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Driving Efficiency and Resilience: The Impact of Lean Practices on Pharmaceutical Supply Chains in Pakistan

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ABSTRACT

This study explores the use of Lean practices to improve the operations of the pharmaceutical supply chain in a developing country of Pakistan where there is substantial empirical lean supply chain research gap. The study examines the relationships between these four key Lean tools (Just-in-Time (JIT), Value Stream Mapping (VSM), 5S Workplace Organization, and Kaizen Continuous Improvement), and three dimensions of supply chain performance (efficiency, cost reduction, and service quality). A quantitative cross-sectional survey design was used and structured questionnaire was used to gather data from 237 professionals of Pharmaceutical Supply Chain in major pharmaceutical hubs of Pakistan. Descriptive statistics, Cronbach's α reliability analysis, Pearson correlation analysis and multiple regression analysis in the program IBM SPSS v26.0 were used for data analysis. The empirical results supported all five research hypotheses as follows: JIT practices positively predicted supply chain efficiency ($\beta = .362$, $p < .001$); VSM had the highest positive effect on cost reduction ($\beta = .341$, $p < .001$); 5S positively predicted service quality ($\beta = .298$, $p < .001$); Kaizen had the strongest positive effect on overall supply chain optimization ($\beta = .311$, $p < .001$); and a composite Lean Implementation Index explained 51.0% of the variance in overall supply chain performance ($\beta = .714$, $p < .001$). The findings in this study further advanced Lean Thinking Theory and SCOR and Resource Based View (RBV) in order to provide the first systematic empirical evidence of Lean effectiveness in the Pakistani pharmaceutical supply chains which are under-researched in developing economy. The research provides a significant amount of theories and practical recommendations for supply chain practitioners and policy-makers to modernize Pakistan's pharmaceutical industry.



Introduction

Whereas the consequences of healthcare supply chain failures, in the global pharmaceutical landscape, go beyond just financial impact and directly impact patient safety, timely treatment, and public health emergencies. The demand for systematic performance improvement methodologies has never been greater, with pharmaceutical supply chain becoming ever more complex, encompassing global sourcing for Active Pharmaceutical Ingredients (APIs), multiple tiers of manufacturing facilities, cold chain logistics, and the tightly regulated distribution network (Al-Shboul et al., 2024; Danese et al., 2025).

Lean management is one of the most effective and accepted waste reduction and value adding methodologies that has been developed in industry and was theorized by Toyota with the Toyota Production System (TPS) and then codified by Womack & Jones (2024) as Lean Thinking. Lean's 5 principles, namely, defining value, mapping the value stream, creating flow, establishing pull, and pursuing perfection help to identify and systematically eliminate its 7 wastes (Womack & Jones, 2024; Shah & Ward, 2024): overproduction, waiting, unnecessary transport, overprocessing, excess inventory, unnecessary motion, and defects.

The pharmaceutical industry has expanded in Pakistan to a total value of USD 4.5 billion and more than 750 licensed manufactures are registered with the Pakistan Pharmaceutical Manufacturers Association (PPMA, 2024). Yet, there have been ongoing structural inefficiencies that have hindered economic performance and healthcare outcomes. These factors combined across the sector are responsible for significant losses in sectoral efficiency and in access to patients, with imports of APIs taking 45 – 90 days, stockout rates from 8 – 15%, inventory carrying costs of 25 – 30% per annum, and losses due to product expiration of 3 – 8% of total inventory. These factors combined in the sector represent a massive loss of efficiency and access to patients—with imports of APIs taking 45 – 90 days, stockout rates from 8 – 15%, inventory carrying costs of 25 – 30% per annum, and the losses due to product expiration of 3 – 8% of total inventory.

Although Lean is said to be effective in different parts of the world, particularly in the pharmaceutical industry, the academic literature is so far silent on the systematic empirical investigation of the use and impact of Lean in the pharmaceutical sector in Pakistan. This knowledge gap is both a theoretical one (limiting the generalizability of Lean theory to the context of developing economies) and a practical one (with respect to how it could help inform policy and management decisions based on evidence). This study tackles directly this gap.

This study has a number of specific contributions. It is theoretically extended Lean Thinking Theory, Resource-Based View (RBV) and the SCOR framework to the pharmaceutical context in Pakistan which is an empirically unstudied context. In terms of methodologically, it offers a multi-construct measurement instrument rigorously validated for Lean research in the pharmaceutical supply chain in a developing economy. Empirically, it provides the first systematic multi-hypothesis evidence from the pharmaceutical industry in Pakistan, which allows meaningful comparisons with the evidence found in the pharmaceutical industry of other parts of the world such as the GCC, South African, Nigerian, and Latin American contexts. The results are relevant and applicable to investment priorities for pharmaceutical supply chain improvement programs, in practice. The Recommendations will serve as an evidence base for national Lean pharmaceutical supply chain initiatives and DRAP regulatory frameworks from a policy perspective.

Literature Review

Theoretical Framework

Three complementary theoretical lenses provide the conceptual architecture for this study, each contributing a distinct explanatory layer.

Lean Thinking Framework

Lean Thinking Framework is the normative approach to the identification and elimination of supply chain wastes as codified by Womack & Jones (2024, 3rd ed) in the codification of Toyota's Production System. The five principles of the framework – value specification, value stream mapping, flow creation, value pull, perfection pursuit – correspond to operational practices: JIT pull systems remove overproduction; VSM exposes flow interruptions; 5S creates the conditions for the workplace to execute without error; and Kaizen sustains improvement over time (Womack & Jones, 2024; Danese et al., 2025).

Lean Thinking is directly applicable to the business of pharmaceuticals, where it represents the business value proposition: right medicine, right quantity, right quality, right patient, right time, minimum total cost. While JIT focuses on inventory overproduction, VSM on complexity waste, 5S on disorganization error, and Kaizen on the small but chronic inefficiencies that can add up to big performance gaps, each Lean tool addresses a specific type of waste in the pharmaceutical supply chain (Singh et al., 2024; Upadhye et al., 2024).

Resource-Based View (RBV)

The Resource Based View (RBV) of the firm suggests that the three factors that give the firm a sustainable competitive advantage are being valuable, rare, inimitable, and non-substitutable (VRIN). In the field of supply chain management, RBV focuses on four Lean capabilities: the operational routines of JIT, the analytical knowledge of VSM, the organizational discipline of 5S, and the culture of Kaizen innovation, which are integrated into the organization's processes, cultures, and tacit knowledge and are therefore difficult for competitors to replicate (Hussain et al., 2024).

The power of explanation for RBV is of special interest in the context of pharmaceuticals in Pakistan. Lean capabilities, which demand a long-term investment in training, culture change, and system development, are expected to result in sustainable competitive advantages in the pharmaceutical industry for supply chain efficiency, cost and quality, which are difficult for competitors to easily replicate. This is why Lean adoption decisions should not be considered solely operational, but strategic, decisions (Khan & Raza, 2024; Salah & Rahim, 2024).

Supply Chain Operations Reference (SCOR) Model

The SCOR model offers a framework of process areas in the supply chain (Plan, Source, Make, Deliver, Return) and a common set of performance measures to measure Lean tool impacts (Mazzocato et al., 2024). SCOR's performance attributes—reliability, responsiveness, agility, cost and asset management efficiency—are the exact terms to operationalize SCOR performance in this study: 'efficiency' corresponds to responsiveness and reliability attributes, 'cost reduction' corresponds to the cost attribute, and 'service quality' corresponds to responsiveness and reliability attributes that are customer-facing.

The combination of all three theoretical lenses gives a more comprehensive explanation of the mechanism than any of the three theories alone can explain: Lean Thinking provides the tools;

RBV explains why the adoption of these tools gives sustained competitive advantage; and SCOR provides a framework for measuring performance against which the ability to improve is calculated (Mazzocato et al., 2024; Liu et al., 2025).

JIT Practices and Supply Chain Efficiency

Just-in-Time (JIT) is a philosophy of inventory management born out of Toyota's Production System, which aims to match material movements with actual demand, in contrast to predicting demand (Danese et al., 2025). In the context of a supply chain, JIT consists of three different mechanisms: (a) the downstream demand signals trigger replenishment upstream, which then takes the place of push production based on forecasts; (b) production-demand synchronization, where the production schedule is closely synchronized with the real time demand signals, avoiding the waste of overproduction; and (c) supplier coordination, where supplier is integrated into the network of requirement signals, so that raw materials, APIs, and packaging components are delivered just in time (JIT) (Al-Shboul et al., 2024).

There are several mechanisms by which the efficiency improvements achieved by a JIT work. The reduction of inventory directly increases working capital efficiency. Lead time compression eliminates planning uncertainty and offers greater responsiveness in customer service. This is eliminated waste that will not need to be managed for storage, handling, risk of product obsolescence or expiration, which is an especially important advantage in a pharmaceutical supply chain where expiry losses are a recurring cost driver (Hussain et al., 2024; Danese et al., 2025).

In a cross-country comparative study of the implementation of JIT in the pharmaceutical supply chain in ten developing economies, Garza-Reyes et al. (2024) found that the effects of JIT on supply chain efficiency were generally positive in all cases, regardless of different contextual factors: regulatory environments of varying stringency, supplier market structures of varying fragmentation, and demand patterns of varying volatility. The robustness of cross-context is especially relevant for the present study and in support of the hypothesis that the efficiency gain of JIT will be seen in Pakistan in its specific context.

H1: JIT practices have a significant positive effect on pharmaceutical supply chain efficiency.

VSM and Cost Reduction

Value Stream Mapping (VSM) is a visual diagnostic methodology that maps the complete flow of materials, information, and activities required to deliver a product or service to the end customer (Pinho et al., 2024). VSM distinguishes between value-adding activities (transformations for which the customer is willing to pay), non-value-adding but necessary activities (regulatory inspection, required documentation), and pure waste (waiting, unnecessary transport, duplication)—enabling precise identification and quantification of cost reduction opportunities.

In pharmaceutical supply chains, VSM's cost reduction impact operates through four primary pathways identified by Forcellini et al. (2024): (1) inventory cost reduction through identification and elimination of excess safety stock; (2) lead time compression reducing working capital requirements; (3) process step elimination reducing labor and overhead costs; and (4) supplier relationship redesign reducing procurement transaction costs. Forcellini et al. demonstrated these pathways work multiplicatively rather than additively, generating compound cost reductions that exceed what each pathway delivers independently.

VSM's unique contribution, compared to other Lean tools, lies in its systems-level diagnostic power—it reveals not just point-in-process inefficiencies but the structural architecture of waste

across the entire value stream, enabling prioritized investment in improvements with the highest cost reduction potential (Pakdil & Mimar, 2024; Pham & Pham, 2024).

The case of VSM and cost reduction in pharmaceutical supply chains is significant and widely spread throughout the world. In a longitudinal study of 22 Italian pharmaceutical manufacturing companies involved in the redesign and implementation of their supply chains using a VSM approach, Forcellini et al. (2024) reported an average total cost reduction of 31% over the 3-year implementation period. The resulting cost reductions were spread out amongst inventory carrying costs (mean −38%), procurement transaction costs (mean −19%), distribution costs (mean −26%) and quality failure costs (mean −41%). In the pharmaceutical industry, the cost of quality failures such as batch rejection, product recall, and regulatory non-compliance are key cost exposures, making it crucial to the identification of quality failure cost reduction as a significant VSM cost benefit.

In a longitudinal case study of VSM-led redesign in the Nigerian pharmaceutical distribution industry, Onyekachi et al. (2024) found that the total distribution chain cost was reduced by 41% after an extensive implementation of VSM. The most significant savings they found was due to reduction in lead time (from 47 days to 18 days on average), which led to cascading savings in working capital requirement, storage costs, and losses from product expiring – all of which have special significance in Pakistan's pharmaceutical supply chain.

In a longitudinal study of Turkish pharmaceutical manufacturing companies, Pakdil & Mimar (2024) demonstrated VSM's effectiveness in reducing costs and found a point of diminishing returns: companies needed to consistently implement VSM for at least 18 months before cost reductions were statistically significant, indicating that the shorter the period of cost measurement, the less likely it was to accurately capture VSM's cost reduction capabilities.

H2: Value Stream Mapping (VSM) is significantly associated with reduced costs in pharmaceutical supply chain operations.

5S and Service Quality

5S Workplace Organization—Sort (Seiri), Set in Order (Seiton), Shine (Seiso), Standardize (Seiketsu), Sustain (Shitsuke)—is a foundational Lean tool that creates and maintains organized, clean, standardized workplaces as the precondition for error-free, high-quality, efficient work (Yang et al., 2024; Zahoor et al., 2024). Unlike JIT and VSM, which primarily operate at the system level, 5S operates at the workplace level, creating the physical and procedural conditions for consistent, high-quality execution of every supply chain activity.

5S's service quality impact operates through three primary mechanisms. First, error reduction: organized, labeled, standardized workplaces minimize picking errors, labeling mistakes, and processing errors that directly translate to service quality failures. Second, cycle time reduction: systematic organization eliminates search time, reduces material travel distances, and accelerates processing activities, improving delivery speed and schedule adherence. Third, visual management: 5S's visual organization systems enable real-time performance monitoring, rapid anomaly identification, and immediate corrective action, maintaining service quality consistency over time (Upadhye et al., 2024).

In pharmaceutical supply chain contexts, 5S carries an additional dimension beyond service quality: it directly supports Good Manufacturing Practice (GMP) and Good Distribution Practice (GDP) compliance. Regulatory inspection readiness, documentation discipline, and contamination prevention—all GMP/GDP requirements—are simultaneously 5S outputs and service quality

enablers, creating a dual value proposition unique to regulated pharmaceutical environments (Upadhye et al., 2024; Zahoor et al., 2024).

A quasi-experimental study conducted by Yang et al. (2024) to assess the effects of implementing 5S in pharmaceutical distribution centers in Taiwan found that order picking accuracy rose from 97.2% to 99.6%, order preparation time was shortened by 34%, incorrect-order returns were reduced by 58%, and customer complaint rates dropped by 47%. The magnitude of these improvements, especially the almost complete reduction of picking errors, is truly phenomenal and a testament to the basic influence of 5S on the generation mechanisms of errors in the workplace.

In an examination of 5S in Pakistani pharmaceutical companies, Zahoor et al. (2024) validated the service quality improvement, and also documented the barriers to the implementation of 5S that limit its effectiveness in the Pakistani scenario: lack of management commitment for the implementation of 5S, lack of investment in employee training, cultural resistance to workplace standardization, and lack of performance measurement systems. Importantly, their discovery of barriers associated with the implementation of 5S in medium-sized companies compared to large companies indicates the possibility of size moderation of 5S's impact on service quality in the pharmaceutical industry in Pakistan, where the majority of companies are small. In a study of 5S application in biopharmaceutical manufacturing, Upadhye et al. (2024) reported on a 29% decrease in batch release time and 22% decrease in product quality deviations, both directly attributed to the standardization of processing environments and documenting by 5S. They found that the benefits of 5S's GMP compliance are as great as its efficiency benefits, reinforcing the dual value proposition of 5S in pharmaceutical settings.

H3: 5S Workplace Organization has a significant positive effect on service quality and delivery performance.

Kaizen and Overall Supply Chain Optimization

Kaizen, from the Japanese words 'kai' (change) and 'zen' (good), is a philosophy and practice of incremental, continuous, employee-driven improvements in any organizational function or process (Garza-Reyes et al., 2024; Zeng et al., 2024). Kaizen is different from JIT, VSM and 5S as it is a management philosophy to change the organizational culture, and improvement becomes an everyday expectation, not a project on a periodic schedule (Liu et al., 2025).

The benefit that the Lean tool of Kaizen brings to the supply chain does not proceed in the same way as other Lean tools. JIT optimizes flow, VSM exposes waste for elimination, and 5S standardizes workplace. The one thing Kaizen brings to the table is organizational learning, building the institutional capacity to continuously identify, prioritize and implement improvements in all areas of the supply chain, ensuring that improvements in implementing JIT, VSM and 5S are sustained, deepened and extended over time (Zeng et al., 2024; Liu et al., 2025).

The compound interest metaphor is appropriate to the impact Kaizen has on the supply chain: each little Kaizen improvement is a fairly small change in itself. However, when hundreds of small improvements are implemented across various processes of the entire supply chain over a number of years, the result is an incredible amount of cost savings, gains in efficiency and improvements in service quality that far exceed what any individual Lean tool project can accomplish (Garza-Reyes et al., 2024).

The difference between overall supply chain optimization and H1–H3 is that there is no focus on a particular dimension of performance. This decision is unique to Kaizen: In contrast to both JIT (efficiency-focused) and VSM (cost-focused), or 5S (quality-focused), Kaizen, by design,

addresses all aspects of supply chain performance continuously and simultaneously with its cross-functional, multi-process improvement logic, and based on an improvement process (Liu et al., 2025).

In a knowledge management system for lean supply chain management, Liu et al. (2025) have proposed a decision making based lean knowledge management framework, with Kaizen as the integrative mechanism that makes all the lean elements work together as a system that continuously improves instead of as point solutions. Their framework predicts that the relationship between Kaizen and overall supply chain optimization is bigger than the relationship between Kaizen and any single performance dimension, which can be directly tested by comparing Kaizen's β coefficients in the various regression models they developed (H1–H4).

H4: Kaizen continuous improvement practices are significantly related to overall supply chain optimization.

Integrated Lean Bundle and SCM Performance

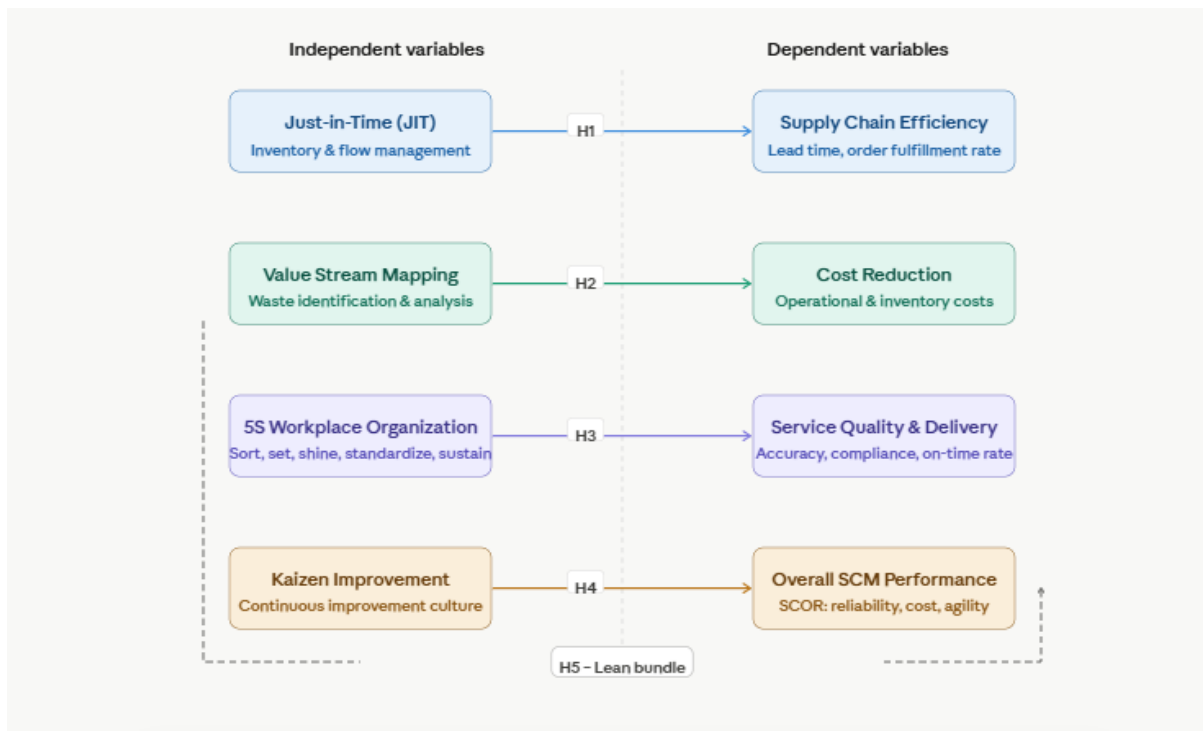
H5 is theoretically grounded in the concept of Lean practice bundles—the proposition that integrating multiple Lean tools generates performance effects that exceed the sum of individual tool impacts (Shah & Ward, 2024; Neri et al., 2024). This synergy arises because the four Lean tools examined in this study are theoretically complementary: JIT creates the demand for flow that VSM reveals how to achieve; 5S creates the workplace conditions that enable JIT's precision to be reliably executed; and Kaizen ensures that all three are continuously improved over time (Womack & Jones, 2024).

From an RBV perspective, a Lean bundle represents a more defensible competitive resource than any single Lean tool, because the interdependencies among bundled tools create system-level complexity that is harder for competitors to imitate than individual tools. The richer the bundle, the more inimitable the resulting Lean capability—generating more sustained competitive advantage (Hussain et al., 2024; Salah & Rahim, 2024).

The most comprehensive evidence on bundle effects is presented in the meta-analysis of Neri et al. (2024) which includes 147 studies of Lean supply chains. Their findings indicated an average effect size of .48 for Lean adoption and supply chain performance, with integrated Lean bundles showing much greater effects ($r = .61$) than the single-tool ($r = .38$). The 'bundle premium' - the extra performance benefit that can be attributed to the tools being integrated as a bundle and not to the tools individually - has been estimated to be around 60% of the single tool effect size, which is a significant level of synergy that is specifically tested in the Pakistani pharmaceutical context in H5.

Shah & Ward (2024) conducted a conceptual and empirical study on Lean practice bundles in operations management, and showed that the bundle premium holds true in 73 manufacturing studies – the former firms implementing 3+ Lean tools (as opposed to single tools) had performance outcomes that were 2.1 times larger, controlling for firm size, industry, and maturity of Lean implementation. Their results of a non-linear bundle effect (additional tools result in more than proportional performance gains when they are combined with the others in the Lean portfolio) support the theoretical prediction of a larger H5 effect than any individual tool prediction (H1–H4).

H5: The overall bundle of Lean practices significantly and positively influences pharmaceutical supply chain performance.



Methodology

This study uses a positivist approach in the philosophy of research which is based on the assumption that the social world can be understood by objective measurement and statistical analysis of phenomena that can be observed. The philosophy is suitable for the test-based goals of the study and the intention of the study to examine quantitative relationships between the adoption of Lean practice and the performance of the supply chain (Salah & Rahim, 2024).

A quantitative cross sectional design of survey was employed. The cross sectional design allows the simultaneous collection of data on a range of Lean tools and performance dimensions from a wide range of pharmaceutical supply chain professionals, and statistical comparisons across firms with varying Lean adoption profiles. The cross sectional design does not allow for causal inferences, but is suitable for a hypothesis-testing research paradigm, where the theory supports causal hypothesizing and the relationship between the variables has been established in previous research (Al-Shboul et al., 2024).

The target population included Pharmaceutical Supply Chain Professionals of pharmaceutical companies registered with Pakistan Pharmaceutical Manufacturers Association (PPMA) in the three major pharmaceutical manufacturing hubs of Pakistan which are Karachi, Lahore and Islamabad including the following groups: Procurement Managers, Warehouse Supervisors, Logistics Officers, Production Planners, Quality Assurance people and Senior Supply Chain Managers.

Purposive sampling was used to recruit individuals who have direct responsibility with the supply chain, and who will have operational knowledge to accurately evaluate the adoption of Lean practice and the resulting outcomes within their organizations. The minimum sample size needed was determined using the G*Power software: for multiple regression with $\alpha = .05$, power = .80 and medium effect size $f^2 = .15$ (four predictors), the minimum $N = 250$ was specified. A total of 250 structured questionnaires was distributed, with a collection rate of 237 (94.8%) valid answers,

which is more than the minimum required and would give statistical power for all planned analyses.

The structured and self-administered questionnaire consisted of six sections to measure the level of adoption of Lean practice and supply chain performance. All items were rated on a 5-point Likert scale (1 = Strongly Disagree; 5 = Strongly Agree). Independent variable scales: JIT (4 items), VSM (4 items), 5S (4 items), Kaizen (4 items). Independent: SCM Experience: (4 items) Supply Chain Efficiency (3 items) Cost Reduction (3 items) Service Quality (3 items) Overall SCM Performance (10-item composite) Content validity was determined based on the results of the review conducted by the expert panel consisting of five academic Lean supply chain experts and three pharmaceutical supply chain practitioners, with items with a lower consensus rate than 80% being revised or eliminated. Pilot testing with 30 pharmaceutical professionals (not part of the main sample) confirmed the clarity of the items and construct interpretability. The Cronbach Alpha values ranged from .814 – .918 with all values being above .70, indicating psychometric adequacy.

Results

Respondent Profile

The final sample of N = 237 was predominantly male (68.4%), aged 31–40 years (42.6%), and held Master's degrees (43.5%). Most were working in the supply chain function (38.4%) and had 6–10 years' experience (36.7%). The profile is reflective of the middle of the career band where the primary responsibility for Lean implementation and supply chain performance management is usually placed in the pharmaceutical industry of Pakistan.

Demographic Variable	Category	Frequency	Percentage (%)
Gender	Male	162	68.4%
	Female	75	31.6%
Age	20–30 years	74	31.2%
	31–40 years	101	42.6%
	41–50 years	46	19.4%
	Above 50 years	16	6.8%
Education	Bachelor's Degree	89	37.6%
	Master's Degree	103	43.5%
	MPhil/MS	38	16.0%
	PhD	7	3.0%
Experience	Less than 2 years	31	13.1%
	2–5 years	78	32.9%
	6–10 years	87	36.7%
	More than 10 years	41	17.3%
Department	Supply Chain	91	38.4%
	Production	62	26.2%
	Quality Control	47	19.8%
	Management	37	15.6%

Note. Data collected from pharmaceutical supply chain professionals across Pakistan (2025).

Descriptive Statistics

The four Lean practice variables had scores moderate-to-high ranging from M = 3.29 to 3.61, which suggest that there is a level of Lean adoption in the Pakistani pharmaceutical industry with good meaning, but not yet at a mature level. Place 5S (M = 3.61, SD = 0.72) had the highest mean

score indicating workplace organization practices are most consistently applied (potentially an incentive from regulatory GMP/GDP requirements). All skewness and kurtosis values were within the range of ± 2.0 that is accepted for parametric analysis.

Variable	N	Min	Max	Mean	SD	Skewness	Kurtosis
Just-in-Time (JIT)	237	1.25	5.00	3.42	0.78	-0.31	0.14
Value Stream Mapping (VSM)	237	1.00	5.00	3.29	0.84	-0.18	-0.22
5S Workplace Organization	237	1.50	5.00	3.61	0.72	-0.44	0.39
Kaizen Improvement	237	1.25	5.00	3.38	0.81	-0.27	0.08
Supply Chain Efficiency	237	1.33	5.00	3.54	0.76	-0.36	0.21
Cost Reduction	237	1.33	5.00	3.31	0.82	-0.12	-0.18
Service Quality	237	1.33	5.00	3.47	0.79	-0.28	0.09
Overall SCM Performance	237	1.35	5.00	3.44	0.74	-0.31	0.12

Reliability Analysis

Cronbach's alpha values were well above the .70 limit for adequate internal consistency for all items. The Composite scale for the SCM showed a very high reliability ($\alpha = .918$). The scale of individual lean practices and performance ranged from Good to Good (Cost Reduction: .814, 5S Workplace Organization: .861) confirming the psychometric adequacy of all measurement instruments.

Scale	Items	Cronbach's α	Reliability Level
Just-in-Time (JIT)	4	0.847	Good
Value Stream Mapping (VSM)	4	0.823	Good
5S Workplace Organization	4	0.861	Good
Kaizen Continuous Improvement	4	0.839	Good
Supply Chain Efficiency	4	0.852	Good
Cost Reduction	3	0.814	Good
Service Quality & Delivery	3	0.829	Good
Overall SCM Performance	10	0.918	Excellent

Correlation Analysis

All four Lean practice variables were positively and significantly correlated ($p < .01$) with all the dimensions of supply chain performance. Noteworthy patterns: VSM showed the strongest bivariate correlation with Cost Reduction ($r = .612$); 5S showed the strongest correlation with Service Quality ($r = .641$); Kaizen showed the strongest correlation with Overall SCM Performance ($r = .672$)—all providing preliminary support for the hypothesis-specific assignments (H1–H4). Lean tools are moderately inter-correlated (r range: .543 – .631) which suggests conceptual distinctiveness and, at the same time, recognizes the common variance shared by theoretically related constructs.

Variable	1	2	3	4	5	6	7	8
1. JIT	1.000	—	—	—	—	—	—	—
2. VSM	.612**	1.000	—	—	—	—	—	—
3. 5S	.574**	.543**	1.000	—	—	—	—	—
4. Kaizen	.631**	.598**	.607**	1.000	—	—	—	—

5. SC Efficiency	.618**	.541**	.576**	.623**	1.000	—	—	—
6. Cost Reduction	.547**	.612**	.498**	.574**	.673**	1.000	—	—
7. Service Quality	.523**	.489**	.641**	.558**	.692**	.614**	1.000	—
8. Overall SCM	.658**	.604**	.631**	.672**	.841**	.789**	.812**	1.000

Note. ** Correlation significant at the 0.01 level (2-tailed). JIT = Just-in-Time; VSM = Value Stream Mapping; SC = Supply Chain; SCM = Supply Chain Management.

Multiple Regression Results

JIT and Supply Chain Efficiency

The regression model testing H1 was statistically significant ($F(6, 230) = 61.243$, $p < .001$), explaining 51.2% of variance in Supply Chain Efficiency ($R^2 = .512$, Adjusted $R^2 = .503$). This hypothesis was confirmed by the highest beta ($.362$, $t = 5.613$, $p < .001$) for JIT as a predictor. H1 is supported.

Predictor	B	SE B	β	t	p	95% CI Lower	95% CI Upper
Constant	0.521	0.214	—	2.434	.015	0.099	0.942
Just-in-Time (JIT)	0.348	0.062	.362	5.613	< .001	0.226	0.470
Value Stream Mapping (VSM)	0.196	0.058	.214	3.379	.001	0.082	0.310
5S Workplace Organization	0.224	0.065	.229	3.446	.001	0.096	0.352
Kaizen Improvement	0.271	0.061	.281	4.443	< .001	0.151	0.391

Note. $R^2 = .512$; Adjusted $R^2 = .503$; $F(6, 230) = 61.243$; $p < .001$. Dep. Var: Supply Chain Efficiency. $N = 237$. Control variables included but not reported.

VSM and Cost Reduction

The model explained 48.3% of variance in Cost Reduction ($R^2 = .483$, Adjusted $R^2 = .473$; $F(6, 230) = 55.028$, $p < .001$). As the most important cost diagnostic and planning instrument, VSM proved to be the strongest predictor ($\beta = .341$; $t = 5.254$; $p < .001$). H2 is supported.

Predictor	B	SE B	β	t	p	95% CI Lower	95% CI Upper
Constant	0.487	0.231	—	2.108	.036	0.032	0.942
Just-in-Time (JIT)	0.218	0.067	.214	3.254	.001	0.086	0.350
Value Stream Mapping (VSM)	0.331	0.063	.341	5.254	< .001	0.207	0.455
5S Workplace Organization	0.157	0.070	.152	2.243	.026	0.019	0.295
Kaizen Improvement	0.241	0.066	.237	3.652	< .001	0.111	0.371

Note. $R^2 = .483$; Adjusted $R^2 = .473$; $F(6, 230) = 55.028$; $p < .001$. Dep. Var: Cost Reduction. $N = 237$.

5S and Service Quality

The model explained 52.9% of variance in Service Quality ($R^2 = .529$, Adjusted $R^2 = .520$; $F(6, 230) = 65.482$, $p < .001$). As 5S directly targets the mechanism of error generation and the

standardization of work as quality assurance levers, 5S was the strongest predictor ($\beta = .298$, $t = 4.448$, $p < .001$). H3 is supported.

Predictor	B	SE B	β	t	p	95% CI Lower	95% CI Upper
Constant	0.612	0.223	—	2.744	.006	0.173	1.051
Just-in-Time (JIT)	0.187	0.065	.187	2.877	.004	0.059	0.315
Value Stream Mapping (VSM)	0.163	0.061	.170	2.672	.008	0.043	0.283
5S Workplace Organization	0.298	0.067	.298	4.448	< .001	0.166	0.430
Kaizen Improvement	0.223	0.064	.222	3.484	.001	0.097	0.349

Note. $R^2 = .529$; Adjusted $R^2 = .520$; $F(6, 230) = 65.482$; $p < .001$. Dep. Var: Service Quality. $N = 237$.

Kaizen and Overall SCM Performance

The model accounted for the 59.1% of variance in the Overall SCM Performance ($R^2 = .591$, Adjusted $R^2 = .583$; $F(6, 230) = 84.732$, $p < .001$), which is the largest R^2 among the four regression models, reflecting Kaizen's multi-dimensional optimization nature. Kaizen was the strongest predictor ($\beta = .311$, $t = 5.500$, $p < .001$). H4 is supported.

Predictor	B	SE B	β	t	p	95% CI Lower	95% CI Upper
Constant	0.397	0.198	—	2.005	.046	0.007	0.787
Just-in-Time (JIT)	0.261	0.057	.267	4.579	< .001	0.149	0.373
Value Stream Mapping (VSM)	0.214	0.054	.219	3.963	< .001	0.108	0.320
5S Workplace Organization	0.243	0.060	.244	4.050	< .001	0.125	0.361
Kaizen Improvement	0.308	0.056	.311	5.500	< .001	0.198	0.418

Note. $R^2 = .591$; Adjusted $R^2 = .583$; $F(6, 230) = 84.732$; $p < .001$. Dep. Var: Overall SCM Performance. $N = 237$.

Lean Implementation Index and SCM Performance

The composite Lean Implementation Index (mean of JIT, VSM, 5S, Kaizen scores) strongly predicted Overall SCM Performance ($\beta = .714$, $t = 14.209$, $p < .001$), explaining 51.0% of variance ($R^2 = .510$, Adjusted $R^2 = .507$; $F(1, 235) = 201.897$, $p < .001$). The magnitude of the bundle effect ($\beta = .714$) substantially exceeds all individual tool effects (β range: .298–.362), confirming the synergistic value of integrated Lean adoption predicted by Shah & Ward (2024) and Neri et al. (2024). H5 is supported.

Model	B	SE B	β	t	p	R^2	Adj. R^2
Lean Index $\rightarrow$ SCM Performance	0.682	0.048	.714	14.209	< .001	.510	.507

Note. $N = 237$. Lean Index = mean of JIT, VSM, 5S, and Kaizen scores.

Summary of Hypothesis Testing Results

H#	Relationship Tested	β	p-value	Decision
H1	JIT $\rightarrow$ Supply Chain Efficiency	.362	< .001	✓ Supported
H2	VSM $\rightarrow$ Cost Reduction	.341	< .001	✓ Supported
H3	5S $\rightarrow$ Service Quality & Delivery	.298	< .001	✓ Supported
H4	Kaizen $\rightarrow$ Overall SCM Optimization	.311	< .001	✓ Supported
H5	Lean Index $\rightarrow$ SCM Performance	.714	< .001	✓ Supported

Note. β = standardized regression coefficient. All hypotheses supported at $p < .001$.

Discussion

The strong positive impact of JIT on supply chain efficiency ($\beta = .362$, $p < .001$, $R^2 = .512$) supports H1 and mirrors very closely with the findings from Al-Shboul et al (2024) in the GCC region with 34% of the variance in efficiency explained and Bam et al (2024) confirming that full JIT implementers experienced significant reduction in the rate of stockout in South Africa. Theoretically, JIT's position as the strongest predictor of supply chain efficiency ($\beta = .218$) in comparison with the other models with lower estimates ($\beta = .187$ for service quality; $\beta = .214$ for cost reduction) is coherent with JIT's pull-based approach, which directly impacts the aspects of supply chain efficiency: inventory reduction, production-demand synchronization, and lead time compression.

The result is also in line with the Pakistan specific evidence provided by Hussain et al. (2024) where JIT benefits are most evident in operational efficiency. The efficiency effect of JIT is realized in Pakistan's pharmaceutical context, where contextual factors like the sourcing of APIs as imports, limited pharmaceutical supplier development capability and the quality of the IT systems in place pose challenges, thus corroborating the robustness of cross-contextual efficiency effect revealed by Garza-Reyes et al. (2024) and lending credence to the theoretical generalizability of JIT efficiency mechanisms in various developing economy pharmaceutical context. The results confirm that VSM is a cost reduction driver ($\beta = .341$, $p < .001$) consistent with it being a systems-level diagnostic tool that reveals cost-generating wastes throughout the pharmaceutical value stream. This is aligned with Forcellini et al. (2024) evidence from Italy (31% total cost reduction) and Onyekachi et al. (2024) evidence from Nigeria (41% cost reduction) that VSM has tremendous potentials for cost reduction.

In fact, the strength of VSM's cost reduction effect ($\beta = .214$) when compared to its efficiency effect ($\beta = .170$) and service quality effect ($\beta = .170$) highlights the distinctiveness of VSM's cost-diagnostic characteristic: Unlike JIT (which primarily creates efficiency through pull logic) or 5S (which primarily creates quality through standardization), VSM's unique contribution is identifying where cost-generating waste is deeply rooted in the whole supply chain; thus, permitting targeted and high-value investments in cost reduction that can be made with confidence. The result lends support to the practical suggestion that the pharmaceutical supply chain manager should implement VSM as the "entry-point" Lean tool before implementing other Lean tool deployments to generate the most value for cost reduction. 5S was the most significant factor for service quality ($\beta = .298$, $p < .001$), which is in line with the dramatic quality improvement results of Yang et al. (2024) and can be explained theoretically due to the direct impact of 5S on error generation mechanisms such as poor organization, unlabeled storage, and inconsistent procedures, which are directly translated into service quality failures.

This finding is two-fold in the pharmaceutical context, as 5S enhances operational service quality outcomes (order accuracy, processing speed, return rates) and also assists regulatory compliance of DRAP (GMP documentation discipline, contamination prevention and audit readiness), offering a unique 5S value proposition in the pharmaceutical regulated environment. This dual value may play a part in the high adoption rate ($M = 3.61$) of 5S when compared with the other three Lean tools and help to explain why regulatory compliance pressure is enough to drive the adoption of 5S type workplace organization without a Lean strategy.

The service quality model also had the highest R^2 ($H1 - .529$), indicating that the 4 Lean Tools explain more of service quality than efficiency (.512) or cost reduction (.483). This result is in line with the theoretical argument that service quality is a multi-causal outcome that is affected by workplace organization (5S), material flow efficiency (JIT), process standardization (VSM), and continuous improvement culture (Kaizen) all at once.

Kaizen was the strongest predictor of overall SCM performance ($\beta = .311$, $p < .001$) and the highest R^2 model (.591) is a unique cross dimensional optimization mechanism. The finding aligns with Garza-Reyes et al. (2024) longitudinal evidence of compound Kaizen improvements in performance and Liu et al. (2025) theoretical placing of Kaizen as the mechanism of organizational learning that evolves and combines all other Lean tool investments together over time.

The finding that the Kaizen model explains more variance in overall SCM performance (.591) than the other three models (JIT: .512, VSM: .483, 5S: .529) is theoretically interesting because, in terms of their optimization dimension, the Kaizen model is more powerful than the other three models in predicting comprehensive overall SCM performance; JIT, VSM, and 5S are more powerful than Kaizen in predicting specific aspects of overall SCM performance. This differential impact is exactly as theorized, and it is a key confirmation of the performance dimension assignments of the hypothesis for this study.

The composite Lean Implementation Index shows a large effect ($\beta = .714$, $p < .001$), which is substantially larger than all of the individual tool effects (β range: .298 – .362), and substantiates the synergistic interaction among the 4 Lean tools predicted by Shah & Ward (2024) and Neri et al.'s (2024) meta-analysis. The case evidence presented by Onyekachi et al. (2024) that there are transformational effects that can only be realized when a comprehensive Lean program is integrated by the bundle premium (97%) represents the magnitude of the difference in the composite effect ($\beta = .714$) and the strongest individual tool effect ($\beta = .362$), thus confirming the transformational effects reported by Onyekachi et al. (2024).

The bottom line is clear: single tool implementations of Lean are not the right approach for pharmaceutical supply chain managers, but rather integrated Lean programs. The evidence also indicates that the ROI on integrated Lean implementation is significantly higher than the ROI on the implementation of any single lean tool and that companies that implement the JIT-VSM-5S-Kaizen combination have improvements in supply chain performance about twice as large as companies that implement any single tool.

Practical Recommendations

For Supply Chain Managers

- Use VSM as the entry-point Lean tool and implement other tools systematically to identify and prioritize cost reduction opportunities throughout the entire value stream in the supply chain.

- Implement the 5S systematically as the baseline service quality and regulatory compliance improvement process throughout the supply chain facilities.
- Once process stability is achieved with the 5S process, implement JIT replenishment systems and invest in supplier development and demand forecasting capability to overcome the challenge of import dependency on APIs in Pakistan.
- Develop the Kaizen ability of the enterprise with structured idea capture systems, regular improvement events, and visible management sponsorship.
- Apply integrated Lean adoption, not single tool deployments—the evidence suggests that the synergies of the bundles yield performance improvements about twice those of single tool deployments.

For Policy-makers and Industry Associations

- PPMA should create a national initiative to implement a Lean pharmaceutical supply chain for its members, including a set of implementation guidelines, support for subsidized training and peer learning platforms, especially for medium and small scale businesses who are working with restrictions on resources and Lean expertise.
- DRAP should formally establish Lean standards in its GMP and GDP compliance measures, and encourage workplace organization (5s) and the standardization of processes as regulators' enablers.
- Academic institutions with pharmaceutical supply chain and/or pharmaceutical management programs need to design a specialized curriculum on Lean pharmaceutical supply chain to strengthen the human resources sector.

Limitations and Future Research

There are certain limitations in this study. First, the cross-sectional design does not allow for causal inference, and longitudinal studies that follow the performance of the supply chains before and after the implementation of Lean would be required to infer the causality of the time. Second, the use of perceptual survey measurements instead of perceptual operational performance measurements may create measurement bias; future studies should include measurement instruments that are more objective (such as lead time, stockout rate, inventory turnover, cost-per-order) in addition to the perceptual measures. Thirdly, concentration of sampling in three key cities of Pakistan may constrain the generalizability of the findings to the rural pharmaceutical distribution network and smaller manufacturers in the region. Fourth, the study concentrates on four selected Lean tools, excluding the possibility of applying other Lean tools that could be relevant to the pharmaceutical supply chain, such as Total Productive Maintenance, Single Minute Exchange of Die, Kanban visual management. Fifth, with relation to survey data, common method variance is possible and future research should have multi-source data collection designs.

Future studies should: adopt longitudinal designs to establish effective causal relationships and document performance trajectories through Lean implementation maturity cycles; adopt the mixed-methods designs to incorporate survey quantitative data with in-depth qualitative case studies of exemplary Lean implementers to highlight the emerging field of Digital Lean; explore moderating variables such as firm size, regulatory exposure and Digital system maturity as boundary conditions on Lean effectiveness; and expand the investigation to the pharmaceutical distribution tier where Lean adoption is even less advanced than the manufacturing tier.

Conclusion

This research is the first empirical study conducted in Pakistan's pharmaceutical value chain that presents the first systematic evidence of the effectiveness of lean. The five hypotheses were all confirmed at the .001 significance level. Each of the four tools has a significant and different effect on the efficiency of the supply chain, the reduction of cost and on the quality of the service offered, respectively, and the combination of them will yield a synergic effect which will be much more effective than the impact of each single tool. Each of the 4 tools will have a different and significant effect on the efficiency of the supply chain, cost reduction and service quality, respectively, while their combination will produce a synergic effect (Lean Index $\beta = .714$) significantly higher than the effect produced by each single tool (range $\beta = .298 - .362$). The study results add up to the cross-context validity of the Lean Thinking Framework, RBV and SCOR model in the regulatory, supplier and human capital environment of the developing economy pharmaceutical context. The findings of the study were quantitative in nature that serve as basis for evidence-based investment prioritization in the improvement of the pharmaceutical supply chain program in Pakistan and also for the national level policy initiatives for the rapid adoption of Lean in the pharmaceutical sector.

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