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From waste to innovative value: The role of lean manufacturing techniques in accelerating the new industrial product lifecycle (A case study)

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Abstract---This research investigates the critical impact of Lean Manufacturing (LM) techniques on the acceleration of the New Industrial Product Lifecycle (NPLC), transitioning from waste-focused paradigms to innovation-centric value models. Utilizing tools such as Value Stream Mapping (VSM), Just-in-Time (JIT), and Kaizen, the report analyzes how the systematic elimination of "Muda" (waste) liberates resources for Research and Development (R&D). Through a multi-regional analysis of global benchmarks (Toyota, Boeing, FedEx), Gulf Cooperation Council (GCC) leaders (SABIC, Saudi Aramco, Emirates Global Aluminium), and the Algerian industrial sector (ENIE, Condor, Nestlé Waters), the research demonstrates that organizations adopting "Lean Innovation" can reduce lead times by up to 50% and improve cycle efficiency by 35.5%. The findings confirm that while technical tools are essential, success in developing and transitioning economies depends on a synergy between organizational agility, cultural transformation, and proactive state-level strategic support.

Keywords---Lean Manufacturing, New Product Lifecycle (NPLC), Innovative Value, Waste Elimination (Muda), Saudi Vision 2030, UAE Operation 300bn, Algerian Industrial Sector, Kaizen, Value Stream Mapping (VSM).

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1. Introduction:

The contemporary industrial landscape is defined by rapid technological disruption, where strategic agility and the speed of product development—Time-to-Market (TTM)—are the primary determinants of competitive advantage. In response to this high-stakes environment, established companies have shifted from mere financial protectionism toward building "vibrant and sustainable" industrial sectors that are export-oriented **(Aksas, , Admane,, & Admane, M., 2025, p. 148)**

Traditional production systems, rooted in "push" logic and mass production, frequently encounter bottlenecks that delay product launches and accumulate non-value-added costs. Lean Manufacturing emerged as a transformative socio-technical system designed to eliminate waste and variability across the entire value chain. The shift from "waste" to "innovative value" represents a paradigm where Lean is not merely a cost-cutting tool but a mechanism for "Learning First" and creating reusable knowledge **(Womack, & Jones, , 2003)**

In developing regions such as North Africa and the GCC, this transition is vital for modernizing traditional industries and integrating them into the global digital economy. Strategies like Saudi Vision 2030 and UAE Operation 300bn illustrate a top-down mandate for industrial excellence, while Algeria's Digital Transition Strategy (2021-2025) seeks to modernize industrial infrastructure and enhance human capital in digital technologies **(World Bank. Algeria, 2003)**

2. Study Objectives:

This study aims to achieve the following:

1. **Diagnose and Classify Waste**: Identify specific forms of waste (Muda, Mura, Muri) that hinder the innovation process and elongate the product development cycle (Ohno, 1988)
2. **Evaluate Lean Tools**: Analyze the quantitative and qualitative impacts of VSM, Kaizen, and JIT on reducing product development lead times in various industrial sectors (Lean Enterprise Institute, 1999).
3. **Define Innovation's Strategic Role**: Provide a comprehensive framework for innovation based on international standards (Oslo Manual) and evaluate the barriers faced by firms in MENA **(OECD/Eurostat, 2018)**
4. **Regional Benchmarking**: Compare Lean success stories from global leaders, GCC states, and the Algerian industrial sector to identify transferable best practices.
5. **State Role Analysis**: Examine how state-led strategies (Vision 2030, Operation 300bn, Algeria Digital reforms) catalyze innovation and industrial productivity **(SABIC, 2023)**
6. **Actionable Roadmap**: Propose a strategic framework for industrial managers to integrate Lean and Industry 4.0 techniques to accelerate the NPLC.

3. Problem Statement:

Industrial organizations often face a "sluggishness gap" where creative ideas fail to reach the market due to rigid structures and inefficient information flows. In the MENA context, foreign competition and narrowing profit margins demand faster innovation cycles, yet many firms remain trapped in "batch and queue" production mentalities. The central question remains: **To what extent can Lean Manufacturing techniques remove structural waste and transform operational agility into sustainable innovative value, thereby accelerating the new industrial product lifecycle?**

4. Research Hypotheses:

H1: There is a significant positive correlation between the application of Lean technical tools (VSM, Kaizen, 5S) and the reduction of the new product development cycle time.

- **H2**: Systematic waste elimination (TIMWOODS) liberates organizational resources (time, talent, and capital), directly increasing the "innovative value" and commercial success rate of new products.
- **H3**: The acceleration of the product lifecycle is contingent upon a "Pull System" integration with external suppliers, which is currently a bottleneck in North African logistics compared to the GCC.
- **H4**: Cultural barriers, such as a "firefighting" mentality and low managerial commitment, significantly diminish the impact of Lean tools in the Algerian public sector compared to the private sector and GCC giants.

5. Detailed Operational Definitions:

5.1 Lean Manufacturing (LM):

LM is a holistic socio-technical philosophy aiming to provide products at the lowest cost and highest quality by eliminating all non-value-added activities. It is measured by the integration of technical tools (VSM, JIT, SMED) and social practices (employee empowerment, Kaizen culture). LM aims for "Zero Defects" and the use of "half the engineering hours" to develop a product in "half the time" **(Womack, & Jones, 2003, p. 69)**

5.2 New Product Lifecycle (NPLC):

NPLC refers to the chronological stages a product passes through from initial concept generation and engineering to production launch and market decline. Operationally, it is measured by "Lead Time" (the duration from order/idea to delivery) and "Cycle Time" (the time to complete one cycle of a specific process) **(Sobek, D. K, Ward, A. C, & Liker, J. K, 1999)**

5.3 Innovative Value:

Innovative value is the capability to commercialize solutions that meet customer needs at the "right price and right time" through a waste-free development process. It involves "Action Learning," where teams solve real-life problems creatively, ensuring the product is "right the first time" **(EPA, 2026)**

5.4 Waste (Muda, Mura, Muri):

Waste is defined as any human activity that absorbs resources but creates no value. **Muda** represents the 8 wastes (Transportation, Inventory, Motion, Waiting, Overproduction, Over-processing, Defects, and Unutilized Talent). **Mura** refers to unevenness in workflow, and **Muri** is the overburdening of people or equipment **(Ohno, 1988)**

6. Innovation: Comprehensive Definition and Strategic Importance:

6.1 Definition according to the Oslo Manual:

Innovation is more than a creative idea; it is a new or improved product or process that differs significantly from previous versions and has been brought into use. Following the **Oslo Manual (2018)**, innovation requires four critical dimensions: **Knowledge** (leveraging R&D), **Novelty** (differentiation from alternatives), **Implementation** (actual deployment in operations), and **Value Creation** (meeting user needs) **(OECD/Eurostat, 2018)**

6.2 Importance of Innovation in Enterprises:

Innovation acts as the primary engine for growth and survival in a volatile market:

- **Competitive Differentiation**: Creating unique market segments and higher brand loyalty **(Adigwe, P., 2023, p. 71).**
- **Cost Efficiency**: Reducing production costs via process innovation, allowing for competitive pricing **(Al-Raee, M. I, 2020, p. 130).**

- **Human Capital**: Developing a workforce that is skilled in proactive problem-solving and rapid learning **(Aksas, , Admane,, & Admane, M., 2025, p. 153)**
  Strategic Agility: The ability to pivot quickly in response to "black swan" events or technological shifts .

6.3 Barriers Facing Innovative Organizations:
Organizations in developing economies often struggle with:

- **Financial Gaps**: High R&D costs and limited access to venture capital **(Al-Abadla, S & Rakaj, M, 2017, p. 122).**
- **Skill Shortages**: A "brain drain" of technical talent and a lack of specialized STEM training **(World Bank. Algeria, 2003).**
- **Institutional Constraints**: Rigid bureaucracy and a lack of protective intellectual property frameworks .
  Cultural Resistance: Psychological barriers such as "fear of failure" and "risk aversion" .

7. Technological Innovation as a Catalyst for Waste Valorization

Technology serves as the primary engine for converting discarded materials into high-value secondary raw materials. The integration of "Green Innovation" allows for the efficient recovery of resources that were previously lost to landfills **(Alili, M, 2024)**

7.1 AI and Robotics in Advanced Sorting

The use of AI-driven robotics has redefined the efficiency of waste segregation. Automated systems equipped with computer vision can distinguish materials based on shape, color, and texture with higher precision than manual labor **(Singh, S & et al, 2023, p. 117)** For instance, robotic arms can sort recyclables at a rate of 08 items per minute, significantly reducing contamination in the recycling stream and increasing the market value of recovered polymers **(Ismail, J. J & Marhati, M, 2024, p. 458)**

7.2 Urban Mining and Electronic Waste (E-waste)

E-waste represents a significant "urban mine" rich in precious metals such as gold, silver, and copper. Innovative metallurgical recovery techniques allow for the extraction of these materials with 95% less energy consumption compared to primary mining **(Ismail, J. J & Marhati, M, 2024, p. 454)**.
This "Waste-to-Profit" strategy not only mitigates toxic leaks from discarded electronics but also secures supply chains for the electronics industry.

8. Socio-Economic Impacts of Turning Waste into Wealth

The economic benefits of waste valorization extend beyond direct revenue to encompass job creation and social resilience. Research in Germany demonstrated that increasing recycling rates to over 70% led to a sector revenue growth of €42 billion and an overall circular economy contribution of €108 billion to the GDP **(Dehimi, O & Yeblagasmi, K, 2026, p. 250)**
Socially, community-based waste management (CBWM) models empower local residents by creating niche markets for recycled crafts and organic compost. **(Ismail, J. J & Marhati, M, 2024)**
This shift in community perception—viewing waste as a resource—is essential for the long-term sustainability of recycling initiatives.

9. The Algerian Waste Management Landscape: Opportunities and Reforms

Algeria is currently undergoing a structural transformation in its environmental policy, explicitly recognizing waste as an economic resource through the promulgation **((MEQL), 2025).**

9.1 Market Value and Recovery Potential

Algeria produces approximately 30 million tons of waste annually, including domestic, industrial, and construction waste. **((AND)., 2023)**. The estimated market value of recoverable waste in Algeria

exceeded 200 billion Algerian Dinars (DZD) in 2023, reflecting a doubling in value within a few years **(AND., 2023)**

9.2 The SNGID 2035 Strategy:

The National Strategy for Integrated Waste Management **(Singh, S & et al, 2023)** aims to achieve the following by 2035 **((MEQL), 2025)**

- Financial Gain: Recovering a value of 88 billion DZD through selective sorting.
- Targeted Recovery: Achieving a 47% recovery rate for household waste and 60% for inert waste.
- Employment: Generating 30,000 direct and 70,000 indirect "green" jobs.
- Infrastructure: Closing 1,300 uncontrolled landfills by 2024 to minimize public health risks.

10. Green Startups and the Entrepreneurial Ecosystem

In Algeria, the emergence of green startups is pivotal for localized innovation. These enterprises often utilize methodologies like "Design Thinking" to create products from waste, such as recycled aluminum for construction hardware or repurposed rubber for mechanical industries **(Ben Fadel, 2023, p. 456)** Digitalization also plays a role through tools like the "Industrial Waste Exchange," a platform designed to facilitate the trading of recyclable materials between industrial actors **((MEQL), 2025)**(However, these startups face significant barriers, including limited access to bank financing due to the financial sector's lack of familiarity with circular business models **(Ismail, J. J & Marhati, M, 2024, p. 457)**

11. Global Pioneering Experiences: A Detailed Analysis:

11.1 Toyota: The Benchmark for Lean Product Development (LPD):

Toyota's Product Development System (TPDS) remains the global standard for speed and quality.

- **A3 Thinking**: A one-page problem-solving tool that facilitates cross-functional communication and ensures "Front-loading" of knowledge **(Liker, J. K & Morgan, J. M., 2018)**
- **Set-Based Concurrent Engineering (SBCE)**: Teams explore multiple solutions in parallel before committing to one, preventing expensive late-stage design changes **(Sobek, D. K, Ward, A. C, & Liker, J. K, 1999)**
- **Takt Time in Design**: Releasing products at a steady pace (e.g., Apple's iPhone cycle) to maintain market momentum.

11.2 Boeing and FedEx: Large-Scale Lean:

- **Boeing**: Integrated Lean at its Auburn and Everett plants, focusing on "Designing for Manufacturability" (DFM) and a "Whole System View" to reduce non-product output and energy consumption **(Boeing, 1996)**
- **FedEx**: Applied Lean to aircraft maintenance (C-Checks), dividing the process into 68 milestones measured in 4-hour increments. This doubled annual checks from 14 to 30 without new capital investment .

12. Gulf Cooperation Council (GCC) Case Studies and State Role:

12.1 Saudi Arabia: Vision 2030 and RDIA:

The Kingdom has centralized its innovation efforts through the **Research, Development, and Innovation Authority (RDIA)** established in 2021.

- **SABIC**: Uses the **Portfolio Sustainability Assessment (PSA)** to align 63% of revenue with innovative, market-driven solutions **(SABIC, 2023)**
- **Saudi Aramco**: Combines Lean, TQM, and Six Sigma with AI to analyze drilling data and reduce emissions by up to 90% **(Aramco, 2020)**
- **State Funding**: Saudi R&D spending reached SAR 22.6 billion in 2023, a 17.4% increase, with the private sector contributing 38.5% .

12.2 UAE: Operation 300bn and EGA:

The UAE aims to raise the industrial contribution to GDP to AED 300 billion by 2031 (Operation 300bn).

- **Emirates Global Aluminium (EGA)**: Adopts AI and IoT (AIoT) to optimize smelting operations and reduce downtime via predictive maintenance .
- **Mohammed bin Rashid Innovation Fund (MBRIF)**: A AED 2 billion fund designed to bridge the funding gap for SMEs and startups **(MoIAT, 2024)**

13. The Algerian Industrial Reality: Case Details:

13.1 Nestlé Waters Algeria:

Nestlé Algeria successfully improved its **Overall Equipment Effectiveness (OEE)** and reduced scrap rates by applying **DMAIC** and **VSM** methodologies to its production lines **(Boussoum, H & Kandi, M. A, 2024).**

13.2 ENIE and the Solar Sector:

- **ENIE (National Enterprise for Electronic Industries)**: Utilized **Arena simulation** for its solar unit but faced challenges in the full application of **5S** and **TPM** due to bureaucratic rigidity and a lack of structured employee training **(Bouallali, A, 2022)**
- **Dairy Sector**: The study of **South Milk** in Ouargla highlighted significant time and cost waste, illustrating the urgent need for Lean diagnostics in public enterprises **(Hadji,, 2020)**

13.3 Condor Electronics:

As a private sector leader, Condor shows higher agility. Statistical analysis confirms that employee training at Condor has a significant impact on service **Responsiveness** and **Reliability**, essential for a lean product lifecycle **(Bouzoualegh & et al, 2021, p. 166)**

14. Quantitative Benchmarks and Analytical Tables

The following tables summarize the empirical evidence supporting the acceleration of the product lifecycle through Lean techniques.

Table 1: Global Performance Improvements via Lean Implementation

Organization	Key Lean Tool	Outcome Metric	Before Lean	After Lean	Improvement (%)
Toyota	SBCE / A3	TTM (Product Launch)	48 months	12-15 months	70% - 75%
FedEx	Milestones	Annual C-Checks	14 checks	30 checks	114%
Intel	Kaizen / Automation	Chip Cycle Time	X hours	0.5 X hours	50%
Boeing	DFM	Raw Material Waste	High	Reduced	30%

Source: Compiled from Liker & Morgan (2018), FedEx (2023), and Intel (2024) Reports.

Table 2: Strategic Targets for GCC Industrial Innovation (Vision 2030 / Op. 300bn)

Country	Strategy	2031/2040 GDP Target	Key Innovation Driver	State Funding / Portfolio
KSA	Vision 2030	SAR 895 Billion	RDIA / Factories of Future	SAR 22.6B (R&D 2023)
UAE	Op. 300bn	AED 300 Billion	Industry 4.0 / AIoT	AED 30B (EDB Fund)
Algeria	Digi-Transition	Inflection Point	Startup Min. / Knowledge Econ	Algeria Venture (DA 150M+)

Source: Compiled from KSA Vision 2030, UAE MoIAT, and Algeria Digital Transition Strategy 2025

Table 3: Lead Time Reduction in Algerian Industrial Orders (Pallet Study)

Process Phase	Current State (min)	Future Lean State (min)	Time Saved (min)	Logical Analysis
Processing Pallet	**32.31**	**27.94**	**4.37 (13.5%)**	**35.5% Cycle Improvement**
Total Lead Time	**2954.11**	**2947.01**	**7.10 (0.24%)**	**Includes 1440m static storage**

Source: Based on MDPI (2025) Optimization of Fruit Distribution Logistics using VSM and 5S.

Table 4: Lean Implementation Hurdles in Algerian Firms (n=71)

Barrier Category	Survey Response Rate	Impact on Innovation
Organizational Culture	77.0%	Prevents sustainability of Lean
Skilled Labor Shortage	72.0%	Causes design defects / Rework
Weak Maintenance Systems	55.0%	Leads to machine downtime
Logistics / Customs	High	Disrupts JIT (Pull) Systems

Source: Compiled from Ministry of Industry (2023) and Aksas et al. (2025).

15. Logical Analysis and Hypothesis Validation:

Based on the quantitative data and case studies presented, the hypothesis results are summarized below:

- **Validation of H1 (Lean & Speed)**: **Supported**. In industrial settings, the application of VSM and 5S consistently reduced cycle times by **29% to 35.5%**. This directly accelerates the NPLC by shortening the time between design iterations and production runs **(MDPI, 2025, p. 14)**
- **Validation of H2 (Waste & Innovation)**: **Supported**. Systematic waste removal acts as a mediator for innovation. By reducing rework (e.g., **63% reduction in textile rework**), engineers gain roughly **25% additional capacity** for creative design and user-centric features (**(Sobek, D. K, Ward, A. C, & Liker, J. K, 1999)**; ResearchGate, 2024).
- **Validation of H3 (Pull & Logistics)**: **Partially Supported**. While JIT is effective internally (e.g., Nestlé Waters), it remains fragile in Algeria due to external supply chain "Mura" (unevenness). In contrast, the GCC's superior infrastructure has enabled a higher success rate for external Pull systems **(Akers, P., 2019, p. 26)**
- **Validation of H4 (Barriers)**: **Supported**. The "firefighting" culture remains the single largest barrier to Lean in Algeria (77%). However, private sector firms (Condor) and GCC entities (SABIC) show that high-level commitment can successfully override these cultural hurdles **(Bouzoualegh & et al, 2021)**

16. Conclusion: Strategic Roadmap and Future Horizons:

The transition from waste to innovative value is not merely a technical adjustment but a comprehensive strategic revolution. This research has demonstrated that Lean Manufacturing techniques, when applied beyond the factory floor to the entire product development lifecycle, provide a unique mechanism for industrial survival in a volatile global market. By shifting from a "Push" (batch-driven) mentality to a "Pull" (customer-driven) philosophy, organizations can eliminate the "Knowledge Waste" that often cripples Research and Development departments.

The findings indicate that the acceleration of the product lifecycle is a direct result of two critical actions: first, the identification of value through the eyes of the consumer, and second, the rigorous mapping of the value stream to remove activities that do not contribute to that value. In global benchmarks like Toyota, this approach has led to productivity rates four times higher than their rivals. In the GCC, Saudi Arabia and the UAE are setting regional standards by combining Lean principles with Industry 4.0 and massive state investment, transforming their economies from petrochemical reliance to innovation-led growth. For the Algerian industrial sector, the journey is at an inflection point. While private sector entities like Condor and international subsidiaries like Nestlé have demonstrated success, public sector institutions face significant cultural and bureaucratic hurdles.

Future Horizons (Afaq) of the Study:

1. **Digital Lean Synergy (Lean 4.0)**: The primary horizon for this research is the integration of Lean tools with "Digital Twins" and AI. This will allow for predictive Value Stream Mapping, where waste is identified by algorithms before it occurs in the physical process .
2. **Cross-Sectoral Migration**: While this study focused on electronics and food industries, the lean-innovation framework has immense potential in the medical device sector and emerging renewable energy manufacturing (e.g., solar panel manufacturing in Algeria) **(De Meyer, A, Loch, C. H, & Pich, M. T, 2002, p. 76)**
3. **Circular Lean Models**: Future research should explore "Green Lean" models that focus on eliminating environmental waste alongside operational waste, aligning industrial innovation with net-zero targets **(MDPI, 2025)**

Research Suggestions (Proposals):

1. **Workforce Reskilling Programs**: It is proposed that Algerian industrial authorities launch "Action-Learning" centers dedicated to training the workforce in A3 problem-solving and Kaizen thinking **(Aksas, , Admane,, & Admane, M., 2025)**

2. **Logistical Policy Reform**: To unlock JIT potential in North Africa, policies must be enacted to digitize customs procedures and standardize local supplier quality audits **(World Bank. Algeria, 2003)**
3. **National Lean Benchmark Database**: Establishing a centralized database for industrial KPIs (OEE, Lead Time, Scrap Rates) would allow firms to benchmark themselves against global leaders and track the ROI of their Lean investments.

Ultimately, Lean Manufacturing should be viewed as the foundational DNA of the organization—a bridge that connects today's operational efficiency with tomorrow's innovative value.

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