-749.
- [131]. Zaman, M. A. U., Sultana, S., Raju, V., & Rauf, M. A. (2021). Factors Impacting the Uptake of Innovative Open and Distance Learning (ODL) Programmes in Teacher Education. *Turkish Online Journal of Qualitative Inquiry*, 12(6).
- [132]. Zamith, R. (2018). Quantified audiences in news production: A synthesis and research agenda. *Digital Journalism*, 6(4), 418-435.
- [133]. Zapata, B. C., Fernández-Alemán, J. L., Idri, A., & Toval, A. (2015). Empirical studies on usability of mHealth apps: a systematic literature review. *Journal of medical systems*, 39(2), 1.
- [134]. Zeng, J., Phan, C. A., & Matsui, Y. (2015). The impact of hard and soft quality management on quality and innovation performance: An empirical study. *International Journal of Production Economics*, 162, 216-226.
- [135]. Zhang, B., Niu, Z., & Liu, C. (2020). Lean tools, knowledge management, and lean sustainability: the moderating effects of study conventions. *Sustainability*, 12(3), 956.