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Value Stream Mapping and Waste Reduction Study of Pressure Cooker Body Manufacturing Across Aluminium, Stainless Steel, and Tri-Ply Lines

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Abstract **- In this competitive household equipment manufacturing sector, to have a good manufacturing excellent product it depends on eliminating waste, material streamlined flow, and strong delivery of quality. From decades of literature underscores Lean Manufacturing and Value Stream Mapping (VSM) as foundations of understanding and analyzing bottlenecks on shop-floor, improving throughput time, and driving methodological continuous improvement. This industrial study investigates the cooker-body manufacturing operations at ABC Cookers Limited across three primary product streams: ANODISED COOKERS Aluminum, Stainless Steel, and Tri-Ply. The primary objectives were to document upstream to downstream manufacturing workflows through VSM, segregate and analyze wastes using the TIMWOODS framework, evaluate material and information flows along with traceability which is QR based, diagnose quality rejections and process bottlenecks, and propose low-cost, practical and low-capital improvement solutions. Executed over an eight-week period from 15 June 2026 to 15 August 2026, the study methodology combined extensive operator interactions, Gemba walk, recording of cycle time, ERP transaction audits, and quality benchmarking against IS 2500 Part 1 acceptance sampling standards.**

Investigation revealed that Non-value-added activities were predominate in logistics and administrative areas, with significant divergences around all product lines. The Tri-Ply line had transportation waste due to outsourcing from vendors located around 1,300 km away, whereas the ANODISED COOKERS and Stainless Steel lines experienced multi-processes and hoping, subcontract finishing delays. Across all lines, operations were carried by single-forklift unloading dependencies, paper-intensive four-copy challans for delievery, and untracked in process trolleys. Furthermore, In-house press operations contributed 3-4% out of a 5-6% combined plant rejection rate, high-volume circles lacked QR traceability which were not integrated to ERP. In conclusion plant productivity is lacking because of space constraints, lack of material handling solution and loads of manual work .

To cut down lead times and tighten floor-level oversight, operations should prioritize several quick, cost-effective digital upgrades:

- **Automate Dispatch Paperwork: Link the ERP directly via API to generate digital delivery challans and e-way bills automatically, cutting manual administrative bottlenecks.**
- **Instant First-Off Escalation: Set up digital Andon notifications to immediately alert supervisors when initial sample approvals stall, preventing line idling.**
- **Mobile-Based Quality Audits: Move IS 2500 sampling protocols onto floor tablets or handhelds so inspectors log acceptance runs straight into the central database.**
- **Traceable Packaging Assets: Tag heavy circles and returnable transport crates with scannable QR codes, establishing a closed-loop system that tracks transit cycles and eliminates missing inventory.**

Targeting these high-friction handoffs with off-the-shelf digital tools delivers measurable inventory turnaround and process traceability without committing to a heavy, high-capex overhaul.

Keywords - Value Stream Mapping (VSM), Lean Manufacturing, TIMWOODS Waste Analysis, Pressure Cooker Manufacturing, QR Traceability

I. INTRODUCTION

This manufacturing landscape is defined by rapid shifts in technology, volatile costs of raw-materials, and intense competition across globe. To have an edge, house-hold equipment manufacturing organizations must aggressively pursue operational excellency, optimization of processes, and

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implementation of lean manufacturing. Pressure cooker manufacturing has a complex, multi-stage production system that integrates précised metal forming—such as deep drawing, spinning, trimming, and lipping—with specialized subcontracted metal surface finishing, direct material component assembly, rigorous safety and quality testing, and multi-tier logistics. Because each operation compounds to overall cycle times and directly dictates consumer safety, eliminating non-value-added activities across the production lifecycle has become vital to have a long-term sustenance, reduce operational overhead, and preserve rigorous and must needed quality standards.

Within the Indian cookers sector, ABC Cookers Limited represents an established benchmarking of product integrity, brand equity, and strict protocols of manufacturing. However, even within highly governed manufacturing atmosphere, operational friction and obstacles often emerge across informational and physical workflows. At the shop-floor, distinct multi-material product lines—principally Aluminium (ANODISED COOKERS), Stainless Steel, and Tri-Ply variants—experience various operational bottlenecks. This includes uncontrolled material handling, accumulation of excessive inventory , documentation which is paper-intensive, and uneven inspection quality frequencies. Furthermore, distinguished surface treatment subcontracting and the uneven adoption of direct material QR traceability create prominent visibility gaps between final dispatch, material dispatch and raw-material receiving.

To address these challenges, this study presents an in-depth investigation into the cooker-body manufacturing value streams across ABC Cookers Limited's primary product lines. Utilizing Value Stream Mapping (VSM) as the core investigating methodology, the research systematically tracks start to end information and material flows, separates value-added processes from the classic TIMWOODS wastes, and quality assurance audits checkpoints against standardized sampling frameworks. By alternating the workflow configurations, handling constraints, and cycle times of aluminium, stainless steel, and composite tri-ply bodies, this paper establishes a data-driven diagnosis. Ultimately, it provides actionable, practical, low-cost lean solutions and digital tracking enhancements designed to shorten production lead times, streamline plant logistics, and reinforce control on shop-floor operations.

II. LITERATURE REVIEW AND THEORITICAL BACKGROUND

A. *Literature Review*

Infanteri (2018) analyses lean waste reduction in an aluminium cookware SME WIP, defects, motion, inventory, VSM, 5S, and Six Sigma. D. S. (2025) researched 5S, JIT, Kanban, and Kaizen in an Indian kitchen appliances manufacturer. Kaneku-Orbegozo et al. (2019) conducted a kitchen equipment production analysis, pointing out the presence of cutting and bending wastes, and achieving 13% cost savings; the second indexed record refers to the same study. Luan et al. (2021) assessed polishing tools for the improvement of aluminium cookware surface; Ealias et al. (2025) specified quality attributes of aluminium pots. Abdennadher et al. (2024) investigated coated-aluminium deep drawing and formability. Salsabila and Rochmoeljati (2021) and Arnando (2015) addressed lean waste reduction and quality improvement in stainless-steel processing. Karim et al. (2012) studied VSM in metal stamping, and Damsiar and Tjprc (2020) combined work study with lean methods in a metal-press line. Nivya (2016) examined forging VSM, while Murugananthan et al. (2014) mapped foundry flow. The research by Ravichandran (2015) optimized value ratio in pressure vessel forming process. VSM application in pumps manufacturing was reported by Dighe & Kakirde (2014). Jaiswal & Soni (2017) discussed VSM in small scale industries. The study in steel industry conducted in 2020 was based on non-value added activities. Inventory and delay management were the focus of the study carried out by Dewa & Lusiba (2018).

B. *Theoritical Background*

The research is rooted in Lean Manufacturing – a production system approach based on Toyota Production System (TPS). Its key feature is the emphasis on creating customer value via eliminating all kinds of non-value adding activities. The analytical basis is made by Value Stream Mapping (VSM) – visualization of material and informational flows from receipt to shipment. This process cycle times, changeovers and materials buffers distinguishing necessary transformations from operational inefficiency.

Operational inefficiency in manufacturing lines is analysed according to the framework of the types of waste called TIMWOODS (Transportation, Inventory, Motion, Waiting, Overproduction, Overprocessing, Defects, and Underutilized Skills). Thus, transportation inefficiency is associated with delays, such as forklift dependence, manual transportation, unnecessary QR codes and excessive paperwork. Continuous improvements follow the scheme of the Plan-Do-Check-Act (PDCA) cycle and Kaizen approach, including low cost incremental shop floor improvements. In addition to this, workplace management issues are analysed using 5S (Sort, Set in Order, Shine, Standardize, and Sustain) method in order to deal with poor allocation and storage of subcontracted parts. Diagnostic tools, such as 5-Why technique and Ishikawa (Fishbone) analysis help to identify the root causes behind observed process inefficiencies.

Lastly, the research combines Quality Management and the idea of a digital supply chain. The evaluation of process capability and quality management occurs using the acceptance sampling criterion (IS 2500 Part 1). The concept is further strengthened using ideas surrounding digital traceability, where the use of QR codes in minimizing errors associated with manual data logging and enhancing material visibility within the production process cycle is evaluated.

III. MATERIALS AND METHODS

A. *Research Objectives*

This study evaluates cooker-body manufacturing across ABC Cookers Limited's primary material lines to achieve five core objectives:

(1) Using Value Stream Mapping (VSM document the start-to-end manufacturing process from raw material receiving to final dispatch of product

(2) Identify value-added and non-value-added activities while classifying wastes using Lean Methodology (TIMWOODS)

(3) Analyse material, information flows, quality inspection processes, and QR-based traceability at all manufacturing stages

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(4) Evaluate process bottlenecks, delays, quality issues, and operational challenges affecting efficiency

(5) Formulate feasible process improvement solutions aimed at enhancing throughput, eliminating waste, standardize quality, and strengthen overall performance of operations.

B. Research Design and Data Collection

The application of the industrial case study was performed by conducting this on the shop floor for a duration of eight weeks between 15 June 2026 and 15 August 2026. Primary data collection was done via the performance of the Gemba walk, process tracking, time studies involving the use of calibrated stopwatches to measure the cycles of operations, and semi-structured interviews with line operators, supervisors, and process engineers. The secondary data were collected from plant layouts, standard operating procedures, ERP transaction history, QR-Goods Receipt Record (GRR), and quality control logbooks. The study traced the full product transformation process from the receipt of raw materials, store staging, press shop processing (forming, deep drawing, trimming, spinning, lipping, and laser cutting), subcontracted finishing (buffing, anodizing, and sunray), incoming inspection, assembly, pressure testing, and dispatch packing.

C. Analytical Framework and Quality Evaluation

Value Stream Maps for the current state were developed for the ANODISED COOKERS Aluminium, Stainless Steel, and Tri-Ply product lines, which helped to identify the movement of materials, cycle time, manning, and flow of information. Inefficiencies in operations were identified using the TIMWOODS method of waste identification, and root cause analysis was done using Ishikawa and 5 Why methods to find out delays caused by internal movements, paperwork, and staging. Quality control activities were analysed against the standard of IS 2500 Part 1 acceptance sampling procedure, resulting in the development of check sheet to check dimensions, surface imperfections, and drawing defects.

IV. DATA ANALYSIS AND DISCUSSION

Document Existing Manufacturing Process Using Value Stream Mapping (VSM)

TABLE I.
END-TO-END COMPARATIVE VALUE STREAM MAPPING ACROSS PRODUCT LINES

Parameter / Operational Metric	**SKUs**		
	ANODISED COOKERS (Aluminium) Line	***Stainless Steel (SS) Line***	***Tri-Ply Cooker Line***
Total Major Process Stages Mapped	10 stages	11 stages	11 stages
Body Forming Strategy	100% In-house Press Shop operations	Hybrid In-house (4 key forming steps)	Fully outsourced forming operations
In-House Press Shop Operations	Deep drawing, stretching, trimming, forming, spinning, lipping, MHB holing, oval cutting	dishing, and trimming	and lipping handled externally; optional in-house oval cutting)
Critical In-House Cycle Times	Pressing: 10–14 s; Deep draw: 10–12 s (Parkash Mechanical Press)	Laser cutting: 30–35 s; Cladding: 25–30 s (Electrotherm Press)	Oval cutting: 75–90 s (when processed in-house)
Subcontract Surface Finishing Hops	3 sequential hops (Buffing, Anodizing, Glossing)	1 combined vendor (Chamfering, Buffing, and Sunray finishing)	Multi-vendor network (Drawing/ Spinning/ Lipping, Buffing, Vendor Oval Cutting)
External Transit Distances	Local: 4–5 km; Outer tier: 100–200 km	Regional cluster: 80–275 km	High dispersion: 80–1,300 km (Palghar, Surat, Delhi)
Longest External Dwell Time	1–3 days per hop (cumulative 3–9 days)	2–3 days cumulative dwell time	2–3 days forming + 2 days vendor oval cutting
Body-to-Body Joining Method	Mechanical riveting (MHB / SHB)	Electric projection welding (MHB / SHB)	Electric projection welding (MHB / SHB)
Gate-Exit Dispatch Documentation	4 physical Delivery Challan copies	4 physical Delivery Challan copies	4 physical Delivery Challan copies
Total Major Process Stages Mapped	10 stages	11 stages	11 stages

The diagnostic analysis of the value stream architectures of the main product lines of ABC Cookers Limited is provided in Table 1. It is clear that there are basic differences in operation determined by metal type and its forming process. While the line

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of ANODISED COOKERS Aluminium involves deep forming in house with fast machine cycles (10-14 sec), it involves cumulative multi-hop delays in three sequential stages of surface finishing (buffing, anodizing, glossing). On the other hand, the line of Stainless Steel utilizes in-house laser cutting and cladding and is faster due to consolidated finishing vendors. As for the Tri-Ply line, it utilizes the outsourced production process without in-house forming, which makes the plant suffer from heavy geographic dispersion involving 1,300 km distance and long dwell time of vendors. In spite of the difference in physical factors, all the three lines have similar operational bottlenecks at administrative interfaces characterized by four-copy physical Delivery Challan process in the course of subcontracting.

Identify Value-Added and Non-Value-Added Activities and Classify Wastes (TIMWOODS)

TABLE II.
TIMWOODS OPERATIONAL WASTE CLASSIFICATION AND SHOP-FLOOR AUDIT

TIMWOODS Waste Category	Wastes Classification			
	Observed Shop-Floor Manifestation	***Process Location / Product Lines Affected***	***Value Addition Status***	***Business Impact & Operational Severity***
Transportation	Repeated multi-hop vendor transits up to 1,300 km; manual cart transfers between internal bays	Raw Material Stores, Subcontract Flow; All lines (Severe on Tri-Ply)	Non-Value-Added (NVA)	Extended cumulative production lead times; vulnerability to in-transit transit damages
Inventory	Buffer accumulation of 1–3 days dwell time at external job-workers; untracked floor WIP	Job-worker locations, Press Shop staging; ANODISED COOKERS, SS, Tri-Ply	Non-Value-Added (NVA)	Elevated working capital lock-in; poor intermediate material visibility and staging clutter
Motion	Non-standardized travel (2–25 m) to subcontract staging; manual trolley movement across bays	Subcontract bay, Press-to-Assembly corridors; All product lines	Non-Value-Added (NVA)	Operator physical fatigue, ergonomic strain, and variable transit times across shifts
Waiting	Forklift dependency at unloading; sequential physical and visual checks during gate entry/exit	Gate Entry, Unloading Bay, Press Shop; All product lines	Non-Value-Added (NVA)	Truck idling, operational idle time, and delayed line feeding during shift handovers
Over-processing	Generation, distribution, and individual signing of 4 physical challan copies; duplicate QR printing	Dispatch, Gate Exit, Final Packaging; All product lines	Non-Value-Added (NVA)	Redundant clerical labor, administrative overhead, and recurring label waste
Overproduction	Regulated under plant Make-to-Stock (MTS) batch schedules (minimal uncoordinated over-runs)	Central Press Shop, Assembly Lines; ANODISED COOKERS, SS, Tri-Ply	Necessary Non-Value-Added (NNVA)	Controlled risk of obsolescence; batching drives localized lot staging buffers

This information is captured in Table 2 below, which illustrates the operational resistance within the product life cycle within the lean manufacturing concept of TIMWOODS. Through the analysis, it has been revealed that the production process within the factory faces tremendous operational challenges, mostly because of Transportation, Waiting, and Overprocessing. The transportation wastes tend to grow exponentially based on the geographical location of the supply chain and as a result, cause severe resistance on the Tri-Ply production line because of far job-work routes. Operation waiting resulting from single forklift and logistics coordination creates direct imbalance in the process. On the other hand, overprocessing waste is manifested in many ways including paperwork-based checks, like managing the four hardcopy delivery challans at gate exit an printing QR labels in packaging.

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Most importantly, value-adding activity only takes place during the processes of Press forming, Finishing and Assembling..

Analyse Material Flow, Information Flow, Quality Inspection, and QR Traceability

TABLE III.
MATERIAL FLOW, QUALITY GOVERNANCE, AND QR DIGITAL TRACEABILITY AUDIT- PART 1

Direct Material / Component	**Vendor Wise Analysis**		
	Approved Vendor Base	***Inbound Movement Mechanism***	***Quality Checkpoints & Inspection Standard***
Aluminium Circles	Vendor A	Vendor truck, Gate, Stores, Press	Visual, dimensional, sheet thickness (IS 2500)
Stainless Steel Circles	Vendor B	Vendor truck, Gate, Stores, Press	Thickness, surface inclusions, dimensional check
Lid Circles	Vendor C	Vendor truck, Gate, Stores, Press	Sheet thickness, diameter, drawability inspection
Main Handle (MHB)	Vendor D	Trolley transfer, Riveting / Welding	Visual defect check, hole alignment, fitment
Die Cast Components	Vendor E	Inbound crates, Stores, Assembly	Visual finish, flash presence, thread verification
Stainless Steel Discs	Vendor F	Palletized delivery, Press Shop	Thickness tolerance, surface finish, diameter
Locking Loops	Vendor G	Boxed delivery, Assembly staging	Dimensional check, tension check, profile check
Rivets	Vendor H	Bagged inventory, Hardware Stores	Material hardness, shank diameter, head profile
Vent Tubes	Vendor I	Internal bins, Assembly / M	Thread pitch, bore clearance,
		Sub-assembly	finish inspection
Cover Heads	Vendor j	Staged bins, Lid assembly line	Visual inspection, thread integrity, plating check
Rubber Gaskets	Approved vendor tier	Sealed boxes, Final assembly line	Elasticity, dimensional profile, flash check
Safety Valves	Approved vendor tier	Specialized trays, Final assembly	Pressure relief pop-off calibration, threading
Semi-Finished Cooker Bodies	Internal Press & External Subcontractors	Trolleys / Return crates, Incoming QC	13 parameters (Profile, diameter, dents, cracks)

TABLE IV.
MATERIAL FLOW, QUALITY GOVERNANCE, AND QR DIGITAL TRACEABILITY AUDIT- PART 2

Direct Material / Component	**Direct Material wise Traceability**		
	ERP Auto-Challan Integration	***QR Code Coverage for Purchase GRR***	***Digitization & Traceability Status***
Aluminium Circles	Fully Integrated	Missing (No QR)	Critical High-Volume Digitization Gap
Stainless Steel Circles	Fully Integrated	Missing (No QR)	Critical High-Volume Digitization Gap
Lid Circles	Fully Integrated	Missing (No QR)	High-Volume Raw Material Gap
Main Handle (MHB)	Fully Integrated	Missing (No QR)	Hardware Digitization Gap
Die Cast Components	Fully Integrated	Missing (No QR)	Hardware Digitization Gap
Stainless Steel Discs	Fully Integrated	Missing (No QR)	Forming Substrate

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Direct Material / Component	Direct Material wise Traceability		
	ERP Auto-Challan Integration	***QR Code Coverage for Purchase GRR***	***Digitization & Traceability Status***
			Digitization Gap
Locking Loops	Fully Integrated	Missing (No QR)	Fastener Hardware Gap
Rivets	Fully Integrated	Partial (Modern only)	Fragmented Vendor QR Adherence
Vent Tubes	Fully Integrated	Partial (Recent lots missing)	Inconsistent Supplier QR Compliance
Cover Heads	Fully Integrated	Partial (Sadhguru only)	Fragmented Vendor QR Adherence
Rubber Gaskets	Fully Integrated	Fully Implemented	Complete QR Traceability Closed-Loop
Safety Valves	Fully Integrated	Fully Implemented	Complete QR Traceability Closed-Loop
Semi-Finished Cooker Bodies	Challan tracked	Missing on internal trolleys	Paper-reliant inspection handoffs

Table 3 and 4 highlights a comparison between movement of materials, frameworks for quality control, and digital traceability systems. While all vendors use ERP for challans but there is significant gap between QR traceability of the materials. Only around 40% components feature end-to-end QR traceability and implementation coverage. Surprisingly, the components such as lid and aluminium do not have traceability for QR codes . Quality inspection is random and does not follow any specific standards; however, execution remains predominantly paper-bound. Lack of tagging on the trolleys on shop-floor creates significant chaos and dependence on the person supervising it causing lack of traceability and identification of material after , before metal finishing, material in WIP and what needs to go for assembly.

TABLE V.
MULTI-CRITERIA PROCESS BOTTLENECK AND ROOT-CAUSE DIAGNOSTIC ANALYSIS PART-1

Manufacturing Node / Process Stage	Root Cause Analysis		
	Primary Operational Bottleneck Root Cause (5-Why / Ishikawa Finding)Observed Delay / Metric	***Primary Operational Bottleneck Root Cause (5-Why / Ishikawa Finding)Observed Delay / Metric***	***Primary Operational BottleneckRoot Cause (5-Why / Ishikawa Finding)Observed Delay / Metric***
Raw Material Receiving & Unloading	Prolonged truck dwell time and receiving bay congestion	Single forklift dependency; absence of designated unloading berths; driver break overlap	45–90 min vehicle waiting during peak hours
In-House Press Shop Forming	Line stagnation; staging clutter near trimming and laser cutting	Suboptimal layout; lack of buffer management; untagged intermediate transport trolleys	15–30 min batch transit and staging latency
First-Off Quality Approval	Press lines idling awaiting setup buy-off	Quality inspector unavailable on-floor; paper-based notification procedures	20–40 min setup idle time per tooling changeover
Subcontract Dispatch & Staging	Staging aisle congestion; dispatch delays at internal transfer	Ambiguous physical loading areas (2–25 m variation); 4-copy hardcopy challan sign-offs	30–60 min gate departure latency
External Vendor Processing	Extended dwell times; multi-day processing queues	Lack of visibility into external buffer stock; geographic dispersion up to 1,300 km	1–3 days dwell time per subcontract hop
Incoming Subcontract Inspection	Staged body backlog at receiving inspection bay	Manual data entry into logbooks; irregular application of IS 2500 sampling tables	2–4 hours lot clearance queue time
Final Packaging & Dispatch Exit	Aisle blockages; carton deterioration;	Space constraints; moisture-susceptible cardboard	10–20 min dispatch verification delay per shipment

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Manufacturing Node / Process Stage	Root Cause Analysis		
	Primary Operational Bottleneck Root Cause (5-Why / Ishikawa Finding)Observed Delay / Metric	***Primary Operational Bottleneck Root Cause (5-Why / Ishikawa Finding)Observed Delay / Metric***	***Primary Operational BottleneckRoot Cause (5-Why / Ishikawa Finding)Observed Delay / Metric***
	redundant labeling	cartons; duplicated QR reprint cycles	

TABLE VI.
MULTI-CRITERIA PROCESS BOTTLENECK AND ROOT-CAUSE DIAGNOSTIC ANALYSIS PART-2

Manufacturing Node / Process Stage	Root Cause Analysis	
Raw Material Receiving & Unloading	Inbound transit scuffs, denting from manual offloading	High Operational Bottleneck
In-House Press Shop Forming	Dominates scrap: 4–5% line rejection (wrinkles, draw cracks)	Critical Quality & Flow Bottleneck
First-Off Quality Approval	Line idling rather than defects; loss of productive machine hours	High Availability Loss
Subcontract Dispatch & Staging	Handling scratches, corner denting during manual truck loading	High Logistics Overhead
External Vendor Processing	1–2% vendor return rejection (buffing burns, uneven anodizing)	Critical Lead Time Inflator
Incoming Subcontract Inspection	Risk of defective lots entering assembly undetected	High Quality Assurance Bottleneck
Final Packaging & Dispatch Exit	Carton compression damage; duplicate scanning errors at warehouse	Medium Operational Overhead

Table 5 & 6 identifies bottlenecks within the plant at operational, mechanical, and informational points. Operational data reveals that the main operational bottlenecks are due to material handing issues and administrative obstacles and not because of limits placed on the machines' primary cycle times. The raw material handling and internal transportation points have suffered immensely due to limited capacity for forklifts and poor planning in transit pathways, leading to vehicle idle times of as high as 90 minutes. In terms of quality, the Press Shop constitutes the main hub of defects, responsible for 4-5% of the cumulative rejection rate of 7-8% for the whole plant, due to metal deformation defects like wrinkles, breaking of metal when forming and tearing of metal edges. Subcontractor activities lead to major inflations in lead times, due to dwell times for materials of up to three days alongside paper-based incoming inspections.

Recommend Feasible Lean and Digital Improvement Initiatives

TABLE VII.
ACTIONABLE LEAN INTERVENTIONS, DIGITAL ARCHITECTURE, AND PROJECTED BUSINESS IMPACT- I

Targeted Operational Bottleneck	Actionable Lean Interventions, Digital Architecture, and Projected Business Impact		
	Lean & TIMWOODS Classification	***Proposed Automation / Digital Solution***	***Practical Implementation Roadmap*** M
4-copy hardcopy delivery challan sign-off	Over-Processing	Digital Invoice & E-Sign Workflow	QR-coded digital challan, gate scan, mobile e-sign, ERP integration
Machine idle time awaiting setup buy-off	Waiting / Motion	Digital First-Off Andon Alert System	Operator triggers "Setup Ready", QC receives instant alert, tablet sign-off
Unloading delays and vehicle congestion	Waiting / Transportation	Digital Vehicle Queue & Dynamic Bay System	Pre-arrival QR booking, automated token call, dedicated docking bay
Recurring shop-floor aisle clutter	Motion / Delay	Digital 5S Mobile Audit Framework	QR tags per zone, weekly mobile audits with photo verification, auto-scoring
Single-operator dependency during breaks	Waiting	Digital Roster & Shift Relief Notification	ERP shift roster, automated notification of relief operators during breaks
Single-forklift handling dependency	Waiting / Transportation	Telematics Forklift Utilization Tracking	IoT hour-meters and tracking to audit actual uptime before approving capital assets
Unexpected forklift maintenanc	Waiting / Equipment Loss	QR-Based Preventive Maintenance (TPM)	QR tag on assets, operator daily pre-shift

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Targeted Operational Bottleneck	Actionable Lean Interventions, Digital Architecture, and Projected Business Impact		
	Lean & TIMWOODS Classification	***Proposed Automation / Digital Solution***	***Practical Implementation Roadmap***
e breakdowns			mobile checks, predictive alerts
Heavy manual exertion moving trolleys	Motion / Transportation	Powered Electric Tug / Motorized Trolleys	Deploy electric tugs on high-frequency transit routes (Press Shop, Assembly)
Rework stock mixed with prime inventory	Inventory / Defects	QR-Coded Dynamic Rework Quarantine	Red-tagged QR lots, software-locked ERP status, dedicated physical cage
Untracked internal material carts	Inventory / Motion	Smart QR-Enabled Trolley Tracking	Laser-etched QR tags per cart, milestone tracking (Bay, Subcontract, Line)
Manual e-way bill generation overhead	Over-Processing / Redundancy	Automated ERP-to-E-Way Bill API Bridge	Direct API bridge pushing ERP sales orders to the government e-way portal
Disorganized packing material staging	Storage / Motion	Visual Digital Packaging Supermarket	Fixed barcode-racked locations, automated min/max replenishment alerts
Carton moisture damage during transit	Inventory / Quality Cost	Returnable Smart Plastic Crates	Heavy-duty foldable plastic totes with RFID/QR, vendor closed-loop return
Aisle congestion near laser oval cutting	Delay / Motion	Designated FIFO Paint-Marked Lanes	Color-coded floor bays and physical roller racks ensuring strict FIFO discipline
Inability to track real-time cooker WIP	Inventory / Tracking Waste	Digital Multi-Stage WIP Milestone Scan	Tablet milestone scanning at Press, Buffing, Anodizing, and Final Assembly
Repeated duplicate QR label printing	Over-Processing	Duplicate Print Prevention Interlock	Print-server validation preventing re-printing without supervisory override
Inconsistent AQL sampling enforcement	Defects / Quality Governance	Digital IS 2500 AQL Quality Portal	Mandatory digital check sheet logging 13 inspection points before ERP release

The roadmap of comprehensive improvement in a low capital expenditure manner has been mapped out in Table 7 in context to the operational landscape of ABC Cookers Limited. The initiatives proposed have helped address directly the problem of 17 wastage areas in the shop floor through the implementation of the Lean work place design and selected applications of digital technology under the Industry 4.0 revolution. The major interventions in the form of setting up an ERP system linked with API for e-way bill creation and digital sign-off for delivery challans help eliminate over processing and reduce turnaround time at gates. In the shop floors, implementing an inspection notification via the Andon system and QR trolley tracker systems would directly help solve the waiting problem and hidden WIP respectively. Moreover, instituting a digital IS 2500 system would eliminate wastage from the 4-5% press shop and 1-2% vendors by making the parameter checking mandatory. The aggregate capital cost of which is not very significant.

V. FINDINGS, CONCLUSIONS AND SUGGESSIONS

A. Findings

During the analysis of the empirical study at ABC Cookers Limited, it became clear that there were several operational discrepancies and lean waste generators for each of the ANODISED COOKERS Aluminium, Stainless Steel, and Tri-Ply manufacturing processes. First of all, it was found that through Value Stream Mapping, value generation occurs in only three key areas - press shop forming, subcontracted surface finishing, and assembly; however, the support processes add a lot of non-value added overhead. Secondly, it was discovered that the Tri-Ply stream suffers from an extremely vulnerable

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transportation waste because of the total dependence on distant geographically dispersed third-party forming vendors operating up to 1,300 km away with multiday dwell times, unlike other ANODISED COOKERS (10–14 seconds) and Stainless Steel lines. Thirdly, in the case of all three manufacturing processes, the lack of efficiency caused by logistical issues is quite obvious, since the process of passing a challan takes place with the help of four separate copies and because of excessive waiting time (45–90 minutes) caused by using a single forklift during unloading. Finally, the company's pressing process is the leading cause of rejections in the plant (7-8% cumulative rate), producing 4-5% scrap of fractured or wrinkled product. Moreover, it suffers from first-off inspection delays, as well as from the lack of IS 2500 Part 1 AQL sample enforcement. An analysis of the materials traceability showed that the plant experiences digitization problems. While high-risk safety hardware (gaskets, safety valves) has QR-code coverage of 100%, raw materials and intermediate product components (such as aluminium, stainless steel, and lid circles) have no Goods Receipt (GRR) process based on QR codes at all.

B. Conclusions

The comparative Value Stream Mapping study of ABC Cookers Limited reveals that despite individual high efficiencies of the forming/assembly process, the main factors restricting its efficiency relate to logistics hand-offs, administration lags, and traceability issues. As the analysis revealed, the main bottlenecks limiting production efficiency relate to structural wastes not directly associated with lack of machine capacity – namely, excessive transportation efforts, time-consuming waiting related to forklifts operations, and laborious challan deliveries. There was a specific strategic contradiction revealed between various lines, as ANODISED COOKERS and Stainless Steel lines use efficient in-house press but have to go through multiple transportation loops during finishing operations. At the same time, the outsourced forming operation on the part of the Tri-Ply line results in significant lead-time associated with transportation efforts. At the same time, presence of significant amounts of defects (up to 4-5 % of scrap) in the press shop and lack of Goods Receipt with QR code for bulk metals require introducing effective quality governance mechanism. With systematic introduction of capital-efficient lean techniques, such as electronic first-off Andon, standard IS 2500 sampling, smart QR tracking of trolleys and integration of ERP billing system.

C. Suggestions

A roadmap for the success of the initiatives in achieving tangible benefits should consider the following key aspects for all stakeholders:

Management and IT – move away from paper four copies challenge process into an automatic digital signature ERP and e-Waybill process that will lead to minimizing administration cost and fast truck turnover time at the gate.

Plant logistics and floor workers: Introduce a digital vehicle docking schedule in order to avoid single forklift waiting times and introduce electric tugs in the main transport corridors in order to reduce the effort, use of plastic weather resistant returnable trolleys to ensure FIFO lane.

Quality assurance and operators: Introduce mobile-enabled andon and electronic inspection system (IS 2500).

Suppliers and subcontractors: Expand the use of QR code traceability to bulk metal circles and intermediate trolleys and plastic weather resistant returnable trolleys in order to close loop of inventory control and minimize transit damage and smooth material handing.

D. Implications of the study

The findings of the research bring important and tangible implications and benefit for all key primary stakeholder groups:

Executive management and shareholders – minimizing the intermediate redundancy of work, reducing buffer inventory, and eliminating 7-8% of the scrap brings benefits of minimizing working capital, increasing productivity and saving operating margins.

Shop-floor operators and shop-floor supervisors – moving from manual transportation by trolleys to using motorized tugs as well as introducing visual 5S control systems increases ergonomics and minimizes physical stress in the workplace. Andon in real time gives ability to make tooling buy off and eliminates the friction of stopping the line.

Quality assurance and compliance teams: Making IS 2500 AQL check sheet electronic and extending QR traceability to raw circles leads to uniform quality criteria for sampling, fast containment of defects and full traceability of batches.

Suppliers, subcontractors, and transporters – introducing automatic E-Way billing, digitization of challan, and appointment based dock will significantly reduce waiting times of vehicles at plant gate bringing benefits of quick payment, minimized.

E. Future Scope of the study

The outcomes of this research and its base VSM results point to several possibilities for future work on the topic:
Dynamic Modeling: Future studies can implement a discrete event simulation (such as in AnyLogic/Arena) of machine balance, line balancing, and buffer sizes in response to fluctuating demand in advance of reconfiguring the actual physical floorplan.
Industry 4.0 & Automatic Traceability: Future research can look into the operational transition from QR code-based traceability to RFID or Internet-of-Things based smart sensors on the trolley system to enable automatic, touchless, real-time WIP tracking and cycle time monitoring at the machine level.
Supply Chain Optimization: The logistics of the supply chain can be optimized in a dedicated TCO-oriented study to compare the cost implications of the current outsourcing of tri-ply pressing to the option of localizing vendor sites near the main factory site.
Green & Ergonomic Lean: Future studies implementing Sus-VSM (Sustainable Value Stream Mapping) can study the energy footprint of the process of forming, the risk indices (RULA/REBA) of manually moving the trolleys, and the life-cycle effects of plastic crate vs cardboard box substitution.

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