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Bottleneck Identification and Digitization in an SME: A Case-Based Perspective on Enhancing Operational Efficiency

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Abstract

Small and medium-sized enterprises (SMEs) in emerging economies continue to face mounting pre sures to sustain operational flexibility while maintaining cost efficiency. These challenges are compounded by the accelerating need for digital transformation, which often demands capabilities that exceed existing resource limits. This study examines operational bottlenecks within a project-based SME supply chain through a quantitative, data-driven approach and assesses how digital transformation strategies can mitigate such constraints. The analysis draws upon 159 activities across 18 specialised construction projects in India. A composite bottleneck risk score was formulated by integrating the schedule performance ratio (40% weight), duration variance (30%), and activity frequency (30%). Using K-means clustering, activities were grouped into three distinct risk categories. The results show that 86.2% of activities were executed on schedule, whereas only 2.5% experienced major delays. Notably, 93% of high-risk activities were nonetheless completed flawlessly. Their high-risk classification derived not from execution failures but from their systemic importance within the operational network, thereby questioning conventional assumptions in project management that equate risk with underperformance. Three key activities emerged consistently across 94.4% of projects: Procurement and Execution Planning, Fabric Patterning/Cutting/Welding, and Installation on Site. These reflect the organisation's capacity limitations, even under near-perfect operational execution.

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The proposed framework distinguishes between execution risk, which necessitates process enhancement, and systemic risk, which calls for strategic capacity expansion and planning. Complementing the analytical component, the study introduces an Android application prototype as a practical instrument for advancing SME digitisation. The application automates quotation generation and digitises site-inquiry processes, reducing administrative paperwork, minimising human error, and streamlining information flow. Overall, the findings indicate that the integration of data-driven bottleneck identification with strategic capacity planning can significantly enhance operational efficiency in resource-constrained SME environments.

Keywords—Bottleneck Identification, K-means Clustering, Supply Chain Risk Management, Process Digitization, SMEs

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Introduction

Small and medium-sized enterprises (SMEs) make up nearly 90% of businesses worldwide (Costa Melo et al., 2023). In India, they contribute around 31% of GDP, account for 43% of exports, and provide jobs for more than 300 million people. Despite their size and economic impact, SMEs in emerging economies face ongoing challenges with supply chain management and operational efficiency. These factors directly influence their competitiveness and long-term survival. Central to these issues is a strategic dilemma: how can SMEs reduce costs while maintaining operational flexibility in a complex and unpredictable business environment?

In India, SMEs work with limited resources, fragmented supply networks, and increasing demands for agility, transparency, and environmental responsibility (Ramakrishna et al., 2023). To stay competitive and resilient, these firms need to pinpoint high-risk supply chain activities, simplify inquiry and order processes through digitalization, and use affordable digital tools that match their limited technological capabilities.

Supply chain risk management (SCRM) has become essential for SME strategies, especially for companies involved in project-based operations. These operations often require interdependent tasks, tight deadlines, and changing resource needs. Research shows that SMEs, due to their smaller size and lean structures, are more vulnerable to external shocks like demand changes, cyber threats, and shifting regulations (Tukamuhabwa et al., 2021). For example, (Foli et al., 2022) discovered that demand fluctuations, regulatory confusion, and cybersecurity risks greatly influence SCRM practices in both new and established SMEs. Here, identifying and prioritizing bottlenecks—workflow issues that slow down progress and reduce efficiency—becomes crucial for managing risks in project-based supply chains.

At the same time, digital transformation provides SMEs a way to improve operational performance (Khan et al., 2021). Digitalizing supply chain processes—allowing real-time data access, enhancing visibility, and automating order and inquiry management—can cut lead times, lower operational costs, and improve coordination among supply chain partners in India's manufacturing sector (Ramakrishna et al., 2023). Furthermore, sustainability-focused studies (Martínez-Peláez et al., 2023) note that Industry 4.0 technologies, such as the Internet of Things (IoT), big data analytics, and integrated digital platforms, help SMEs balance efficiency goals with environmental care. This blend of performance and sustainability is particularly important for project-based SMEs aiming for resilience and long-term success in uncertain markets.

Despite growing interest in these topics, a research gap remains in understanding supply chain risk identification, bottleneck analysis, and digitalization for sustainability in Indian SMEs that focus on project-based work. To address this gap, this study has three interconnected goals. First, it identifies supply chain activities most at risk for scheduling and efficiency problems. Second, it explores how digitalizing inquiry and order processes can improve both operational and environmental results. Third, it examines practical digital tools for SMEs with limited IT resources. By focusing on these three areas, the study aims to enhance SCRM practices, improve bottleneck management, and guide strategic digital adoption for resource-limited SMEs in emerging economies.

The rest of this paper is organized as follows. Section 2 reviews current literature on SME supply chain management, Theoretical Foundation: Resource-Based View (RBV), and digital transformation frameworks. Section 3 explains the research methodology, including criteria for selecting cases and collecting data. Section 4 presents the results and discussion, followed by the conclusion in Section 5. Section 6 provides the limitations and scope for further study.

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Literature Review

SME Supply Chain Risk Management and Bottleneck Identification

The Merriam-Webster dictionary defines risk as the chance of loss. This means risk involves both loss and its likelihood. The meaning of risk has evolved over time because of its complex nature (Frosdick, 1997). Changes in the global business landscape and fast technological progress have made risk management a complicated subject (Drew et al., 2006). Small and Medium-sized Enterprises (SMEs) that operate in project-driven environments face specific challenges in managing their supply chains. SMEs often have limited resources, which restricts their ability to guard against unexpected disruptions. Within these businesses, some supply chain activities are particularly susceptible to risks that can interrupt schedules and smooth operations. The impact of these risks on operational efficiency is significant and complicated. Procurement processes often experience delays due to budget constraints, unreliable suppliers, or logistical problems. These issues create bottlenecks that affect later stages of the process.

Bottlenecks are constraints in supply chain processes that matter because they delay operations and disrupt scheduling. In SMEs, bottlenecks often lead to higher costs, inefficiencies, and delays that can jeopardize project timelines and the sustainability of the firm. Identifying these bottlenecks is crucial for SMEs. This identification sets the stage for efforts to reduce risks and improve scheduling reliability and competitiveness. Without effective detection and management of bottlenecks, SMEs risk facing long processing times and underused resources. It is important to understand where these constraints exist in the supply chain and how they influence the overall performance of projects.

The growth and development of SMEs are linked to the formalization and improvement of risk management skills. As companies mature, they invest in building skills like standardizing processes, planning based on data, and using risk assessment tools that enhance their readiness. There is a need for tailored frameworks that consider the different stages of the SME life cycle and the specific challenges they encounter. Various levels of organizational maturity affect how SMEs modify their risk management strategies to handle the complexities of their projects (Chen et al., 2025).

Theoretical Foundation: Resource-Based View (RBV)

The best theory for understanding the challenges and opportunities in SMEs is the Resource-Based View (RBV) of the firm. This concept started in the 1980s and was clearly defined by Barney in 1991. RBV suggests that a firm's sustainable competitive advantage comes from its unique resources and capabilities. These resources must be valuable, rare, hard to imitate, and irreplaceable.

Over the years, RBV has shifted its focus to dynamic capabilities. This change moves the strategic emphasis from external market position to the internal resources that support unique skills and innovation. The development of RBV also includes the idea of dynamic capabilities introduced by (Teece et al., 1997). This idea highlights a firm's ability to blend, build, and reshape internal and external skills to respond to rapidly changing environments.

For SMEs, this framework shows how internal resources like supply chain risk management and digital technologies are vital assets. They help improve operational efficiency and adaptability, especially in project-driven operations where being flexible and responsive is crucial (Foli et al., 2022).

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Digital Transformation as a Driver for Efficiency and Sustainability in SMEs

Digital transformation boosts efficiency and sustainability in small and medium-sized enterprises (SMEs), especially those in complex, project-based supply chains. By digitizing inquiry and order processing, SMEs can streamline their daily operations and ensure that information flows accurately, quickly, and in a coordinated way across departments (Costa Melo et al., 2023).

Beyond improving efficiency, digitization helps SMEs achieve their sustainability goals by enabling better resource use and reducing waste. Digital tools make it easier to monitor production activities and supply chain processes, leading to more energy-efficient operations and a smaller environmental footprint. In this way, digital transformation links operational performance with environmental responsibility. It creates connections that improve both competitiveness and sustainability (Teng et al., 2022).

The combined gains in productivity and sustainability give digitally focused SMEs a lasting competitive edge. These businesses enjoy faster workflows and better customer satisfaction thanks to more responsive service delivery. They also become more agile in reacting to market changes. As digital capabilities grow, SMEs can continuously adjust their positions in the market, maintaining innovation and resilience. These traits are crucial in dynamic, project-driven environments (Kohli & Malik, 2025).

Various digital technologies help improve SME supply chain performance by tackling specific operational challenges. Electronic Data Interchange (EDI) automates procurement and order fulfillment. It allows standardized electronic exchanges of transactional data, which reduces errors, shortens lead times, and increases transparency between buyers and suppliers. Customer Relationship Management (CRM) systems enhance coordination with customers and suppliers by recording interactions, tracking communications, and automating follow-ups. Automated order-processing platforms cut down on manual work and improve transactional accuracy (Bhuiyan et al., 2024). Modular software systems also enable SMEs to gradually adopt these digital tools, aligning implementation with available resources and minimizing risks tied to large-scale IT rollouts (Kowalska, 2024). Together, these technologies help SMEs build digital maturity and strengthen their operational capabilities over time.

Despite the benefits of digitization, SMEs face several challenges in applying these technologies. Financial constraints remain a major barrier, limiting their ability to invest in advanced digital systems or maintain them over time. Also, a lack of internal IT expertise often makes it hard to manage and integrate new technologies effectively. As a result, SMEs need affordable, low-maintenance digital solutions that fit their operational scale and provide value without overburdening existing resources (Telukdarie et al., 2023). This study addresses the identified research gaps through three objectives:

1. To systematically identify supply chain activities that pose the greatest scheduling and efficiency risks in SMEs working with project-oriented operations.

2. To explore how digitization of enquiry and order processing can enhance operational efficiency and sustainability.

3. To identify practical digital tools that SMEs can

implement with limited Information Technology (IT) resources and technical expertise.

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Methodology

This section creates and confirms a multi-dimensional framework for finding bottlenecks by combining schedule performance ratio, duration variance, and activity frequency metrics. It also discusses the development and analysis of an Android application that digitizes site inquiry forms and simplifies the quotation process to improve the "Procurement and Execution" project plan activities. We examined 159 activities across 18 completed specialty construction projects in India, using K-means clustering to classify risk categories objectively. The results showed outstanding portfolio performance: 86.2% of activities were completed on time, while only 2.5% faced serious delays. Clustering identified three risk levels, revealing a crucial finding: 93% of high-risk activities were executed perfectly on schedule. Their classification depended on systemic importance rather than poor execution. We found three critical activities present in 94.4% of projects and discovered that all severe delays focused on a single cascade event. The framework effectively distinguishes between systemic risk, which requires capacity planning, and execution risk, which requires process improvement. This approach allows for targeted resource allocation and proactive management of bottlenecks in construction projects.

Research Context and Study Design

We used a quantitative research design with Python programming to analyze historical project data from a specialty construction firm in India that focuses on fabric-based structures. We looked at 18 completed projects based on four criteria: (1) completion status with final handover documented, (2) complete data available for all critical fields, (3) execution between April and October 2025, and (4) representation across three project categories. The projects included three types: Tensile Structures (4 projects), Awnings (10 projects), and Canopies (5 projects), totaling 18 projects of different sizes determined by the case study company management. Initially, we extracted 169 activities from the dataset, and after data validation, 159 had complete data and formed our final analytical dataset. The research follows the framework shown in Figure 1.

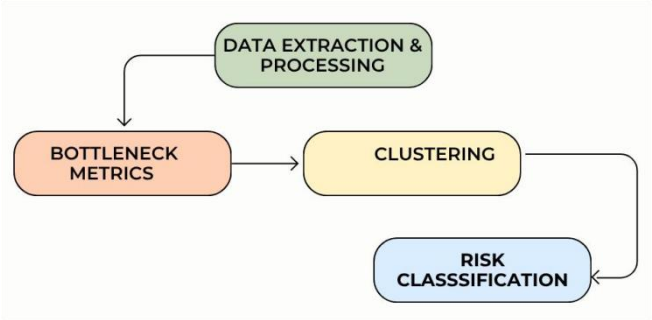

Figure 1: Research Framework

Data Extraction and Processing

The Python algorithm extracted data using automated Portable Document Format (PDF) parsing. It retrieved seven key variables for each project activity: activity name and description, planned start and end dates, actual start and end dates, and both planned and actual duration measured in days, along with project remarks that captured contextual information.

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The data structure included both date ranges and calculated durations. For activities with date ranges, it took the first date as the start and the last date as the end, calculating duration as the difference plus one day for inclusive counting. This dual capture of dates and durations was crucial for schedule analysis. It allowed for the calculation of absolute timeline deviations (did the activity start or end as planned?) and relative duration performance (did the activity take as long as expected?).

Bottleneck Metrics Framework

Three primary metrics were calculated for each activity to capture distinct aspects of bottleneck behavior.

Schedule Performance Ratio (SPR) is a time-based performance metric that measures how closely actual activity completion times follow the planned schedule. It shows the degree of conformity between planned and actual timelines. In other words, it indicates how well the project adheres to its baseline schedule. Values below 1.0 indicate early completion, 1.0 represents perfect on-schedule execution, and values above 1.0 signal delays.

$$\mathbf{SPR}_i = \frac{T_{actual,i}}{T_{planned,i}}$$

Duration Variance (DV) measures absolute deviation from plan:

$$\mathbf{DV}_i = T_i^{\mathbf{actual}} - T_i^{\mathbf{planned}}$$

Activity Frequency (AF) counts occurrences across all projects:

$$\mathbf{AF}_i = \mathbf{n}_i$$

The proposed bottleneck score formula:

$$\mathbf{BS} = \mathbf{0.4\ SPR}_i + \mathbf{0.3\ DV}_i + \mathbf{0.3\ AF}_i$$

is a composite metric designed to quantify the extent to which a given activity contributes to process-level bottlenecks. Each component reflects a distinct dimension of performance degradation:

SPR captures the proportional difference from the planned execution time. By giving the highest weight to SPR, the formula highlights time inefficiency as the main sign of bottleneck behavior. This matches well with established project management metrics, like Earned Value Analysis, where schedule performance is a key factor in determining process health [Andre Henrique Alves Carneiro, 2024].

DV offers a clear measure of delay, adding to the relative nature of SPR. It looks at the size of the deviation regardless of the baseline. This is especially helpful when there is a mix of activities with very different planned durations. Including DV ensures that activities with significant overruns are penalized, even if their SPR values are moderate because of long planned durations.

AF adds a structural aspect to the bottleneck score by considering how often an activity appears in the process. Activities that occur frequently and have poor time performance can worsen overall system efficiency. By factoring in AF, the formula recognizes the systemic effect of ongoing inefficiencies, which is important in fields like manufacturing.

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Experts suggested a weight of 0.4 for Schedule Performance Ratio (SPR), 0.3 for Delay Variance (DV), and 0.3 for Activity Frequency (AF) based on their practical experience with how bottlenecks appear in real-world situations. SPR got the highest weight because it represents proportional inefficiency—how much longer an activity takes compared to its planned duration. Experts identified this as the most important sign of a bottleneck. DV helps capture the total time lost, making sure that large delays are acknowledged even when planned durations differ. AF takes into account how often an inefficient activity happens, highlighting its cumulative effect on the system. Together, these weights provide a balanced measure that reflects expert insight and can be applied across various fields.

The 40% weight on Schedule Performance Ratio emphasizes its role as the main indicator of execution performance. Delay Variance receives a 30% weight to capture the total magnitude of deviation, while Activity Frequency's 30% weight shows its systemic importance and potential to cause further issues.

Risk Classification Using K-Means Clustering

K-Means clustering is a method that groups data into K clusters based on similarity. It begins by placing K random centroids and then assigns each data point x_i to the nearest centroid μ_k. After the assignment, it recalculates each centroid as the average of all points in its cluster. This process continues until the centroids no longer change. The goal is to minimize the total squared distance between each point and its assigned centroid, expressed as:

$$\sum_{k=1}^{k} \sum_{x_i \in c_k} \|x_i - \mu_k\|^2$$

K Means clustering was used to categorize activities into three risk levels: low, medium, and high. This classification was based on four standardized features: composite bottleneck score (BS), schedule performance (SP), delay variance (DV), and activity frequency (AF). The algorithm employed k-means++ seeding with three clusters (k=3). We conducted ten independent initializations, each allowing up to 300 iterations, and set a convergence threshold of 10-4 to ensure the centroids remained stable. We assigned risk levels by ranking the clusters based on the sum of their standardized centroid values. Higher aggregate scores indicated higher risk levels. This method created an objective, data-driven way to identify activities prone to bottlenecks.

Digitization of Order and Enquiry Processing

The system shows how affordable digital tools can improve efficiency, cut down on errors, and upgrade the customer experience for small and medium-sized enterprises (SMEs).

This application has a two-screen workflow. It is designed for field engineers making site visits. It captures detailed specifications, measurements, and project requirements. Then, it automatically creates professional quotes with accurate pricing calculations as seen in Figure 3.

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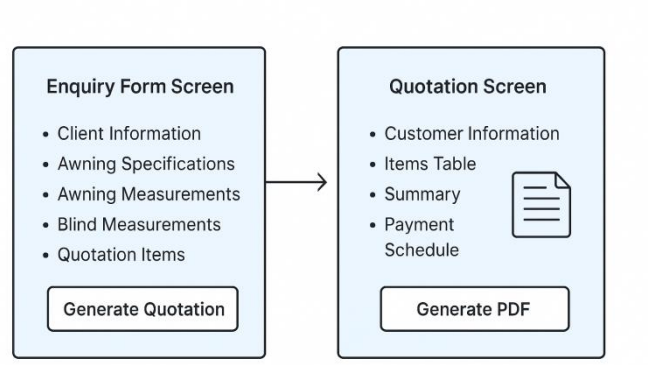

Figure 3: Two-screen workflow

Results & Discussion

Portfolio Performance Overview

The analysis covered 159 activities across 18 projects. Overall execution was strong. Eighty-six percent of activities finished on time, eleven percent completed early, and only three percent faced significant delays. On average, work was done five percent ahead of schedule.

Performance varied by project type. Tensile structures finished twenty-nine percent faster than planned because of better steel procurement and design. Awnings achieved ninety-six percent on-time execution but had one problem project that caused delays across the entire portfolio. Canopies showed the most consistent performance, with little variation from planned schedules.

These results show that the organization generally performs well. This makes a follow-up analysis of bottlenecks especially important, as it uncovers limitations even in well-managed operations.

Two Distinct Types of Risk

Bottleneck scores ranged from 0.22 to 0.75. Analysis of the highest-scoring activities revealed an unexpected pattern: activities earned high scores for completely different reasons, representing two distinct management challenges:

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Table 1: Top 10 Bottleneck Activities

Rank	Activity Name	Score	Risk Type	Actual Performance
1	Fabric Patterning (Problem project)	0.75	Execution	100% overrun
2	Awning Assembling	0.68	Execution	100% overrun
3	Rainguard Preparation	0.56	Execution	100% overrun
4	Fabric Order Date	0.52	Execution	29% overrun
5	Installation on Site	0.50	Systemic	0% overrun (perfect)
6	Procurement & Execution Plan	0.50	Systemic	0% overrun (perfect)
7	Fabric Patterning/Cutting/Welding	0.48	Systemic	2% overrun (near-perfect)
8	Quality Check & Handover	0.45	Systemic	0% overrun (perfect)
9	Steel Procurement	0.44	Systemic	0% overrun (perfect)
10	Site Measurement	0.43	Systemic	0% overrun (perfect)

Execution Risk (Ranks 1-4): These activities scored high because they failed in real projects. They took 29-100% longer than planned due to operational problems, such as transport delays, quality issues that required rework, or failures in coordination. We need immediate operational fixes, like better quality control, reliable suppliers, and improved workforce skills.

Systemic Risk (Ranks 5-10): These activities scored high even though they never experienced delays. They achieved perfect or nearly perfect performance but appear in 76-94% of all projects. Their risk comes from how often they occur, not from any failures. For instance, the "Procurement & Execution Plan" appeared in 17 of 18 projects with 100% on-time completion. These represent limits in organizational capacity. They work well now but could become bottlenecks if project volume increases without expanding capacity.

This distinction is important. Execution risk means "fix this broken process now," while systemic risk means "this process works but limits future growth."

The Unexpected Nature of High-Risk Activities

The K-means classification algorithm sorted all 159 activities into three risk levels based on their bottleneck scores, schedule performance, and frequency patterns.

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Table 2: Clustering results

Risk Level	*Count (%)*	*Typical Performance*	*What Drives the Classification*
High-Risk	*57 (36%)*	*93% completed on time*	*Appears in many projects (avg. 16 times); critical path position*
Medium-Risk	*90 (57%)*	*100% completed on time*	*Moderate frequency (avg. 5 times); routine execution*
Low-Risk	*12 (8%)*	*100% completed early*	*Low frequency (avg. 7 times); generous time buffers*

The surprising finding is that only 4 out of 57 high-risk activities (7%) faced delays. The other 53 activities (93%) ran smoothly and on time but were labeled as high-risk because of their strategic importance. These activities are common across projects and hold critical positions.

This challenges traditional views in project management. "High-risk" usually suggests "poorly managed" or "likely to fail." However, these results indicate that high-risk activities often perform the best and are vital to the organization. The real risk comes from their strategic dependency, not from poor execution.

Strategic Capacity Constraints

Three activities showed up in 94% of projects (17 out of 18), highlighting the organization's main capacity limits:

Procurement and Execution Plan appeared in every project, achieving 100% on-time completion. This is the planning-to-execution gate; work cannot start until this is done. It reflects the organization's ability to kick off new projects. When many projects arrive at once, the capacity of the planning staff becomes the limiting factor.

Fabric Patterning, Cutting, and Welding were present in all projects with 96% on-time performance. This is the main fabrication task common to all project types. It indicates shop floor capacity, which is the primary production limit for the organization. During busy periods, the availability of the fabrication shop decides how many projects can run at the same time.

Installation on Site showed up in all projects, also with 100% on-time completion, despite facing documented external challenges like site readiness issues and weather delays. This reflects the capacity of the field crew and shows effective coordination in tough situations. However, it relies on external factors, which makes it vulnerable.

These three activities need proactive capacity planning, even with strong historical performance. Because they are in nearly every project, any limit on capacity will immediately impact the entire portfolio. As the number of projects increases, these will likely become bottlenecks before any activities at risk of execution do.

How Delays Cascade Through Projects

One Awnings project showed how a single delay affects related activities. This project had all four major delays in the entire 159-activity portfolio, while the other nine Awnings projects completed 95% on time.

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This isolated incident is important for two reasons. First, it shows vulnerability to chain reactions when activities are closely linked with few buffers. Second, the fact that only one of the ten Awnings projects faced this issue confirms that the overall process works well. This was a specific project failure, not a flaw in the process design. The organization's usual execution is strong; these chain reactions are rare events, not signs of widespread problems.

Implications for SME Project Management

This research developed a framework that identifies scheduling bottlenecks and distinguishes between different types of risk. The results challenge traditional project management thinking in SME environments.

Traditional methods treat all high-scoring activities as execution problems that need immediate attention. However, these results reveal that 93% of high-risk activities perform well. They are high-risk due to their strategic importance to business operations, not because they are failing.

This finding impacts how resources should be allocated. SME managers should focus their efforts on the small group of activities with actual execution problems, which is only 7% of this portfolio. They should also build organizational capacity around activities that are strategically important but operationally sound, making up 93% of the portfolio. Mixing up these two groups leads to misallocated resources, fixing problems that don't exist while ignoring capacity constraints that hold back growth.

The three universal activities—procurement planning, fabrication, and installation—represent the organization's capacity limit. These activities deserve strategic attention, not because they fail, but because they determine the maximum sustainable project volume. Investing in more planning staff, fabrication capacity, or installation crews directly boosts throughput. On the other hand, investing in fixing already-excellent execution offers little return. Understanding this difference changes how SMEs prioritize scheduling and efficiency improvements.

Operational fixes focus on execution risk, while capacity investments address systemic risk. Both are important, but they need different solutions applied to different activities.

Enhanced Operational Performance

Digitizing the order and inquiry process, especially by automating quotation generation and replacing manual site inquiry forms with digital systems, can greatly improve operational performance in project-based industries. The system shows how digital transformation can be put into action in small and medium-sized enterprises. It emphasizes the potential of modern technologies like Python to offer affordable, scalable, and easy-to-use solutions for digitizing SME processes. This creates a solid base for wider operational improvements. Figure 4 shows the benefits of the digitization system.

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Figure 4: Digitization Benefits

By streamlining data capture and cutting down on paper-based workflows, engineers on-site can submit accurate, standardized information in real time. This minimizes delays and miscommunication between field and office teams. Automated quotation systems further shorten turnaround time, eliminate repetitive manual calculations, and ensure consistency in pricing and scope.

All these improvements lead to faster decision-making, less administrative work, and better resource distribution. Ultimately, this enhances project delivery timelines and customer responsiveness.

Conclusion

This research tackles an important gap in supply chain risk management, digital transformation, and sustainability for small and medium-sized businesses in emerging markets. We examined 159 activities from 18 specialty construction projects in India. Through this analysis, we created and tested a multi-dimensional framework that questions traditional views on project risk management in environments with limited resources.

Key Findings

Our composite bottleneck scoring method effectively distinguishes between two different types of risk that need different management approaches. Execution risk, which accounts for 7% of high-risk activities, identifies tasks that fail during implementation and face delays of 29-100% due to operational issues. These tasks need immediate process improvements. Systemic risk, making up 93% of high-risk activities, identifies tasks that run smoothly but highlight limits in organizational capacity due to their strategic significance and frequency. These tasks need capacity expansion instead of process fixes.

This finding challenges the common belief that "high-risk" equals "poorly managed." Our results show that the most strategically important tasks are often the best performers; their risk comes from strategic dependency rather than execution failure.

Practical Implications

Three universal critical activities appear in 94.4% of projects: Procurement & Execution Plan, Fabric Patterning, Cutting, Welding, and Installation on Site. These activities define the organization's capacity limit, even with nearly perfect execution. The Android application prototype shows that meaningful digital change is possible within the resource limits of SMEs. It offers benefits like reduced paperwork, automated calculations, real-time data access, and a smaller environmental impact through paperless workflows.

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Strategic Recommendations

We suggest a three-step approach: (1) Immediate Operational Fixes for the few activities that have actual execution failures; (2) Capacity Expansion Planning for frequent activities that set throughput limits; (3) Targeted Digitization with low-cost tools for high-impact applications before moving to complex platforms. This approach ensures that limited SME resources go towards efforts with the most significant impact.

To optimize supply chains in SMEs, it's essential to recognize the key difference between activities that fail during execution and those that succeed but create capacity constraints. By creating clear frameworks to distinguish between these activities and designing accessible digital tools, this research offers SMEs practical ways to improve operational efficiency and environmental sustainability within their resource limits. The combination of identifying data-driven bottlenecks, strategic capacity planning, and practical digital transformation gives SMEs in emerging markets a clear path to building resilience and gaining a competitive edge, even with limited resources.

Limitations and Scope for Further Study

This study looked at a specific construction firm that performed exceptionally well, achieving 86.2% on-time execution. However, this may not reflect all small and medium-sized enterprises (SMEs). The methodology concentrated on project-based construction operations; other areas like manufacturing, services, or technology may show different trends. The digital prototype needs long-term validation to assess ongoing use and lasting efficiency improvements.

Future research should apply this framework to various sectors to find common principles and industry-specific trends. Long-term studies following operations for 2-3 years would help capture seasonal changes, growth paths, and the development of bottleneck issues as organizations grow. Research should also focus on creating digital tools beyond quotation management, developing integrated platforms that include measurement systems for tracking results over time. Future efforts should use optimization algorithms to find the best metric weightings for different situations and expand the framework to include predictive analytics with machine learning for risk forecasting.

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