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ASSESSMENT OF QUALITY RISKS IN SUPPLY CHAINS IN KENYA: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

In the context of intensifying efforts to enhance performance of supply chains, and the timely introduction of products and technologies within competitive markets, organizations and their supply chains have often overlooked the quality risks associated with new product development, particularly concerning design and engineering. This oversight is starkly illustrated by the recent widespread and detrimental product recalls across the automotive, food, pharmaceutical, and smartphone manufacturing sectors, which have brought the issues of product and process quality, as well as associated risks, to the forefront. Additionally, the alarming rise of counterfeit and contraband products in Kenyan supply chains and globally has reached a critical level of concern. Consequently, this study sought to identify and evaluate various quality risks present in the supply chains in Kenya. Utilizing systematic literature survey, the study provided comprehensive overview of supply chain quality risks, the risk perspectives, strategies for risk mitigation, and challenges to management of supply chain quality. The study concluded that supply chains must employ proactive mechanisms for quality determination and anticipation in order to enhance resilience.

Keywords*: Quality Risk, Mitigating, Challenges, Counterfeit, Supply Chain, Assessment*

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INTRODUCTION

A product of high quality is characterized by its suitability for intended uses, the absence of defects or minimal variations, and adherence to customer specifications (ISO 9000, 2005; Deming, 1992; Juran, 1988; Crosby, 1982). In the contemporary market economy, product quality is crucial not only due to its implications for public health but also because the sustainability of a business hinges on its capacity to attract, retain, and engage customers through a superior brand (Ghadge, Fang, Dani & Antony, 2017; Weckenmann, Akkasoglu & Werner, 2015). Furthermore, exceptional product quality is essential for enhancing brand reputation, increasing market share, improving operational efficiency, boosting profits, reducing production costs, and fostering better supply chain relationships (Goodden, 2010).

In the current manufacturing and horticultural sectors, product quality and safety serve as vital competitive advantages. The emphasis on high-quality management standards has transitioned from reactive strategies to more proactive approaches (Chen, 2013). This shift indicates that companies are moving away from traditional craft-system inspections aimed at defect detection and correction, instead prioritizing process and system-oriented methodologies encompassing quality control, quality assurance, quality management, and total quality management (Weckenmann et al., 2015; Ghadge et al., 2017). To facilitate this transition, various methodologies have emerged, including the seven tools of quality management (Q7), Deming's PDCA cycle, and the "Five-times-Why" technique, all of which aid in identifying and rectifying errors. Moreover, a comprehensive consideration of the entire production process, involving multiple entities, has enabled the application of statistical methods to address practical challenges. This has led to the establishment and widespread adoption of Statistical Process Control (SPC) to promptly respond to changes and minimize waste production. Additionally, the statistical Design of Experiments (DoE) has been developed to efficiently identify and adjust significant input parameters, thereby optimizing output results related to product quality.

The transition towards preventive quality assurance has been significantly bolstered by the introduction of various innovative methodologies that employ logical reasoning for preventive analysis, such as Failure Mode and Effects Analysis (FMEA) and Fault or Event Tree Analysis (FTA, ETA). Following this, a supplementary toolkit known as the New Seven Tools (N7) was established, which serves to enhance the traditional Q7 framework with a systematic approach focused on logic-based information.

The risks associated with product quality can lead to severe repercussions, including physical harm, product contamination, diminished performance, increased legal costs, reduced tax income, reputational damage, and a decline in customer trust (Stevenson & Busby, 2015). A notable instance of product quality failure occurred in a Norwegian aviation disaster that resulted in the loss of 55 lives (IACC, 2005). In recent years, numerous individuals in developing nations have suffered illness or death due to the consumption of counterfeit, contraband, or contaminated medications (Lister, 2006; ACA, 2017; Matiangi, 2018).

Over time, the evidence surrounding product quality risks and failures has escalated considerably (Ghadge et al., 2017). The frequency of product recalls and associated damages across the automotive, food, pharmaceutical, and electronics sectors has reached alarming proportions. Environmental disasters, such as oil spills in the Gulf Coast and the Niger Delta, have resulted in extensive ecological harm and substantial financial repercussions for the companies involved (Goodden, 2010; APICS, 2015). In Kenya, the surge in counterfeiting and the trade of contraband goods has heightened concerns regarding product quality risks (ACA, 2018). These recurrent incidents underscore the critical need for conducting root cause analyses to explore how supply chain risk management processes can mitigate and eradicate these challenges.

The aim of this research is to examine a range of quality risks, the obstacles to achieving superior product quality, and the proactive strategies for addressing the underlying causes of product quality risks. The literature review initiates with an exploration of product quality risks. A mixed research methodology is employed to gather both primary and secondary data. The study presents the challenges, mitigation strategies,

and emerging trends relevant to the topic. Finally, the conclusions are drawn, future research directions are proposed, and managerial implications are outlined.

LITERATURE SURVEY

In the daily operations of major businesses on a global, regional, and national scale, quality risks are omnipresent and are continuously addressed (Rao & Goldsby, 2009). The demand for a deeper understanding and the exploration of more scientific approaches to identify and manage quality risks within supply chains has reached a critical juncture. The prevalence of quality risks in supply chains has been exacerbated by contemporary factors such as increased uncertainties in supply and demand, the globalization of markets, environmental unpredictability, and the accelerated pace of product and technology life cycles (Christopher & Lee, 2014). Additionally, the rising trend of outsourcing manufacturing, distribution, and logistics has resulted in intricate international supply network dynamics, thereby heightening exposure to supply chain risks (Christopher and Towill, 2002).

Quality risk encompasses a set of uncertain and causal circumstances whose occurrence can lead to detrimental effects, losses, or adverse outcomes in supply chain operations (Simon, Hillson & Newland, 2011). Zsidisin, Petkova, Saunders, and Bisseling (2016) contend that supply quality risk refers to the potential emergence of quality-related issues linked to supplied components, which, if identified, can result in significant delays in deliveries and production interruptions further along the supply chain. Conversely, if these issues remain undetected, they may lead to subpar quality in use or even pose threats to consumer safety and well-being. The investigation of quality risks encompasses both product and service dimensions. Regardless of the focus area, risk is inherently tied to the possibility of undesirable losses, characterized as negative consequences, and the element of uncertainty (Tummala & Schoenherr, 2011). Recently, there has been an increasing concern that global systems for the production and distribution of food and manufactured goods have significantly deteriorated in terms of resilience, sustainability, competitiveness, and the capacity to meet and manage customer expectations (ACAK, 2018; Leat & Revoredo-Giha, 2013).

Growing exposure to quality risk factors, including design flaws, defective conditions, unethical practices in design or product tampering, inadequate handling, and quality degradation, has been identified as a significant issue (Goodden, 2010; Amadi, 2017). Furthermore, factors such as intellectual property violations, labor-related challenges, cybersecurity threats, data breaches, cultural and ethical considerations, knowledge transfer and maintenance, as well as climate change, have also played a substantial role in the increasing prevalence of quality risks. Utilizing the framework established by Zsidisin (2003), Zsidisin et al. (2016) have categorized supply chain quality risks based on the characteristics of components, suppliers, and markets. This classification identifies potential supply chain quality risks, which include component complexity, frequent changes in product design, global sourcing challenges, supplier shortages, insufficient competencies, absence of quality management systems, lack of quality focus, issues with sub-tier suppliers, and limited understanding of product applications and market demands. As previously noted, the evidence of quality risks is underscored by recent significant product recalls and substantial penalties (Ghadge et al., 2017). In both the United States and Europe, the recall of millions of products has been accompanied by exorbitant logistics costs, litigation expenses, and penalties affecting major corporations in various sectors, including automotive (Volkswagen, Audi, Porsche, BMW, Toyota, Daimler, Firestone), food (Lactalis), pharmaceuticals (Johnson and Johnson), electronics (Samsung Electronics), and agriculture (Monsanto), reaching alarming levels. The environmental disasters, such as oil spills in the Gulf Coast and the Niger Delta, along with the resulting ecological damage and financial repercussions for the involved companies, have been extraordinarily significant (Goodden, 2010; APICS, 2015).

In instances of product recalls, the repercussions of quality risks manifest as significant losses, including diminished sales, decreased production capacity, and heightened marketing expenditures. Zsidisin et al. (2016) indicate that these quality risks can lead to a range of detrimental outcomes within supply chains, such as diminished prices for goods, product liability issues, insurance challenges, reputational harm, expensive product recalls, decreased profitability, loss of market share, restricted access to capital or liquidity, elevated litigation expenses, product contamination, and difficulties in retaining skilled personnel. Furthermore, product recalls can contribute to a decline in brand equity, a reduction in consumer trust, and potential legal ramifications, including lawsuits and bankruptcy (Bates, Holweg, Lewis & Oliver, 2007).

In Kenya, the surge in counterfeiting and the distribution of illicit goods has intensified concerns regarding product quality risks (ACA, 2018). Reports have emerged concerning the sale of contaminated sugar, expired pharmaceuticals, and instances of misdiagnosis. Additionally, the presence of counterfeit manufacturers producing and distributing food items and other consumer products has been documented. These recurring incidents underscore the urgent need for root cause analyses to explore how supply chain risk management strategies can effectively mitigate and resolve these challenges.

Numerous scholars are concentrating on identifying the fundamental causes of risks before they escalate into a global catastrophe (Qvale, 2013; Bates et al., 2007; Fosters, Wallin & Ogden, 2011). Evidence from the aforementioned and various other instances within the automotive and food industries indicates that a failure in the safety and security of a single product can lead to significant repercussions throughout the global supply chain. Ensuring the safety, security, and reliability of products and services utilized by consumers has become a primary objective for contemporary businesses. As noted by Qvale (2013), reliability pertains to a system's ability to withstand external threats, while safety is associated with specific types of failures that can result in catastrophic outcomes. Although product safety and security are often defined and addressed as separate entities, it is posited that safety and security risks are interconnected and exert considerable influence on one another.

Quality Risks

In the ongoing pursuit to enhance sales and profitability while striving to be the first to introduce innovative products and technologies into the competitive market, manufacturers are focused on reducing production costs and increasing operational efficiencies. However, they often overlook deficiencies in new product development that are linked to quality. This study identifies several causes of quality risks, including insufficient understanding of necessary practices, design flaws, unethical design or production issues, product tampering, inadequate handling, quality degradation, intellectual property violations, labor-related challenges, cybersecurity threats, data breaches, knowledge transfer and retention issues, as well as the impacts of climate change. The analysis of supply chain quality risks is framed within the categories of components, market, and supplier, as outlined by Zsidisin et al. (2016). Furthermore, Rao et al. (2009) categorized product and service quality risks into environmental, industrial, organizational, problem-specific, and decision-maker-related factors.

Design Defects

In the context of globalization, consumers increasingly prioritize quality over cost when choosing products from international markets. This shift, combined with the complexities inherent in global supply chains, highlights the significance of quality issues stemming from design defects, which pose a substantial risk to supply chain networks (BDO, 2016). Design defects are a primary contributor to product quality risks, affecting entire product lines that adhere to a flawed design rather than just a subset of defective items (Ghadge et al., 2017; Goodden, 2010; HIG, 2018). Such defects can lead to serious consequences, including injuries, accidents, and fatalities, as well as failures to meet customer expectations, often resulting in product recalls. Design defects can be categorized into two main types (HIG, 2018): unintentional design errors and deliberate design choices.

According to Mulvenna, Boger, and Bond (2017), unintentional design errors occur when designers do not fully grasp the implications of various design elements or fail to apply widely accepted engineering principles for safe product design. These errors are akin to manufacturing defects, as they can be evaluated against established standards of proper conduct. Common examples of unintentional design errors include the selection of inadequate materials or components for a product and the failure to recognize hidden hazards, as exemplified by the Takata airbag design.

Conscious design error refers to unethical practices in product design where the designer knowingly accepts the risks associated with a particular design to enhance product functionality or reduce costs, believing that these benefits justify the acceptance of such risks. This may involve manipulating test data or selectively presenting information to appeal to consumers. Assessing these situations is challenging, as the defects cannot be evaluated against an objective standard of defectiveness; rather, they must be considered in light of the context in which the product was created and whether a reasonably prudent manufacturer would have made similar decisions. Typical examples of design errors stemming from conscious choices include the omission of essential safety features or the failure to provide adequate warnings or instructions. Notable instances include the use of mercury in cosmetics to improve performance and Volkswagen's implementation of technology designed to circumvent emissions testing in their vehicles. Such unethical design practices violate fundamental principles of good design, which emphasize honesty, impartiality, and fidelity, all aimed at protecting public safety, health, and security (Poepoe, 2017).

Labour Challenges

Manufacturers are increasingly confronted with the challenge of addressing the talent gap. Contemporary factory positions demand enhanced technical skills as well as soft skills, and companies are vying for a new cohort of workers within a limited talent pool. Labor-related issues are reported by nearly all manufacturers (97 percent) this year, with concerns regarding labor strikes rising to 66 percent, an increase from 62 percent in 2015. Additionally, as significant strategic and technological transformations affect the industry, the importance of an effective leadership team has never been more pronounced. For the second consecutive year, approximately 74 percent of manufacturers express worries about attracting and retaining essential personnel.

The skills gap is affecting manufacturers across various sizes and sectors. Despite offering wages and benefits that surpass the average, the manufacturing sector is projected to face two million unfilled positions over the next decade. Manufacturers are competing for the same talent pool as Silicon Valley and other technology-driven industries. It is essential to inform the upcoming generation about the potential career opportunities available within the manufacturing sector.

Information Security

Manufacturers this year are setting a modest yet realistic target of achieving satisfactory performance, reflecting a cautious optimism that is echoed in their primary concerns. Our annual examination of the most frequently identified risk factors reveals that supply chain issues remain paramount, with 100 percent of the manufacturers surveyed acknowledging this challenge. Additionally, emerging and escalating risks related to cybersecurity, competition, labor, pricing, regulations, and international operations are significant sources of anxiety for these manufacturers.

In the realm of cybersecurity, a single vulnerability within the security framework can enable hackers to compromise a product feature, an entire supply chain, or a vital component of infrastructure. Given the high stakes involved in the manufacturing sector, there is no room for complacency or negligence. Security must be integrated into products and processes from the initial design phase through to distribution, and it should be prioritized and continuously monitored (Shaghaghi, 2016).

Quality Fade

A significant concern in outsourcing is the phenomenon known as quality fade. This refers to the intentional and covert decline in the quality of labor, aimed at increasing profit margins. Quality fade manifests through gradual yet subtle deteriorations in human capital, which often go unnoticed by the buyer. Initially, during the hiring process, the products or services may align with the buyer's expectations. However, over time, the support team may be replaced by less skilled personnel, ultimately undermining the quality of the services provided. To counteract this risk, it is advisable for buyers to regularly implement customer satisfaction surveys. Failing to do so may result in high customer attrition, and any subsequent investigations into the underlying issues may reveal solutions only after the opportunity to restore customer trust has passed.

Consequently, the buyer may find themselves in a disadvantageous position after outsourcing, having incurred costs for the services while simultaneously losing their customer base. Fortunately, buyers can take proactive measures to mitigate quality risks, such as establishing a service level agreement (SLA) with the supplier. The forthcoming article in this series will delve into the specifics of SLAs. According to Zsidisin's (2003) classification, supply quality risks can be categorized based on component, market, and supplier characteristics.

Component Risks

Two characteristics of components can serve as potential sources of supply quality risks: the complexity of the components and the frequency of design alterations. The complexity associated with components can elevate quality risks, as it raises the likelihood of non-conformance in the components procured (Kaufmann & Carter, 2006; Mitchell, 1995). Moreover, the occurrence of frequent design changes can exacerbate supply quality risks, as it increases the chances that suppliers may struggle to implement the necessary modifications to both design and production processes to align with the requirements of the purchasing firm (Noordewier et al., 1990; Stump, 1995; Zsidisin et al., 2000).

Market Sources.

According to the framework established by Zsidisin (2003), two market characteristics can serve as potential sources of quality risks: global sourcing and supplier scarcity. Firstly, global sourcing can elevate the risk of substandard quality (SQR) due to the heightened likelihood of failing to meet quality standards, which may arise from cultural differences and communication barriers (Jia & Zsidisin, 2014; Tse and Tan, 2011; Zsidisin, 2003), as well as from the complexity introduced by extended distribution channels in terms of both distance and tiers (Natarajarathinam et al., 2009; Rao et al., 2009; Zsidisin & Wagner, 2010). Secondly, the presence of supplier scarcity can exacerbate SQR, as reliance on single sourcing and the absence of alternative suppliers diminish the motivation for suppliers to uphold high-quality standards (Kraljic, 1983; Pfohl et al., 2011).

Supplier Sources.

Five characteristics of suppliers can serve as potential contributors to Supplier Quality Risk (SQR): insufficient capabilities and competencies, absence of a quality management system, lack of a quality-oriented approach, reliance on sub-tier supply chains, and inadequate understanding of product applications and market demands. Firstly, the supplier's capabilities and competencies are critical in determining their ability to meet the specifications set by the purchasing firm. A deficiency in skilled personnel and suitable equipment can lead to substandard quality, thereby increasing the risk of SQR (Lee & Billington, 1993; Pfohl et al., 2011; Theodorakioglou et al., 2006). Secondly, the absence of a quality management system, such as those outlined in the ISO standards, can exacerbate SQR by heightening the chances of component non-conformance (Tse and Tan, 2011).

Thirdly, a lack of emphasis on quality within the supplier's operations can further elevate SQR (Zsidisin et al., 2000); organizations that do not foster a culture of quality—characterized by practices such as training and continuous improvement—are likely to encounter more quality-related issues compared to those that prioritize quality (Ahire et al., 1996; Choi & Liker, 1995). Fourthly, the presence of sub-tier suppliers within the supply

chain can increase SQR, as the purchasing company may have diminished visibility regarding potential quality concerns (Rao et al., 2009; Tse et al., 2011). Lastly, a supplier's limited understanding of product applications and market requirements can lead to increased SQR, as a comprehensive grasp of these elements is essential for achieving high-quality outcomes (Krause & Ellram, 1997; Monczka et al., 1998; Theodorakioglou et al., 2006).

Even with optimal initial design efforts, there remains a possibility that defects may emerge in the field. This can occur due to various factors, such as an underestimation during the risk assessment phase, the emergence of a defective component that went unnoticed, manufacturing defects impacting a specific segment of the product line, or the oversight of the Design Review or Product Safety Team in considering potential misuse of the product. Consequently, issues may still arise.

As these unexpected challenges begin to manifest, typically prior to any significant incidents, the critical question becomes whether the organization is sufficiently attentive to the early warning indicators. Initial reports often originate from Customer Service, Account Management, Sales, Distribution, Technical Support, or Warranty Returns, raising the issue of whether this information reaches the appropriate individuals. In the case of the Toyota crisis, Mr. Toyoda characterized it as "their failure to connect the dots," highlighting that while the company was receiving reports of product failures from North America and Europe, this information did not effectively reach Corporate Japan or the relevant department, if such a department existed.

One of the primary prerequisites in this proactive initiative is for contemporary manufacturing executive teams to acquire the skills necessary to conduct Design Reviews and Product Safety-Hazard Analysis Reviews. This process is essential for identifying and mitigating the risks associated with the release of products that may be defectively designed. It is important to note that this knowledge is not inherently intuitive, and it is likely that engineers have not received formal training in this domain, nor have other members of the manufacturing team. Furthermore, it is crucial to designate and communicate to the entire management and customer service teams who the appropriate individual is for relaying information regarding specific field failures and incidents. Drawing an analogy from the current administration, this person effectively assumes the role of the company's "Product Safety Czar." Additionally, all customer-facing personnel must be trained to distinguish between routine product issues and those that could pose significant safety or liability risks. This necessitates comprehensive training and the establishment of clear procedures.

Existing certified Quality programs, including the routine execution of Failure Mode and Effects Analyses (FMEAs), Six Sigma, Lean methodologies, and other initiatives aimed at enhancing efficiency, will not alter the trajectory of the increasing trend in product recalls. Historical evidence, as seen with companies like Toyota, General Motors, Ford, and Firestone, demonstrates that these approaches have not been effective. A focused training regimen in this area is essential to comprehend the persistent shortcomings in manufacturing, as well as in related domains such as marketing defects, insufficient contracts and agreements, document control, supplier management, and other factors that contribute to product liability litigation.

The recent turmoil at Toyota has acted as a crucial warning for manufacturers, akin to how the BP disaster exposed shortcomings in corporate governance. Generally, it is only after a notable catastrophe that organizations become aware of the essential modifications required in their operations. The critical inquiry at this juncture is whether manufacturing firms will genuinely internalize the insights gained from this experience.

CHALLENGES TO ACHIEVEMENT OF QUALITY

Corruption and resistant to change

Hosea (2014) highlights that corruption represents one of the most significant global challenges, undermining the efforts of nations, businesses, and professional service providers, particularly in developing countries, to

deliver value to their customers. The practice of bribery coerces design engineers, corporate leaders, and service professionals into violating safety, health, and other regulations, thus posing serious social risks (Klitgaard, MacLean-Abaroa, & Lindsey, 2007). As noted by Poepoe (2017), this corruption fundamentally compromises the principles of integrity in product design, impartiality, and transparency. In Kenya, instances of poorly designed and constructed buildings receiving approval, the sale of expired medications, contaminated cosmetics and sugar, and the flourishing of counterfeit industries can all be attributed to the prevalence of bribery (Kimeu, 2014).

Costs

The relationship between the costs of high quality and poor quality presents a paradox. The adage "A stitch in time saves nine" encapsulates the idea that investing in high quality now can prevent significantly greater expenses related to rectifying quality issues in the future. Thus, it is crucial to address potential problems early to avert more substantial difficulties later on. Nevertheless, the practical implications of implementing risk assessments, quality circles, continuous improvement initiatives, and supplier development can be quite costly. Additionally, establishing quality management standards and systems, along with the engagement of quality consultants, can impose a considerable financial burden, particularly on smaller enterprises.

Technology

Technology provides organizations with improved opportunities for design, production, sales, and interaction; however, these advancements also present novel challenges for quality management. The transient nature of technology renders its implementation both costly and disruptive. According to Caldwell, Harland, Powell, and Zheng (2013), the difficulties linked to e-business encompass inadequate software development processes, shortcomings in e-business protocols, and the inadvertent and erroneous handling of transactions. Furthermore, the introduction of new processes, business models, and technologies by participants brings forth additional challenges. Vaidyanathan and Devaraj (2003) identify these challenges as including the absence of standards, regulations, and guidelines, insufficient systems support, as well as external factors such as legal, environmental, and political considerations. Additionally, issues related to trust, confidentiality, scalability, and security further complicate the landscape.

Lack of communication between design and manufacturing departments

The presence of disruptions in communication, coordination, or control among the essential departments of design and manufacturing invariably leads to production defects. In the absence of effective communication and coordination, even the most thorough design initiatives may fail to prevent the emergence of defects in the final product. This can occur due to an underestimation during the risk assessment phase, the emergence of a defective component that was overlooked, or a manufacturing flaw that impacts a particular segment of the product line.

Lack of visibility into top risks

One of the significant challenges in achieving high-quality standards is the inability of design review or product safety teams to consider potential misuse of their products. As quality issues begin to emerge—often prior to any major incidents—organizations must evaluate whether they are sufficiently attentive to early warning indicators. These initial reports typically arise from various channels, including customer service, account management, sales, distribution, technical support, or warranty claims. The critical question is whether this information reaches the appropriate individuals. In the case of the Toyota crisis, Mr. Toyoda highlighted the company's "failure to connect the dots," noting that while information regarding product failures was being received from North America and Europe, it did not effectively reach the relevant departments in Corporate Japan. To address this issue proactively, it is essential for contemporary manufacturing executive teams to acquire the skills necessary to conduct Design Reviews and Product Safety

Hazard Analysis Reviews, thereby identifying and mitigating the risks associated with launching products that may be defectively designed.

TYPOLOGY OF QUALITY RISK MITIGATION

The concept of quality has been integral to human civilization since its inception. Addressing the risks associated with product and service quality necessitates the implementation of various strategies and principles. Scholars have posited that the mitigation of these quality risks can be achieved through one or more of the following approaches:

1. Transitioning from traditional craft-based inspection techniques to a focus on process and system quality
2. Employing proactive risk assessment techniques, including Failure Mode and Effects Analysis (FMEA), Fault Tree Analysis (FTA), and Root Cause Analysis (RCA)
3. Implementing a Supply Quality Management Process (SQMP)
4. Establishing a Supply Chain Risk Management Process (SCRMP)
5. Utilizing Performance-Based Contracting (PBC)
6. Developing a Business Continuity Plan (BCP)
7. Enhancing supply chain relationship management and supplier development initiatives

Shift from craft-based product inspection methodologies to process and system quality

Product Quality-Product Inspection

Quality inspection emerged as the initial framework of quality management during the era of mass production. This approach primarily concentrated on ensuring that manufactured goods were delivered without defects. The primary objective was to maintain a level of quality that was deemed adequate to prevent customer complaints and claims for recourse (Womack, 1991). To achieve this, the final products underwent inspection, and defective items were eliminated from the production line. Consequently, these inspection activities were integrated as a supplementary final step in the production process. The extensive nature of these inspections led to significant costs associated with both identifying and rectifying faulty components, as well as high rates of waste. Furthermore, the corrective measures necessitated additional time, as numerous production tasks had to be completed initially and then redone correctly. Customer requirements, beyond the fundamental standards mandated by laws or regulations, were largely overlooked. Instead, the characteristics and range of products were predominantly dictated by the preferences of the organizations themselves. The T-Model of Ford serves as a quintessential illustration of this period.

Process Quality

The imperative to reconcile the escalating demands for delivery timelines, production expenses, and anticipated quality has led to a significant paradigm shift, transitioning the emphasis from product quality to process quality. By 1940, the evaluation of manufacturing processes became essential for facilitating production control, particularly aimed at mitigating the substantial losses and waste associated with the previously dominant inspection approach. Process quality is fundamentally grounded in the well-established principles of quality control and quality assurance.

Quality Control

The expanded emphasis on the entire process emerged from the realization that identifying and rectifying errors was significantly less effective than addressing their root causes. As a result, the focus shifted from merely inspecting quality and responding to issues, to actively managing quality. This transition led to the abandonment of the concept of merely eliminating waste in favor of a quality control circle model. Quality control became grounded in the principle of developing systems that utilize statistical control programs to

assess the extent of quality failures, with the objective of minimizing associated costs. Among the various tools employed in quality control, statistical control procedures were particularly prevalent.

Quality Assurance.

A significant expansion of process analysis emerged from a pivotal shift in the conceptual framework regarding process and product quality. Previously, the focus was primarily on the characteristics of the final product, with adjustments made to input parameters only after deviations from the desired quality were detected, thereby establishing a reactive correction mechanism. However, beginning in the 1960s, a proactive approach was adopted, emphasizing not only the control of product and process quality but also the anticipation and prevention of potential risks and issues before they materialized. This led to the development of quality assurance methodologies. Quality assurance introduced a customer-centric viewpoint, along with principles of quality planning and continuous improvement (Geiger, 1994; Pfeifer, 2001; Juran, 1988). This evolution was significantly influenced by the intensifying competition resulting from the onset of internationalization, which increased the number of suppliers in domestic markets. Consequently, the scope of quality assurance activities expanded to encompass the entire product lifecycle within the organization, rather than being limited to the production phase alone.

The enhanced impact of the three factors—quality, costs, and time—led to an increase in quality design and planning initiatives informed by production experiences, resulting in the establishment of more extensive control circles.

System Quality

As customer demands continue to escalate due to competitive pressures, the complexity of products has significantly increased. Consequently, it became essential to account for the interdependencies with suppliers. The reliability and efficiency of the entire supply chain cycle have gained paramount importance, as the intricate nature of purchased components often renders swift supplier changes unfeasible. In response, the traditional linear approach to quality management has evolved into a more comprehensive system-oriented perspective. This new framework not only encompasses the linear aspects of the value-creation process but also integrates the connections and interdependencies with various other processes and activities within the organization. Therefore, in addition to a process-oriented analysis of workflows, a system-oriented approach has been adopted. This shift towards system quality orientation has facilitated the development of numerous quality tools, including quality management systems and methodologies, and has contributed to the rise of total quality management.

Quality Management.

The growing intricacy of entities and their interrelations in quality management has necessitated the establishment of documentation and activities aimed at fostering mutual trust among partners. This evolution culminated in the development of the ISO 9000 series, which delineates fundamental requirements for quality management. Alongside this standardization, the emergence of certification became both feasible and sought after, enabling a network of suppliers and industrial customers to rely on the quality-oriented performance of their partners. It is important to note that the significant advancements in quality management compared to previous paradigms have not stemmed from the introduction of new techniques or methodologies. Rather, they have arisen from the establishment of a cohesive, harmonized, and internationally recognized framework of standards and accredited certification bodies, which facilitate mutual trust and enhance partnerships among enterprises. Consequently, the extensive efforts required to monitor supplier quality have been alleviated. Furthermore, the focus has expanded from traditional manufacturing processes and tangible products to encompass the increasingly vital service processes and intangible products. To address this new domain, numerous existing quality management tools and methods have been modified to meet the specific requirements of service quality, particularly in light of the challenges associated with reproducible data.

Total Quality Management.

The fourth and most recent paradigm shift has become distinctly apparent over the past decade. This shift is characterized by an expanded application of quality management principles to public and social sectors, alongside a collective emphasis on maintaining high standards of quality. Consequently, the motivation for implementing quality management has transitioned from being predominantly market-driven to being recognized as essential for delivering superior outcomes. As a result, quality management frameworks are now being adopted in fields that do not face direct competition, such as education, healthcare, and public administration, where there is a strong desire for continuous improvement.

In this context, the role of employees has gained prominence, overshadowing the influence of machines and other technological elements. The necessity for all organizational members to commit to high-quality standards has led to the emergence of Total Quality Management (TQM), which acknowledges the interconnectedness of leadership, employee engagement, processes, customer satisfaction, and overall business performance. This recognition has given rise to Total Quality Management and Business Excellence Models, such as the European Foundation for Quality Management (EFQM) Model, which also incorporate aspects related to employee well-being that were previously overlooked due to a focus on mechanistic perspectives.

Failure Mode and Effects Analysis (FMEA), Fault Tree Analysis (FTA), Event Tree Analysis (ETA)

FMEA serves as a highly effective methodology for assessing potential failures and associated risks during the design, process, and service phases. This approach contributes significantly to quality enhancement, reduction of defects, and timely delivery (Ghadge et al., 2017). It is recognized as a structured process for analyzing a system to pinpoint possible failure modes along with their causes and impacts on system performance (Gandhi and Agrawal, 1992). Conducting this analysis in the early phases of a system allows for the most cost-effective removal or mitigation of identified failure modes (Stamatis, 1995). A critical metric within the FMEA framework is the Risk Priority Number (RPN), calculated as the product of occurrence (O), severity (S), and detection (D) ratings, as expressed in equation (1) (Tay & Lim, 2006):

$$RPN = O * S * D \quad \text{EQ1}$$

The FMEA process can be outlined in the following steps (Tay & Lim, 2006; Teng & Ho, 1996):

1) Establish a scale table for Severity, Occurrence, and Detection.

2) Analyze the intent, purpose, goals, and objectives of the product or process, typically determined through the interaction of components and process flow diagrams, followed by a task analysis.

3) Identify potential failures within the product or process, encompassing issues, concerns, and opportunities for improvement.

4) Assess the consequences of failures on other components, subsequent processes, operations, customers, and regulatory requirements.

5) Determine the potential root causes of identified failures.

6) Implement initial methods or procedures to detect or prevent failures in the product or process.

7) Assign severity ratings to evaluate the seriousness of the effects of potential failures.

8) Estimate occurrence ratings to gauge the frequency of potential failure causes.

9) Evaluate detection ratings to assess the likelihood of process controls identifying specific root causes of failures.

10) Calculate the RPN as the product of the three input ratings: severity, occurrence, and detection.

11) Implement corrections, which may necessitate revisiting Step (2) if required.

Several researchers have proposed a novel framework for managing risks within supply chains, emphasizing the importance of assessment as a pivotal component. Norrman and Jansson (2004) introduced a model known as ERMET (Ericsson Risk Management Evaluation Tools). Similarly, Brun et al. (2006) presented another framework referred to as SNOpAck (Supply Network Opportunity Assessment Package). Furthermore, additional models have been employed to aid in the identification of supply chain risks through brainstorming techniques, including IDEF0 (Sinha et al., 2004) and AHP (Wu et al., 2006).

Supply Quality Management Processes (SQMPs)

Supply Quality Management Processes (SQMPs) encompass a series of procedures and practices aimed at overseeing the supply function to enhance the quality of components (Lo & Yeung, 2006). According to Zsidisin et al. (2016), SQMPs can be categorized into three primary domains: supplier selection, supplier development, and supplier integration.

The supplier selection process entails identifying suppliers based on their capacity to deliver products that meet specified quality standards (Mutuku, Ochieng & 2021; Lyson and Farrington, 2012; Lo and Yeung, 2006), among other relevant factors. By selecting suppliers with the necessary capabilities, established quality management systems, and a strong commitment to quality, organizations can significantly mitigate the risks associated with quality. Furthermore, when engaging in global sourcing, the quality risks can be effectively managed through a thorough supplier selection process that ensures suppliers are well-informed of and actively uphold quality standards and requirements.

Supplier development represents a strategic initiative by the buyer to enhance the capabilities and competencies of both potential and existing suppliers (Ochieng, 2014). This process often involves the buyer's active participation at the supplier's location to provide feedback on quality performance, establish a credible commitment to quality, underscore the significance of quality to the supplier, and enhance the supplier's knowledge and performance through training, recognition, and certification opportunities (Ellram, 1995; Krause & Ellram, 1997; Krause et al., 2000; Lascelles & Dale, 1990; Lo & Yeung, 2006; McCutcheon & Stuart, 2000; Monczka et al., 1998; Stuart, 1997; Trent & Monczka, 1999).

Supplier development initiatives can effectively mitigate various quality risks associated with suppliers. To enhance supplier quality, buyers may assess supplier performance and offer constructive feedback. In terms of market-related risks, buyers can diminish quality concerns by equipping suppliers with training and technical support to navigate component complexities, thereby minimizing the necessity for frequent alterations in product design.

Supplier integration encompasses the alignment of business strategies, the cultivation of buyer-supplier relationships, the sharing of operational data, and the establishment of collaborative alliances (Ellram, 1995; McCutcheon and Stuart, 2000; Monczka et al., 1998; Stuart, 1997; Trent and Monczka, 1999; Tse et al., 2011; Lo and Yeung, 2006). This integration can significantly lower quality risks through various mechanisms. For instance, in relation to component sources, buyers can collaborate with suppliers in the design and development of components, thereby simplifying complexity through early engagement. Additionally, buyers can proactively communicate forthcoming product and design modifications to suppliers, enabling timely adjustments in their processes. From a market perspective, establishing a long-term partnership can position the supplier as a preferred customer. In terms of supplier capabilities, buyers can enhance the necessary skills and competencies of suppliers by nurturing a relationship that prioritizes quality.

Supply Chain Risk Management Process (SCRMP)

The process of supply chain risk management builds upon the foundational risk management framework initially proposed and subsequently refined by Tummala et al. (1994) and Tummala & Mak (2001).

Additionally, it incorporates insights from research conducted by Ellegaard (2008), Finch (2004), Manuj and Mentzer (2008), and Schoenherr et al. (2008). The Supply Chain Risk Management Process (SCRMP) is structured into three interconnected phases that engage with various drivers and risk categories to inform supply chain decision-making. Phase I encompasses the identification, measurement, and assessment of risks. Phase II focuses on the evaluation of risks, alongside the development of mitigation strategies and contingency plans. Finally, Phase III is dedicated to the ongoing monitoring and control of risks.

Business Continuity Planning/ Business Continuity Management

The process of developing systems for prevention and recovery is essential for addressing potential threats faced by a company, positioning it as a critical component of risk management. Business continuity planning aims to identify possible threats to an organization's vital activities or success factors, ensuring that these threats can be mitigated or managed effectively to sustain business functions and processes during risk events. This approach focuses on preserving the core deliverables of an organization amid disruptions or ongoing changes.

Norrman and Lindroth (2004) assert that business continuity planning and management (BCP/BCM) encompass broader aspects than those typically addressed by supply chain risk management. BCP/BCM incorporates elements such as crisis management, disaster recovery, business recovery, and contingency planning, which are often overlooked in the context of supply chain risk management. A comprehensive business continuity plan should account for any event capable of disrupting operations, including political risks, strategic risks, natural disasters, infrastructural damage, and supply chain vulnerabilities. A BCP outlines various catastrophic scenarios and the strategic responses an organization intends to implement in the event of a risk occurrence to restore normal operations. The development of a BCP typically involves the engagement of organizational staff and stakeholders, fostering a sense of ownership and the establishment of voluntary norms for risk management. Business continuity management represents a comprehensive approach that identifies potential threats to an organization and provides a framework for enhancing resilience, enabling effective responses that protect the interests of key stakeholders, as well as the organization's reputation, brand, and value-generating activities.

Performance Based Contracting

Performance-based contracting (PBC) involves the association of payment with the fulfillment of service performance criteria, effectively shifting the quality risk to the service provider (Selviadiris & Norrman, 2014). The established performance metrics may be linked to financial incentives or penalties, thereby motivating the provider to enhance their efforts (Hooper, 2008). The successful implementation of performance-based incentive frameworks necessitates comprehensive processes and systems for the measurement and reporting of service performance indicators (Datta & Roy, 2011).

PBC prioritizes the articulation of performance outcomes for the customer, as opposed to focusing on the inputs and processes involved in delivering the service (Martin, 2007). Performance is assessed in terms of both service outputs and outcomes. Outputs pertain to the operational capabilities and performance levels of the service (e.g., percentage of machine availability), while outcomes relate to the value that the customer derives from the service (Axelsson & Wynstra, 2002). This customer value can be quantified in monetary terms (e.g., savings in customer costs) but may also encompass intangible aspects, such as customer satisfaction, which are more challenging to quantify (Bonnemeier et al., 2010).

A significant challenge associated with this approach is the potential misalignment between the intended service objectives and the established performance metrics (Behn & Kant, 1999). Therefore, it is essential to accurately capture the requirements of end-users within the defined measures (Datta et al., 2011). These measures should incorporate both qualitative and quantitative components, thereby enhancing the rigor of the evaluation and compensation processes for providers (McLellan et al., 2008). The creation of precise data

collection and performance measurement systems is a critical focus area, with information technology playing a pivotal role in this endeavor. For example, in the realm of maintenance services, technologies such as telematics and remote diagnostics are employed to gather accurate data on product usage, which is instrumental for effective maintenance planning and cost management (Stenbeck, 2009).

EMERGING TRENDS

In the contemporary landscape, globalization and the intricacies of interconnected supply chains necessitate a comprehensive approach to quality management. This approach must encompass not only technical quality standards but also the integration of social responsibility and sustainability considerations. Organizations aiming to meet customer expectations must extend their focus beyond the mere product, necessitating the establishment of equitable global employment practices and the proactive management of environmental issues, such as resource scarcity, to maintain their reputation (see Figure 1). Additionally, many enterprises are currently confronted with the complexities of global partnerships in areas such as development, procurement, manufacturing, and sales, which are essential for navigating the intensifying competitive landscape. Within this context, the critical dimensions that have emerged, highlighting significant areas where advancements in quality management are imperative have been posited by Weckenmann *et al.*, 2017 in figure 1.

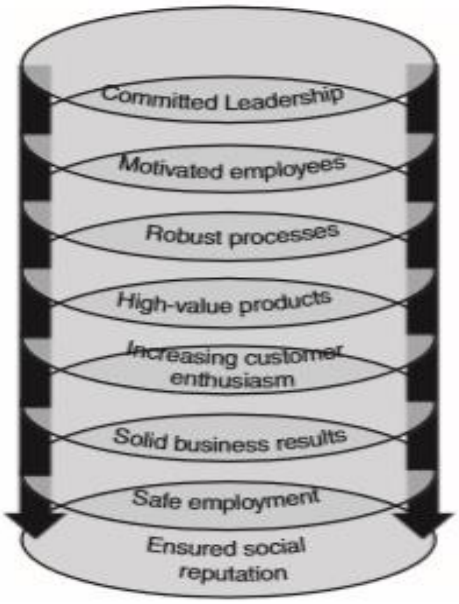

Figure 1: Holistic view of quality management including several dimensions of work and results.

Adapted from Weckenmann *et al.*, 2017

RECOMMENDATIONS

The results and discussions presented in this research indicate that supply chain risks, particularly those related to quality, are complex phenomena that necessitate a hierarchical analysis of various causes and their corresponding effects. Consequently, the study advocates for managerial perspectives on supply chain quality risks to be examined from multiple viewpoints or for the development of diverse quality risk management systems aimed at comparing risk management strategies. Furthermore, the research emphasizes the importance of enhancing risk management efforts and integrating resilience through the establishment of robust supply chains across various sectors, as quality risk factors in one sector can rapidly influence others. Additionally, the study highlights the significance of collaboration among supply chain stakeholders, noting that collaborative arrangements, such as collaborative planning and forecasting (CPFR) and other forms of horizontal and vertical collaboration, have proven to significantly improve risk management outcomes.

CONCLUSIONS

The research highlights various sources of supply quality risks, which can be categorized into several types: design and production defects, information technology vulnerabilities, human factor issues, component-related risks, marketing challenges, and supplier-related risks. In terms of the difficulties associated with managing these quality risks, the study identifies several critical factors, including corruption, cost constraints, technological hurdles, communication and coordination issues, as well as insufficient visibility into the most significant risks. A classification of mitigation strategies is presented, advocating for a transition in quality management from a focus on product inspection to an emphasis on process and systems quality. The development and institutionalization of comprehensive tools such as Failure Mode and Effects Analysis (FMEA), Fault Tree Analysis (FTA), Root Cause Analysis (RCA), Event Tree Analysis (ETA), and Analytic Hierarchy Process (AHP) are also recommended. Furthermore, the study suggests that the implementation of Supply Quality Management Processes (SQMP), Supply Chain Risk Management Processes (SCRMP), Performance-Based Contracting (PBC), Business Continuity Planning/Management (BCP/BCM), and the establishment of professional and business ethics can serve as effective mitigating measures.

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