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BEYOND EFFICIENCY: SMART VALUE STREAM MAPPING AND STQM AS SYNERGISTIC DRIVERS FOR ECO-LEAN TRANSITIONS IN EMERGING MARKETS

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Abstrak

This study explores the integrative role of Lean Green Digitalization (LGD), Smart Value Stream Mapping (Smart VSM), and Sustainable Total Quality Management (STQM) in enhancing operational sustainability and minimizing environmental waste within Indonesian micro, small, and medium-sized enterprises (MSMEs), with a focus on the textile sector. Anchored in the Triple Bottom Line (TBL) framework, this research employs a quantitative design with data collected from 110 purposively selected respondents affiliated with Fit Force, a regional garment manufacturer. Utilizing Partial Least Squares Structural Equation Modeling (PLS-SEM), findings reveal that both LGD and Smart VSM significantly influence STQM and environmental waste reduction, while STQM functions as a critical mediating construct, enabling the translation of digital and lean practices into tangible environmental benefits. These results offer empirical validation for a multidimensional sustainability model that merges digital innovation with quality management to address the resource asymmetries and process inefficiencies characteristic of MSMEs. The study contributes novel insights to the discourse on sustainable industrial transformation, positioning digital-lean integration not only as a strategic imperative for MSME competitiveness but also as a catalyst for inclusive and ecologically responsible growth.

Keywords: Lean Green Digitalization, Smart Value Stream Mapping (Smart VSM), Environment Waste, Sustainable Total Quality Management (STQM)

INTRODUCTION

The rapid advancement of digital transformation has precipitated a critical evolution across global industries, catalyzing significant shifts particularly within micro, small, and medium-sized enterprises (MSMEs). These entities constitute vital components of emerging economies, particularly in Indonesia, where they account for approximately 64 million units, nearly 61% of the national GDP, and employ about 97% of the workforce (Ghaleb & Gül, 2022). The urgency to address the inconsistent readiness of these enterprises for digital adoption is underscored by barriers imposed by limited organizational resources and insufficient capacity for structural adaptation, which hinder their ability to fully exploit digital opportunities (Suriyankietkaew & Nimsai, 2021; Stawicka, 2021). Moreover, the need for proactive digital transformation has become evident, where strategic digital business capabilities and the integration of green intellectual capital are increasingly recognized as mediating factors in enhancing MSME performance (Daryono et al.,2024; Daryono et al., 2025b). These multifaceted challenges threaten their viability and impede their potential contributions to inclusive economic growth.

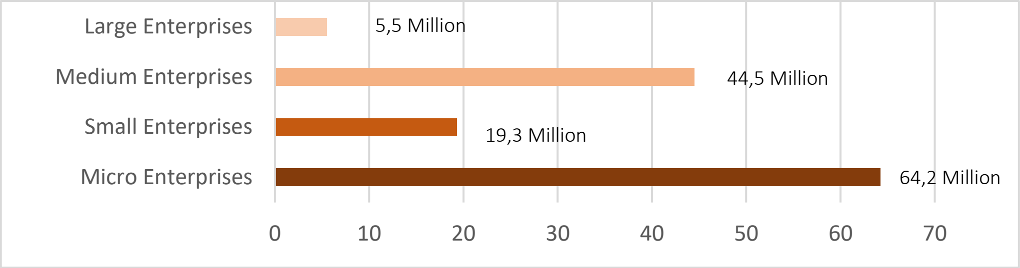

Figure 1.1: Average Number of MSMEs in Indonesia (2021)

Source : https://databoks.katadata.co.id

Integrating environmental sustainability increases the operational complexity of MSMEs, particularly in the textile sector which contributes around 3% to the global carbon emissions (Eggers, 2020). Making the move towards sustainable methodologies is critical in curtailing the ecological footprint associated with traditional practices. Alignment of these initiatives with organizational culture requires focused stakeholder engagement (Boonnual & Boonnual, 2024). Key strategies for sustainable MSME practices include eco-innovation and the incorporation of clean production technologies, both critical to achieving environmentally sustainable operational frameworks (Johnstone & Hallberg, 2020).

Fit Force as one of the MSMEs in the garment manufacturing sector, illustrates some of the multifaceted problems that exist in this domain. Their business operations include the production of various textile items such as screen-printed t-shirts and varsity jackets. However, they continue to face functionality challenges owing to conflicts in resource scheduling and allocation (Yevloyeva & Utegenova, 2023). The differences in the production timetable reveal the fragile balance between sustainability and productivity that small and medium enterprises manage, where even slight shortfalls in operational optimization threaten the competitive advantage and net promoter score as well as customer expectations. It becomes crucial for micro, small, and medium enterprises MSMEs aiming for sustainable advancement to resolve operational inefficiencies through robust frameworks, one of which is the Triple Bottom Line (TBL) Theory that analyzes performance in three dimensions: economics, environment, and social. (Johnstone & Hallberg, 2020). Figure 1.2 illustrates the difference in production time:

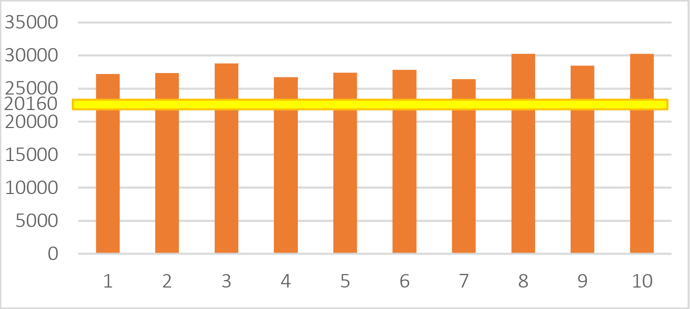

Figure 1.2: Comparison of Actual vs Target Production Time
Fit Force Apparel

The integration of Lean Green Digitalization with Smart Value Stream Mapping (Smart VSM) and Sustainable Total Quality Management (STQM) together form an overarching framework to improve operational efficiency in a corporate ecodiscipline (Lestari et al., 2024). This threefold synergy focuses on the optimization of an enterprise's recources, creation of value, and works toward alignment with sustainability goals strengthening the responsiveness of MSMEs toward contemporary concerns (Uwineza et al., 2024). Empirical studies underline the enabling force of synergy between lean green practices and digital technology with the operational agility of MSMEs.

These underscore sustainability benchmarks (Stawicka, 2021; , Lestari et al., 2024). The implications of these findings are not only theoretical. They provide MSMEs such as Fit Force integrating digitally sustainable practices with business strategy enhances competitive advantage in the face of overwhelming environmental challenges. This investigation will further illustrate the transformative power that merging technologies with sustainable approaches can provide, creating models designed for MSMEs. The anticipated contributions are grounded in action instead of theory, addressing the urgency of sustainable development by providing frameworks for operational excellence.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

A. Triple Bottom Line Theory (TBL Theory)

The TBL (Triple Bottom Line) Theory - developed by Elkington 1994 - focuses on achieving economic growth along with environmental protection and social equity simultaneously. It seems that in recent years, the application of TBL has gained attention in the context of the manufacturing industry, particularly with the adoption of Industry 4.0 technologies and lean manufacturing. These approaches are said to greatly improve TBL by enhancing process efficiency, reducing adverse environmental effects, environmental stakeholder engagement, and creating value (Feng, 2023; Ng et al., 2022)(Alwis et al., 2023). For example, Huang et al. (2024) provided evidence that companies adopting lean green digital transformation strategies tend to increase their profitability and ecological sustainability (Feng, 2023). Additionally, SVSM techniques have been shown to improve the overall control of operations so that greater supply chain environmental waste can be identified and eliminated, thereby ensuring stronger TBL compliance (Ng et al., 2022; Alwis et al., 2023).

The integration of the sustainable STQM practices, within the boundaries of the TBL criteria, serves as an organizational operational lever toward achieving sustainability. The green STQM innovation—including conservation of energy—advocates not only for the TBL environmental dimension, but also promotes social responsibility and employee engagement. Application of STQM practices has been found to foster a culture of continuous improvement which enhances productivity and satisfaction levels among employees (Agrawal & Vinodh, 2020; Alwis et al., 2023). Moreover, businesses that apply STQM practices do fulfill at least the minimum strategic social and legal responsibilities, but strategically benefit from increased positive brand perception (Alwis et al., 2023). The documented empirical evidence regarding the relationship between lean practices, digital innovation, and TBL performance strongly demonstrates the necessity of embracing STQM frameworks to advance sustainability goals while realizing profit and societal value (Feng, 2023; Khanfar et al., 2021; Ng et al., 2022).

B. Lean Green Digitalization

Lean Green Digitalization (LGD) develops an area of manufacturing whereby productivity advancement occurs alongside ecological sustainability. Through this approach, companies can greatly improve waste management, emissions control, energy conservation, and occupational health and safety (Afum et al., 2021; Machingura et al., 2023). Each of green and lean focuses on wastage reduction and operational efficiency, and environmental conservation, respectively. Both sides working together form one integrated system is for the greater good and minimizes ecological harm (Kumar & Rodrigues, 2020; Younnes, 2023).

The processes of production are being transformed systematically with the integration of eco-design philosophies which manage the materials and energy consumed while reducing the negative impact on ecosystems (Huang et al., 2023). Competitive advantage obtained by firms that adopt lean and green policies arises from greater operational effectiveness as well as an increase in demand for sustainable offerings (Machingura et al., 2024; HUDY et al., 2023). Contemporary manufacturing gains greater operational efficiency and sustainable competitive advantage when incorporating LGD, as shown in several case studies that underscore the need for an integrated approach (Črešnar et al., 2020; Amjad et al., 2021).

C. Smart Value Stream Mapping (Smart VSM)

Smart Value Stream Mapping (Smart VSM) is designed to improve operational efficiency in manufacturing by building upon traditional value stream mapping techniques. Despite the potential uses of Smart VSM in pinpointing operational losses, its application in larger scale projects is minimal, therefore limiting evaluations of its overall impact on waste and efficiency improvements (Myeong et al., 2020). Smart VSM focuses even more on the waste and value creation, conversion processes, and the operation flow within lean industries (Terzioglu et al., 2022). In addition, Smart VSM delineates various streams that include but are not limited to: design flow, product flow and information flow that operational processes to manufacturing processes (Garay et al., 2021). As highlighted in (Terzioglu et al., 2022), the Smart VSM approach enhances the visualization of processes, making the analysis and identification of waste easier. Smart VSM is essential in the drive toward sustainability within manufacturing as it integrates environmental assessments with operational practices by measuring value-added ratios, thus aligning green objectives with ecological-centric goals (Myeong et al., 2020). This is an integration because it permits organizations to resolve present-day issues while paving pathways for future optimizations that seek to reduce lead time, production cost, enhance delivery timelines, and uphold product standards (MçGuirk et al., 2021). Conclusively, Smart VSM stands out as a critical instrument for the elimination of waste, and as an advanced blueprint for operational standard refinement across sectors.

D. Sustainable Total Quality Management (STQM)

STQM integrates frameworks of sustainability with Total Quality Management (TQM) and emerges as a novel prerequisite for any organization striving for both product, service excellence, and efficient sustainability. This integrated approach, blending the principles of sustainability with quality management, facilitates organizational compliance with legal obligations as well as meeting the expectations of stakeholders. Antony et al. (2024) suggested that STQM encompasses various processes, tools, and techniques that assist in planning, controlling, and monitoring activities related to quality and helps in sustaining organizational-wide continuous improvement and defect prevention. Integrating quality management with sustainability has increasingly gained attention in the literature, as organizations with well-developed frameworks for STQM tend to be more efficient and competitive in their operations (Pacana & Czerwińska, 2023). The evidence has showed that STQM not only fulfills but, more often than not, exceeds the expectations of consumers which significantly accelerates the adoption of sustainability initiatives driven by the desire to serve the customer (Farrukh et al., 2020). In addition, the effective implementation of STQM is indispensable in achieving sustainable and flexible improvement in STQM for competitiveness and quality resilience in sustainable enduring frameworks (Saha et al., 2022). STQM is an integral part of World Class Industry framework which distinctly underscores gaining competitive edge through high industry benchmark standards and sustainable marked differentiate services (Devi et al., 2022).

E. Environment Waste

Environmental waste refers to the diverse forms of non-value-adding activities that lead to environmental degradation through emission byproducts that pose potential hazards to ecosystems as well as human beings. This concept integrates lean principles which focus on the elimination of waste as a primary operational approach to improve efficiency and minimize costs associated with environmental cleanup and remediation (Gonzales, 2023). Overproduction, delays, transportation, unnecessary processes, defects, inventory, motion comprise the seven different distincts of environmental waste (Gonzales, 2023). Various sorts of waste greatly drive up costs and resources while over-consumption as well as pollution propunctuate detrimental impacts onto the environment (Chester et al., 2021). For example, the overproduction of goods increases materials and products that must be managed or disposed of, adding even more stress to the already burdened waste management systems (Alimin et al., 2022). Also, delays in transportation lead to unnecessary fossil fuel consumption which widens the carbon footprint and neglected defects generate extra materials that require energy and resources to refine, thus increasing the environmental load (Chester et al., 2021). With appropriate handling of such wastes, organizations can improve both operational productivity and environmental sustainability; therefore, the comprehensive control of waste is crucial to reduce its adverse effects on humans and nature (Čulková et al., 2023; Vanapalli et al., 2021).

H1: Lean Green Digitalization significantly affects Environmental Waste

Lean Green Digitalization (LGD) integrates digital technologies with lean theory to improve sustainable practices which are largely centered on eco-waste reduction in the manufacturing domain. Advanced technologies such as real-time analytics and the Internet of Things (IoT) are playing a more crucial role in assisting organizations with their workflows. The incorporation of such technologies enhances operational productivity and curtails resource waste, thus advancing industrial practices towards sustainable developmental goals. Huang and Lau (2024) along with Singh et al. (2021) illustrate how the lean-green-digital (LGD) approach provides pragmatic pathways for achieving better carbon efficiency. Moreover, digitally-enabled transformations of corporates with lean principles amplify corporate environmental responsibility, thereby fast-tracking the move to circular economy constructs with a net-zero emissions ethos (Foo et al., 2021; Ghosh et al., 2022). These developments mark a shift in the paradigm towards sustainability, moving from perceiving it purely as a compliance mandate to a central, long-term driver of corporate strategy for sustained edge over competitors.

H2: Smart Value Stream Mapping significantly affects Environmental Waste

Smart Value Stream Mapping (Smart VSM) is an advancement of traditional lean practices that incorporates modern data analytics and IoT technologies to more accurately and responsively map production flows in relation to ecological considerations. This development elevates the role of VSM from a mere visualization tool to a strategic instrument capable of pinpointing non-value-added activities and optimizing material flow in a manner that systematically reduces waste (Wang et al., 2024; Ali et al., 2020). Earlier research focused on sustainability frameworks empirically on the operational transparency granted by Smart VSM (Kankaanhuhta et al., 2021; Nwaki et al., 2021). Other than its managerial role, Smart VSM assists in embedding metrics of sustainability into the production planning framework. Remeithi and Omani (2022) stressed how it greatly reduces environmentally-damaging waste, illuminating the gap between theory and practice.

H3: Lean Green Digitalization significantly affects Sustainable Total Quality Management (STQM)

The combination of principles Lean-Green Digitalization (LGD) develops along with sustainable quality management reflects an organization’s holistic process management with an emphasis on process control, resource optimization, and sustained advancement. As commented by Dinis-Carvalho et al. (2023), the impact of LGD on strengthening operational resilience is pronounced due to real-time quality control implementation, safeguarding satisfaction from various stakeholders. This is more than a technique; it is a strategic approach that advances the culture of sustainable quality. Predictive maintenance and other technologies which fall under the LGD umbrella have been shown to reduce process variability as stated by Afum et al. (2021) and Silva and Warnapura (2021). Thus, the adoption of quality management practices incorporating LGD is bound to improve operational efficiency while enabling the integration of sustainability as a core practice. The strong relationship between lean-green principles, digital innovation, total quality management, alongside the focus on quality in these modern manufacturing environments reinforces the need to address sustainability issues head on (Swarnakar et al., 2022; Paraschos et al., 2024).

H4: Smart Value Stream Mapping (SVSM) significantly affects Sustainable Total Quality Management (STQM)

Through diagnostics, Data Smart Decision Making Diagnostics, and IoT streams, Smart VSM helps the STQM framework be more precise and stratified in its decisions while implementing STQM. Cyberphysical systems and IoT enable real-time monitoring of waste ratios, energy consumption, and the overall efficiency of production processes (Abualfaraa et al., 2022; AlBalkhy & Sweis, 2020). This type of integration, along with the advancement of the ecological aspect of the quality management system, integrates and internalizes sustainability during the planning and execution phases rather than treating it as an afterthought. Furthermore, Smart VSM assists in taking proactive measures toward actively changing environmental conditions, thus encouraging the adoption of enduringly resilient and flexible frameworks for paradigms of quality systems. (Tripathi et al., 2022; Kai et al., 2023). Thus, Smart VSM transforms from simply a lean tool into a multifunctional strategic device that enables relentless operational excellence in the dynamic and complexity-laden, sustainability-focused landscape of manufacturing.

H5: The relationship between Lean Green Digitalization and Environmental Waste is mediated by STQM

Sustainable Total Quality Management integrates Lean Green Digitalization into eco-waste management systems. While STQM provides a governance framework to ensure innovation implementation within sustainability and quality boundaries, LGD focuses on achieving efficiency-accredited sustainability (Kalemkerian et al., 2022). More recent investigations show stronger STQM networks alongside companies adopting LGD lead to improved environmental performance due to the internalized sustainability thinking on all operational levels. This suggests that some ecological advantages gained through LGD might be undermined in the absence of a sustainable quality framework. Therefore, the intersection of green digitalization and sustainable frameworks provides amplified approaches that strengthen environmental organizational resilience.

H6: The relationship between Smart VSM and Environmental Waste is mediated by STQM

The mitigation of environmental waste using Smart VSM only occurs within the boundaries of STQM as a mediating framework. Without a total quality system in place, Smart VSM risks functioning solely as a passive observational tool which lacks any tactical conversion to action for meaningful, sustained change (Afum et al., 2021). Conversely, the use of Smart VSM in a fully developed STQM system leads to improved ecological efficiency and enhanced operational sustainability developed over time (Hossain et al., 2023; Wurjaningrum & Bhaskoro, 2024). Here, STQM acts as a motivating element that ensures the results of Smart VSM are not ignored, but instead fully utilized within a holistic sustainable framework driven by quality. This highlights the necessity of a more deliberate integration of value stream mapping techniques with management systems to adopt lasting initiatives for sustaining environmentally friendly practices (Abualfaraa et al., 2020).

RESEARCH METHODS

1. Research Design

This study employs a quantitative research design involving the collection of primary data through a carefully constructed survey and structured questionnaire. According to Creswell (2014), the quantitative method offers an opportunity for rigorous empirical examination of the phenomenon under study by converting it into measurable variables, thereby enabling hypothesis testing using statistical tools.

a. Questionnaire Instrument

The research instrument employed is a self-administered structured questionnaire comprising closed-ended items, primarily measured using a Likert-type scale. The questionnaire was systematically designed to align with the constructs under investigation and to elicit quantifiable responses for statistical analysis. The development of items followed best practices in scale construction, ensuring face and content validity through expert reviews and pretesting (DeVellis, 2016). The structure and wording of the questions were intended to minimize ambiguity and enhance the reliability of responses.

b. Survey Method

The survey method was utilized to collect data from selected respondents representing both internal (employees) and external (customers) stakeholders of the Fit Force garment manufacturing firm. Surveys enable the collection of standardized information regarding attitudes, behaviors, and demographic characteristics, and are particularly well-suited for explanatory and descriptive research (Groves et al., 2009). The administration was conducted through online distribution and direct handouts, ensuring broader coverage and participant accessibility.

2. Population and Sampling

a. Population

The target population includes both employees and consumers of Fit Force, a regional apparel and screen-printing firm. The inclusion of both groups aims to capture a holistic perspective on the organizational and customer dynamics relevant to the study variables.

b. Sampling Method

The study employed a non-probability sampling technique, specifically purposive sampling, based on predefined inclusion criteria to ensure relevance and adequacy of data quality. Non-probability purposive sampling allows the researcher to strategically select respondents who meet specific characteristics essential to the research objective (Etikan et al., 2016). This approach is particularly suitable when the research involves specialized populations that are not randomly distributed.

Participants were selected based on the following inclusion criteria:

1. Consumers residing in Kuningan and the Barlingmascakeb region, including Banjarnegara, Purbalingga, Banyumas, Cilacap, and Kebumen.
2. Employees in production-related divisions (tailoring, production, screen-printing operations) with at least one year of working experience at Fit Force, regardless of gender.

c. Sample Size Determination

The minimum required sample size was determined using Cochran's (1977) formula for estimating population proportions, as follows:

$$n = \left(\frac{Z_{\frac{\alpha}{2}}^{2}}{4d^{2}} \right)$$

Where:
n = minimum sample size
Z = Z-value corresponding to 95% confidence level (Z = 1.96)
d = margin of error (0.10)
Substituting values:

$$n = \left(\frac{1{,}96^{2}}{4(0{,}10)^{2}} \right) n = 96{,}04$$

To ensure robustness, a final sample of 110 respondents was selected, exceeding the minimum requirement. This is consistent with Chin's (2000) recommendation for PLS-SEM, which stipulates that an adequate sample size ranges between 30 and 100 cases, depending on model complexity and desired statistical power.

1. Data Collection Procedure

Primary data were collected through a structured questionnaire distributed both electronically and in physical format. Prior to the main survey, a pilot study was conducted with 30 respondents to test the clarity, reliability, and construct validity of the instrument. Feedback obtained was used to refine the questionnaire to enhance comprehensibility and internal consistency.

2. Data Analysis Techniques

Data analysis was conducted through Partial Least Squares Structural Equation Modeling (PLS-SEM) using SmartPLS software, which is well-known for its capabilities on intricate models and smaller sample sizes. The study was conducted in two steps. First, the measurement model (outer model) was scrutinized for the indicator reliability, composite reliability (CR), average variance extracted (AVE), and also for discriminant validity which was calculated using Fornell-Larcker criterion and HTMT ratio. In the second phase, the evaluation of the structural model (inner model) was performed using drie coefficient of determination (R^2), predictive relevance (Q^2), AVE, SRMR, and NFI. The Significance of the path coefficient was evaluated by bootstrapping methods (Hair et al., 2021). Furthermore, to study mediation effects, the steps described by Zhao et al., (2010) were followed paying close attention to the indirect relationships from both theoretical and empirical perspectives.

RESULTS AND DISCUSSION

A. Result

1. Validity Test

Verification of convergent validity was based on the scrutiny of the outer loadings of each indicator. As outlined by Hair et al. (2021), a factor loading of greater than 0.70 indicates sufficient convergent validity. Every indicator in this study exceeded this benchmark, validating that the measurement items accurately capture the latent constructs.

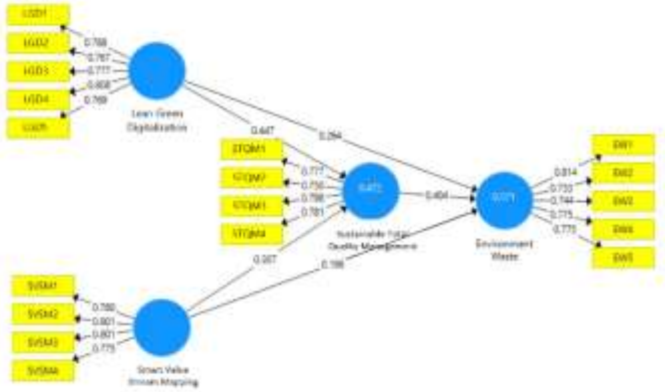

Figure 4.1. Loading Factor Values

2. Discriminant Validity

Discriminant validity was assessed utilizing two established methodologies: cross-loadings and the Heterotrait-Monotrait Ratio of Correlations (HTMT).

Table 4.1 Cross-Loadings of Indicators

Indicator	*Lean Green Digitalization*	*Smart Value Stream Mapping (Smart VSM)*	*Sustainable Total Quality Management (STQM)*	*Environment Waste*
LGD1	**0,788**	0,499	0,578	0,526
LGD2	**0,767**	0,465	0,437	0,535
LGD3	**0,777**	0,525	0,524	0,517
LGD4	**0,808**	0,573	0,504	0,510
LGD5	**0,769**	0,467	0,473	0,458
SVSM1	0,434	**0,780**	0,486	0,390
SVSM2	0,505	**0,801**	0,482	0,464

SVSM3	0,600	**0,801**	0,483	0,521
SVSM4	0,497	**0,775**	0,434	0,534
STQM1	0,570	0,432	**0,777**	0,548
STQM2	0,446	0,343	**0,750**	0,500
STQM3	0,505	0,501	**0,798**	0,525
STQM4	0,480	0,561	**0,781**	0,571
EW1	0,592	0,546	0,494	**0,814**
EW2	0,422	0,487	0,562	**0,733**
EW3	0,448	0,354	0,608	**0,744**
EW4	0,518	0,487	0,566	**0,775**
EW5	0,520	0,454	0,419	**0,775**

Source: SmartPLS 3 Output (2025)

Table 4.2 HTMT Ratio of Constructs

Indikator	*Lean Green Digitalization*	*Smart Value Stream Mapping (Smart VSM)*	*Sustainable Total Quality Management (SSTQM)*	*Environment Waste*
LGD				
SVSM	0,785			
STQM	0,791	0,749		
EW	0,779	0,742	0,856	

Source: SmartPLS 3 Output (2025)

The cross-loading results demonstrate that each indicator's loading on its designated construct surpasses its loading on alternative constructs, thereby reinforcing discriminant validity. Additionally, all HTMT values fall below the critical threshold of 0.90 (Hair et al., 2021), indicating that the constructs are empirically distinct. The clear differentiation of constructs confirms the conceptual soundness of the model. The HTMT value of 0.749, despite the conceptual proximity between Smart VSM and STQM, remains within acceptable limits, suggesting that respondents successfully distinguish between the constructs during the survey process.

3. Path Coefficient

Path coefficients were estimated using Partial Least Squares Structural Equation Modeling (PLS-SEM), and significance was assessed through bootstrapping with 5,000 subsamples. A t-value > 1.96 or p-value < 0.05 denotes statistical significance).

Table 4.3 Path Coefficients

Relationship	*Original Sample*	*t-statistic*	*p-value*
Lean Green Digitalization > Environment Waste	0,264	4,780	0,007
Smart Value Stream Mapping (Smart VSM) > Environment Waste	0,196	2,137	0,033
Lean Green Digitalization > Sustainable Total Quality Management (SSTQM)	0,447	5,138	0,000

Smart Value Stream Mapping (Smart VSM) > Sustainable Total Quality Management (SSTQM)	0,307	3,496	0,001

Source: SmartPLS 3 Output (2025)

Figure 4.3 presents the results of the path coefficient and p-value measurements obtained in this study:

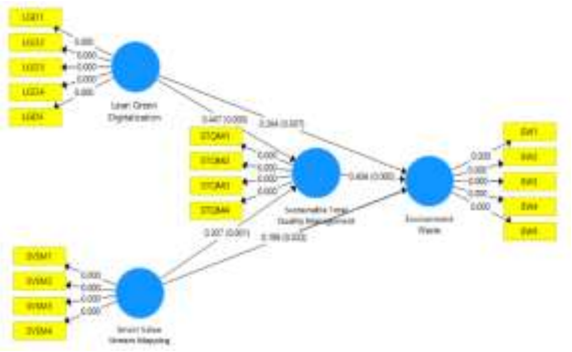

Figure 4.2 Path Coefficient Model Output

The structural model reveals several meaningful relationships. Lean Green Digitalization (LGD) significantly affects both Sustainable Total Quality Management (STQM; β = 0.447, p < 0.001) and Environmental Waste reduction (EW; β = 0.264, p < 0.01), suggesting a dual direct influence on process optimization and environmental outcomes. Moreover, Smart VSM also exhibits significant effects on both STQM (β = 0.307, p = 0.001) and EW (β = 0.196, p = 0.033), highlighting its complementary role in sustainable operations. These findings underscore the synergistic potential of digital lean initiatives and intelligent process mapping for fostering environmental performance.

4. Hypothesis Testing

Hypotheses were tested through t-statistic and p-value assessments. Table 4 consolidates the hypothesis test results, which confirm that all proposed hypotheses were statistically significant, meeting the criteria of t-statistic > 1.96 and p-value < 0.05.

Table 4.4 Hypothesis Test Results

Hypothesized Path	*t-statistic*	*p-value*
Lean Green Digitalization > Environment Waste	4,780	0,007
Smart Value Stream Mapping (Smart VSM) > Environment Waste	2,137	0,033
Lean Green Digitalization > Sustainable Total Quality Management (STQM)	5,138	0,000
Smart Value Stream Mapping (Smart VSM) > Sustainable Total Quality Management (STQM)	3,496	0,001

Source: SmartPLS 3 Output (2025)

5. Mediation Analysis

To determine whether Sustainable Total Quality Management (STQM) mediates the effect of Lean Green Digitalization and Smart Value Stream Mapping (Smart VSM) on Environmental Waste, a mediation analysis was conducted. The bootstrapping results confirm the presence of statistically significant indirect effects through STQM.

Table 4.5 Mediation Analysis Results

Mediation Path	*t-statistic*	*p-value*
Lean Green Digitalization > Sustainable Total Quality Management (SSTQM) > Environment Waste	3,261	0,001
Smart Value Stream Mapping (Smart VSM) > Sustainable Total Quality Management (SSTQM) > Environment Waste	2,682	0,008

Source: SmartPLS 3 Output (2025)

B. DISCUSSION

1. The Influence of Lean Green Digitalization (LGD) on Environment Waste

The results of this study validate Hypothesis 1 by confirming that Lean Green Digitalization (LGD) practices reduce environmental waste adverse impact. These findings corroborate earlier studies that lean green digitalization not only improve the production activities of organizations but also reduce massive amounts of physical and energy waste during the operations in manufacturing industries (Singh et al., 2021; Younnes, 2023). Konveksi Fit Force demonstrates a systematic approach that requires meticulous resource allocation and waste minimization, showcasing Lean Green Digitalisation's ability to bolster operational efficiency while promoting sustainability (Abualfaraa et al., 2020). This aligns with earlier findings suggesting that strategically targeted sustainable actions tend to improve environmental outcomes and overall functionality of an organization (Andersson et al., 2022). Digital transformation of organizations is very likely to enhance the sustainability success, as concluded by this study.

On the contrary, some authors point out the differences in outcomes regarding Lean Green practices and attribute them to context or approach bias (Kovilage, 2020). Studies suggest barriers to effective implementation of Lean Green practices due to lacking managerial support and inadequate funding (Lizarelli et al., 2023). But in the example of Konveksi Fit Force, where Lean Green Digitalization is successfully applied, there is absence of discourse on long uncovered gaps related to the absence of full, holistic, enduring sustainability frameworks (Younnes, 2023). The blend of contradictory empirical evidence supports the argument that contextual inflexibility and inequitable framework application impede harnessing Lean Green approaches for ecological advantages (Singh et al., 2021). This reinforces the concept of strong operational governance while detailing concepts of subsumed Lean Green Digitalization strategies clarifying set managerial devotion frameworks to achieve structured sustainability objectives (Abualfaraa et al., 2020).

2. The Effect of Smart Value Stream Mapping (Smart VSM) on Environment Waste

The relationship between the enhanced efficiency of Smart VSM and the sharp decline in non-value-added activities at Konveksi Fit Force corroborates the claims of many scholars supporting Smart VSM as an essential instrument for devising waste minimization strategies (Thawornsujaritkul & Boonnual, 2024; , Singh et al., 2020). The operational improvements gained within this framework are irrefutably noticeable (Abualfaraa et al., 2022). This aligns with other research suggesting that implementing Lean frameworks transforms ruinously inefficient production processes into resource-conserving, streamlined systems,thus, leaning towards more sustainability (Bait et al., 2020).

In spite of these positive statements, the literature reveals concerning differences in the effects of Lean practices owing to varying degrees of infrastructure and stakeholder commitment (Kovilage, 2020; Andersson et al, 2022). These differences underscore the need for more focused study designed to explain the conditions that Lean strategies wield effectiveness in fostering sustainability which is deeply required (Andersson et al., 2022). The outcomes of this study help address these issues by demonstrating how Smart VSM implemented on purpose within Konveksi Fit Force helps achieve environmental sustainability targets and proposes a sustainable model for other businesses facing the same operational challenges (Singh et al, 2021; Kovilage, 2020) . It is quite straightforward that firms adopting systematic and dedicated lean coupled with Smart VSM strategies stand to improve their performance while meeting critical and urgent environmental objectives.

3. The Effect of Lean Green Digitalization (LGD) on Sustainable Total Quality Management (STQM)

Evaluating the impact of Lean Green Digitalization on Sustainable Total Quality Management (STQM) Processes strongly supports Hypothesis 3, which posits that the level of Lean Green Digitalization directly impacts the effectiveness of SSTQM processes. This supports the previously stated hypotheses that the implementation of appropriate management practices within a Lean Green framework can drastically enhance the management of harmful waste emissions (Abualfaraa et al., 2022; Bait et al., 2020). Konveksi Fit Force's systematic operational model for waste collection is aimed at the strategic improvement of older materials into more useful forms, and thus using them to improve product value as a means of operational excellence (Gholami et al., 2021). The commitment to apply the 5Rs (Reduce, Reuse, Recycle, Recover, Rethink) demonstrates the corporate focus on sustaining an organized and maintained workplace, supporting prior studies that emphasized the synergy between Lean practices and sustainable outcomes (Abualfaraa et al., 2022).

Disputes concerning the extent to which Lean and sustainability practices are adopted across different sectors continue to highlight the impact of resource availability, employee involvement, and manager commitment within an organization to outcomes (Kovilage, 2020; Lizarelli et al., 2023). Through the research conducted at Konveksi Fit Force, the paradox of lean Green Digitalization was uncovered which enabled a stark contrast to some previously held assumptions about environmental sustainability and operational sustainability (Ahmad et al., 2020). Asserting the cohesive application of Lean and sustainability principles deepens understanding on the interplay between Lean approaches and environmental performance and provides a proven model for other businesses seeking to enhance sustainability performance (Singh et al., 2021; Andersson et al., 2022). The findings of the study are not limited to theory alone; they emphasize the need to advance the application of strategic sustainability in contemporary business management frameworks.

4. The Effect of Smart Value Stream Mapping (SVSM) on Sustainable Total Quality Management (STQM)

The research shows that Smart Value Stream Mapping (SVSM) strengthens Sustainable Total Quality Management (STQM) by incorporating sustainability considerations into lean digitalization frameworks, thus contributing to the existing body of knowledge in the field. The studies show that this integration further improves operational productivity while simultaneously developing sustainability through transforming holistic waste minimization strategies. Recent studies have also bolstered these conclusions with digital value stream mapping showing strong potential for driving continuous improvement in green industries (Klimecka-Tatar & Obrecht, 2024; Ullah et al., 2024).Advanced analytical tools like SVSM have been shown by Ullah and colleagues to enhance decision-making within quality management systems and improve sustainability, stakeholder satisfaction, and other relevant outcomes. The Konveksi Fit Force case study appears to further confirm these arguments since it elucidates specific emission and waste reductions that SVSM has achieved, thereby contributing to the discussion on green lean transformations and sustainable manufacturing.

(Klimecka-Tatar & Obrecht, 2024; Ullah et al., 2024).

The focus of lean methodologies has centered on streamlining processes and minimizing costs, often neglecting the environmental aspect. This study suggests a new paradigm with STQM systems that integrates sustainability as a prerequisite for modern operational frameworks. Integration of real-time data and IoT devices in SVSM is a strategic enabler that forms a holistic quality management system, increasing productivity while ensuring ecological sustainability (Wurjaningrum & Bhaskoro, 2024). There is increasing evidence showing the role of digital technology in quality management systems in contemporary manufacturing industries (Tripathi et al., 2022). With evidence from a midscale garment manufacturer, this study claims there is SVSM advanced operational productivity alongside workforce welfare and environmental stewardship. This research recommends resetting the SVSM model—suggesting it functions as a multi-factor lens to promote STQM implementation across diverse industries, rather than a mere diagnostic framework (Tripathi et al., 2021; Prayugo & Liu, 2021).

5. The Mediating Role of STQM in the Relationship between LGD and Environment Waste

The findings of STQM as a mediating variable within the relationship of LGD and environmental waste strongly highlights the necessity of having a core quality management system in order to realize ecological sustainability.This reinforces prior work that has stated the usefulness and effectiveness of lean digital tools is only achievable when embedded within a comprehensive quality management system (Badroos et al., 2022). Hence, absence of such frameworks may result in these organizations missing out on the potential ecological advantages offered by LGD initiatives (Budihardjo & Hadipuro, 2022). Research conducted by AlShehail et al. Salwin et al. in 2021 showed that alignment of digital practices with holistic approach to quality management supports remarkable environmental performance while also aligning ISO and the tacit knowledge of the organization fortifying STQM's role (Samanta et al., 2023).

This piece enhances the resource orchestration theory in the context of how organizations can utilize LGD capabilities through STQM, a system of structured management, aimed at reducing environmental waste. The connection between LGD and sustainability is well established, and has been studied extensively (Dangelico et al, Kaswan et al. 2023). Although the literature has perhaps dealt with the consequences of Lean Green Digitalization (LGD), the gap left by STQM (Sustainable Total Quality Management) remains largely untouched. This research showcases the importance of STQM as a driving framework that correlates digital shifts with eco-sustainability. For instance, Konveksi Fit Force illustrates the effectiveness of strict STQM application via waste reduction. These insights emphasize that embedding quality control in LGD approaches improves ecological effectiveness (Buriak & Makovoz, 2023; Kunyoria, 2022; Schoeman et al., 2020).

6. The Mediating Role of STQM in the Relationship between SVSM and Environment Waste

Integration of digital lean practices evidences an organization's ecological concern when placed within the greater scope of total quality management. This is especially the case with the Environmental Management Systems (EMS) within the STQM framework, which governs the relationship between Smart Value Stream Mapping (SVSM) and the accumulation of waste. The Konveksi Fit Force case exemplifies this where, strategic scheduling coupled with emissions control bounded through SVSM synergized (Queiroz et al., 2022). Earlier works propose that an operation with sustainability objectives employs effective execution only if accompanied by a well-defined and organized quality management system (Ichsan et al, 2021; Pratama & Susilawati, 2021).

This research provides a novel contribution by addressing the ongoing debate surrounding the advantages of Sustainable Value Stream Mapping (SVSM) within the context of quality management. Previous studies (Sekaninová, 2022) recognition for being sustainable did not empirically examine the role of a well-defined quality management system like STQM in improving its environmental performance. This study contributes significantly by demonstrating STQM's critical role in transforming SVSM's diagnostic capabilities into substantial environmental outcomes (Subandi et al., 2023). These implications encompass more than just operational improvements to address systemic inefficiencies described within the broader framework of modern manufacturing sustainability. These findings support an integrated approach that combines digital lean diagnostics with sustainability governance, resulting in a new framework for understanding environmental optimisation practices (Ahmad et al., 2020).

CONCLUSION

The interplay between Lean Green Digitalization, Smart Value Stream Mapping (Smart VSM), and Environmental Waste, in conjunction with Sustainable Total Quality Management (STQM) as a mediating factor, is distinctly intricate and multifaceted at Konveksi Fit Force. This relation emerged during the practical field study. It was observed that algorithmic implementing of Lean Green Digitalization increasing the level of operational environmental waste eradication makes the waste reduction process to be more streamlined and tuned to the value generating steps which add value to the business. Non-Practice activities like recycling fabric remnants and applying the 5R system are great milestones in the direction of sustainable operational excellence. The reduction of production related inefficiencies along with material wastage cannot be achieved without the application of Smart VSM. Smart VSM promotes effective and resourceful decision-making by providing comprehensive information for all production stages starting from raw material sorting, preparation, and culminating in the final output inspection. The methodology of Smart VSM guarantees minimal resource usage and increased accuracy, thereby supporting waste reduction initiatives and contributing to enhanced efficiency as material losses due to errors are minimized.

Additionally, the independent components of Lean Green Digitalization and Smart VSM have been shown to have marked improvements in the effectiveness of STQM. These findings suggest that the combination of these operational frameworks within strategic STQM creates a high-performance production system that is consistent, low-m variance, and enhances customer satisfaction. Commitment to SSTQM ensures control of all production inputs, materials, equipment, and finished goods resulting in high production quality along with safe and ergonomic conditions that improve workforce productivity. This study is critical in illustrating that the influence Lean Green Digitalization has on environmental waste is both direct and especially moderated through SSTQM. The mediating role underscores management practices centered on quality that enable the holistic sustainability opportunities of digital lean approaches. Incorporating STQM and Lean Green Digitalization with effective planning of inventory control systems results in coordinated workflows that enhance product delivery and customer satisfaction.

This comprehensive examination of the relationship between digital lean methodologies and quality management systems, pinpointing their capacity for driving enduring change in small to medium-sized manufacturing enterprises, advances the discussion with a novel contribution to the existing body of knowledge. Further research should test this framework in different industrial contexts to establish its universal relevance, investigate sustained impacts, and assess its adaptability. The conclusions strongly encourage manufacturers to adopt digital lean instruments and cultivate a quality-driven environment as integrated elements of their strategic approach to environmental and operational performance. This research underscores the importance of synergizing lean and quality approaches towards the achievement of greater sustainable manufacturing goals. Not only does this add to the body of literature, but it provides actionable insights for practitioners aiming for sustainable operational performance while enhancing competitive durability.

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