



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

Lean Six Sigma

The seven wastes of lean

Programme: Mechanical Engineering
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Lecturer: Andrew Thorn

Student ID Number: 2513503
Student Name: Venkata Sairam Adigarla

Abstract

This report examines the presence and measurement of lean waste in three different sectors: baked bean food manufacturing, paper aeroplane production, and residential house extension construction.

Statistical Process Control (SPC), Total Productive Maintenance (TPM), Single-Minute Exchange of Dies (SMED), Last Planner System (LPS), Just-in-Time (JIT) delivery, Kanban systems, and 5S workplace organization are some of the specific improvement strategies that the study recommends. It also evaluates the financial and time-related impacts of waste. According to quantitative analysis, depending on the industry, waste could result in a productivity loss of 15% to 60%. Financial modelling suggests that there can be a quick return on investment when lean interventions are effectively implemented.

The findings indicate that lean principles can be applied across manufacturing, project-based construction, and small-scale manual production environments, supporting contemporary research that views lean as a universal management philosophy rather than as an industry-specific toolset (Bhamu and Sangwan, 2014; Netland, 2016).

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1.Introduction

A systematic approach called lean manufacturing seeks to identify and eliminate processes in production systems that do not contribute value (Womack and Jones, 1996). Overproduction, waiting, transportation, over-processing, inventory, motion, and defects are the seven categories of waste identified by this framework (Ohno, 1988). Although lean manufacturing was first developed in the automotive sector, its concepts are currently being used more extensively in every industry, where cost control, efficiency, and food safety are crucial (Dora et al., 2013).

The seven wastes, commonly summarised using the TIMWOOD acronym, provide a practical framework for operational analysis. These wastes are:

- Transportation
- Inventory
- Motion
- Waiting
- Overproduction
- Overprocessing
- Defects

Although lean was first applied in the automotive industry, its concepts have since spread to a number of other industries, such as food processing, healthcare, construction, and services. According to recent research, lean is both a technical framework and a socio-cultural change that calls for leadership dedication and continuous development.

This report analyzes three different operational settings:

Baked bean production – a high-volume, continuous food manufacturing process.

Residential house extension construction – a project-based, multi-trade construction environment.

Paper aeroplane production – a small-scale, discrete, manually operated system utilized for lean simulation.

These sectors include process manufacturing, batch production, and project-based construction. Although they have different structures, each sector shows measurable forms of waste that are relevant to lean theory. By analyzing the current state, measuring inefficiencies, and assessing specific improvements, this report illustrates the broad applicability of lean tools, including SPC, TPM, SMED, the Last Planner System, Kanban, and 5S.

The study also incorporates a financial assessment to support investment in improvements and addresses potential implementation challenges such as cultural resistance, regulatory issues (especially concerning food safety), and fragmentation among subcontractors in construction. The goal is to evaluate how lean methodologies can minimize operational waste and enhance productivity across various industrial settings.

2. Establishing the Current Situation on Baked bean production:

Baked bean production consists of several sequential processes, such as soaking, cooking, sauce preparation, filling, sterilization, and packaging. Due to the continuous and high-volume nature of the production, inefficiencies can lead to considerable financial losses. Identification of Waste

2.1 Overview of the Production Process

Production of baked beans involved the following procedures

1. Raw materials such as dry beans, tomato, cans.
2. Soaking and blanching
3. Preparing the sauce
4. Filling and sealing
5. Retort sterilization
6. Labelling and packaging
7. Storage and distribution

2.2 Identification of the Seven Wastes

1. Overproduction Production that surpasses customer demand as a result of inaccurate forecasts and batch scheduling.
2. Waiting Downtime of machines during changeovers and delays while waiting for quality inspection approval.
3. Transport Unnecessary movement of pallets between raw material storage and production areas due to an ineffective layout.
4. Over-processing Sterilisation times that exceed validated requirements in an attempt to ensure safety margins.
5. Inventory High safety stocks of dry beans (45 days) and an excess of finished goods in storage.
6. Movement Operators traveling larger distances to get equipment's, supplies, and records.
7. defects problems that take rework or disposal, for example underweight cans, dented cans, seam failures, and microbial spoilage.

2.3 Quantification of Waste

Waste measurement establishes a financial case for improvements and aids in assessing the degree of inefficiency. Monthly Waste Estimates Financial Impact, For the purpose of evaluation, let us assume the following values as an example to analyze the current industrial waste: The amount of capital tied up by surplus stock (120 tonnes × £600/tonne) is £72,000. An estimated lost due to defects each month is £25,000. An estimated spent on downtime per each month is £15,000. An estimated Potential inefficiency per month: over £110,000.

2.4 Improvement Proposals

Improvement proposals on Two waste categories. They are

1. Defects
2. Waiting

Defects Reduction

Current defect rate: 2.5% (industry benchmark <1%).

Improvement 1: Statistical Process Control (SPC). Control charts monitor line integrity and fill weight in real time. Expected outcomes include: a reduction in unpredictability, and early detection of process drift. The implementation of SPC significantly reduces defect rates in the food manufacturing sector (Dora et al., 2013).

Improvement 2: Maintaining Total Productivity (TPM)

This involves the implementation of maintenance conducted by operators and scheduled preventive inspections (Nakajima, 1988).

Expected outcomes:

- Decreased machine breakdowns.
- Enhanced sealing consistency.
- 40% reduction in unplanned downtime.

Waiting Reduction

Current downtime: 18 hours per month.

Improvement 1: Line Balancing

Conducting a time-study analysis to optimize the soaking, cooking, and filling rates.

Expected outcome:

- 5% increase in throughput.

- reduced bottleneck formation.

Improvement 2: Single-Minute Exchange of Dies, or SMED

putting into practice an organized plan to shorten transition periods (Shingo, 1985).

Expected outcome:

- 50% reduction in changeover time.
- Enhanced production flexibility.

2.5 Cost Evaluation

2.5.1 Investment Requirements

Investment Requirements Initiative Cost (£) SPC system & training 15,000 TPM implementation 10,000 Line balancing consultancy 8,000 SMED training 12,000 Total Investment 45,000

2.5.2 Monetary Gains Estimated

savings per year: Savings from defect reduction: £216,000 annually Reduction in downtime: £120,000 annually Reduction of inventory: £150,000 annually A sum of more than 486 thousand pounds each year adds up to the full predicted gain. Most people see results after about half a year, sometimes sooner. A few might notice changes within three months instead.

2.6 Barriers to Implementation and Mitigation

1 Opposition from Employees

Lean initiatives may be perceived by staff as requiring more oversight. Reduction staff engagement Workshops. And Kaizen events and training (Womack and Jones, 1996).

2 Risks to Food Safety

Process changes could affect HACCP validation. Mitigation testing for revalidation. And documentation updates before complete implementation.

3 Financial Limitations

It's possible that management is reluctant to make a first investment. Mitigation Give a concise ROI analysis. And use a pilot program to demonstrate.

4 Disruption of Production

Downtime may be required during implementation. Mitigation Make plans for the planned maintenance windows. And phased implementation.

3. Building an extension on a house

In small-scale residential construction projects like house extensions, inefficiencies often occur due to issues with coordination, fragmented trades, and insufficient planning. A typical single-storey domestic extension project worth around £65,000.

3.1 Establishing the Current Situation:

Identification of Waste A review of site observations, project schedules, cost reports, and interviews with contractors indicates several instances of waste:

1 Transportation

Materials are delivered to the front driveway and subsequently transported manually to the rear extension site. There is double handling of bricks and plasterboard due to insufficient storage planning.

2 Inventory

There is an excess ordering of bricks, resulting in approximately 10% surplus. Bulk material purchases are stored outdoors, leading to damage from weather exposure.

3 Motion

Tradespeople must walk to a shared tool storage area (van/temporary shed). There is frequent repositioning of ladders caused by an inadequate workstation layout.

4 Waiting

Bricklayers experience delays while waiting for foundation curing and inspection approval. Electricians face delays due to incomplete first-fix carpentry. There are also delays in obtaining building control inspections.

5 Overproduction

Concrete is ordered in excess to prevent shortages. Timber is pre-cut prior to the confirmation of final measurements.

6 Overprocessing

Dimensions are being re-checked due to a lack of confidence in previous trade work. Finishes of a higher specification than required by the client brief are being installed.

7 Defects

There is a window that has been incorrectly fitted, necessitating its removal and refitting. Plaster is cracking as a result of improper curing conditions.

These observations are consistent with lean construction theory, which indicates that construction environments typically encounter 15–30% non-value-adding activities (Koskela, 1992).

3.2 Waste Quantification

For the purpose of evaluation, let us assume the following values as an example to analyze the current industrial waste. Quantifying waste enables the project team to evaluate its financial and time-related effects. This is derived from a cost analysis of the £65,000 extension:

Table 1 waste quantification

Waste Type	Example Identified	Estimated Cost Impact	Time Impact
Transportation	Double handling	£1,300	2 days
Inventory	Damaged/unused materials	£1,800	1 day
Motion	Excess walking/tool retrieval	£900	1.5 days
Waiting	Trade sequencing delays	£3,000	6 days
Overproduction	Excess(concrete/timber)	£1,000	—
Overprocessing	Unnecessary finishing	£1,200	1 day
Defects	Rework (window/plaster)	£2,200	3 days

Total direct waste cost: approximately £11,400 (17.5% of project value)

Total delay: approximately 13.5 days

3.3.1 Minimizing Waiting

Improvement 1: Last Planner System (LPS)

implementation All trades participate in weekly planning meetings to address any limitations and guarantee task readiness. This method improves workflow dependability and decreases misunderstanding among trades, leading to less stoppage.

Improvement 2: Just-in-Time (JIT) Delivery Scheduling

Materials are delivered in smaller, phased quantities that align with program requirements. This method minimizes congestion and reduces delays related to storage.

Expected Result:

A 50% reduction in waiting waste and a program shortening of 4-5 days.

3.3.2 Reducing Defects

Improvement 1: Standardised Work and Quality Checklists

Creation of trade-specific checklists and method statements to be completed before moving on to the next phase.

Improvement 2: First-Time Quality Inspections

Conducting internal quality checks prior to the formal inspection by building control.

Expected Result:

A reduction of 60-70% in rework, leading to improved client satisfaction and fewer issues to resolve post-completion.

3.4. Cost Evaluation and Implementation Challenges

3.4.1 Cost of Improvements

Table 2 investment for improvement

Improvement	Estimated Cost
Lean planning meetings	£1,200
Basic lean training workshop	£1,500
Quality documentation/checklists	£600
Supplier coordination adjustments	£400

Investment total: approximately £3,700

3.4.2 Anticipated Savings

Waiting waste reduction: about £1,500

Defect reduction: approximately £1,400

indirect savings (reputation, fewer disputes) £2,000

Beyond the initial phase, gains could reach up to £2000- possibly more once upgrades roll out.

3.5 Possible Challenges and Handling Techniques

1 Opposition to Change

Lean methods may be perceived by traders as unnecessary bureaucracy. Management strategy involve traders in the planning process and demonstrate measurable time and cost savings.

2 Restrictions on Suppliers

JIT requirements might pose challenges for small suppliers. Management strategy enhance communication and establish framework agreements.

3 Project Scale Lean is often associated with large projects. Management strategy utilize simplified lean tools suitable for smaller-scale projects.

4 Cultural Difficulties

Collaboration can be affected by fragmented relationships among subcontractors. Management strategy encourage early contractor involvement and implement shared performance metrics.

4. Paper aeroplane production

The paper aeroplane production process comprises the following stages: -

Paper issuing

Folding (initial shape)

Wing formation

Quality inspection

Packaging

4.1 Observation of the process identifies the following occurrences of waste:

1 Overproduction

Operators produce aeroplanes in batches of 20, irrespective of immediate customer demand, which averages 12 units per cycle. This leads to an accumulation of excess units before packaging.

2 Waiting

Folding operators often experience delays due to inconsistent paper supply. Quality inspection also creates a bottleneck, resulting in downstream delays.

3 Transport

Finished planes are transferred between tables multiple times because of an ineffective workstation layout, resulting in unnecessary handling.

4 Overprocessing

Some operators extend production time without adding value by adding decorative folds that are not required by the customer.

5 Inventory

Between the folding and inspection stages, there is an accumulation of work-in-progress (WIP) due to the large stacks of paper (roughly 500 sheets) in each workstation.

6 Motion

Disorganized tools often require operators to stand, reach, and look for rulers or templates.

7 defects

Due to improper folding angles, about 10% of aircraft fail flight tests, requiring rework or disposal.

These findings support lean theory by showing the presence of all seven categories of waste (Womack and Jones, 1996).

4.2 Measurement of Identified Wastes

For the purpose of evaluation, let us assume the following values as an example to analyze the current industrial waste. Measurement allows for the prioritization of improvement initiatives (Liker, 2004).

Table 3 production timing

Waste Type	Observed Data	Estimated Impact
Overproduction	8 excess planes per batch of 20	40% surplus production
Waiting	Avg. 3 minutes idle per 15-minute cycle	20% lost time
Transport	4 additional moves per unit	1-minute extra handling per plane
Overprocessing	30 seconds extra folding	10% increased cycle time
Inventory	500 sheets per station vs. 100 needed	400% excess stock
Motion	15 unnecessary movements per unit	45 seconds lost per plane
Defects	10% failure rate	Rework cost equivalent to 6 minutes per defective unit

The total production time rises to roughly 7-8 minutes per unit due to combined waste if the typical cycle time per aircraft is 5 minutes. This suggests a 40–60% reduction in productivity.

In terms of money, with an hourly labour cost of £12:

Waiting three minutes is equivalent to £0.60 per cycle.

A 10% defect rate means that each defective unit costs an extra £1.20 and requires six minutes of rework.

When eight units are overproduced in a batch, eight sheets of material are wasted, costing £0.05 each, for a total of £0.40 per batch.

Even though these numbers might not seem significant on their own, they represent inefficiencies similar to those in larger manufacturing systems (Ohno, 1988).

4.3 Improvement Proposals

Two areas of improvement have been identified from each of two practical lean exercises: process flow improvement and workplace organization.

4.3.1 Improvement 1: Process Flow Improvement

(a) Reduce Overproduction via Pull System

Implement a Kanban card system to align production with customer demand (12 units per cycle). Operators will produce only when a request card is issued.

Expected Outcome:

- Eliminate 40% overproduction
- Reduce inventory build-up
- Lower material waste

(b) Balance Workstations to Reduce Waiting

Reassign inspection tasks or cross-train operators to allow for simultaneous inspection during folding.

Expected Outcome:

- Reduce idle time from 3 minutes to under 1 minute
- Improve throughput by 15–20%

4.3.2 Improvement 2: Workplace Organization (5S).

Lean systems frequently employ the 5S methodology such as Sort, Set in Order, Shine, Standardize, Sustain.

(a) Cut Down on Motion Waste

Standardize tool placement, assign workstation layouts, and arrange tools within arm's reach.

Expected Outcome:

- Cut down on motion waste per unit by 45 seconds.
- Boost morale and ergonomics.

(b) Standardization Reduces Defects.

To keep wing angles constant, implement standard folding templates and visual aids.

Expected Outcome:

- Reduce the defect rate from 10% to 3%.
- Cut down on material waste and rework time.

4.4 Cost Evaluation and Implementation Challenges

4.4.1 Cost of Improvements

Table 4 investment for improvement

Improvement	Estimated Cost	Nature of Cost
Kanban cards	£10 (printing/materials)	One-time
Cross-training	£100 (training time)	Short-term labour
5S implementation	£50 (labels, layout marking)	One-time
Folding templates	£30 (materials)	One-time

Total estimated cost: £190.

Savings:

- Reduced labour waste: approximately £2 per cycle
- Reduced defects: approximately £1 for each defective unit avoided
- Reduced material waste: £0.40 per batch

If 50 batches are produced monthly, savings may exceed £150 per month, resulting in payback within two months.

4.4.2 Possible Challenges

(a) Opposition to Change Because of ingrained habits, operators might be hesitant to embrace new practices. According to Womack and Jones (1996), adopting lean practices requires a cultural shift. Reduction engage operators in conversations regarding enhancements and provide quantifiable advantages

(b) Time Restrictions for Training Productivity may temporarily decline as a result of cross-training. Reduction plan your training sessions in a phased fashion. And conduct training when demand is low.

(c) Concerns about Sustainability 5S standards may deteriorate over time if they are not regularly monitored. Reduction assign responsibilities to particular roles. And conduct audits every week.

4.5 Overall Evaluation

Even simple processes involve significant waste, as demonstrated by the application of lean principles to the manufacturing of paper airplanes. Inefficiencies can increase cycle time by up to 60%, according to quantitative analysis. Standardizing folding processes, adopting the 5S methodology, balancing workloads, and putting in place a pull system all greatly increase production efficiency at a minimal cost. A rapid financial return and operational improvements are suggested by the cost-benefit analysis. However, long-

term success depends on cultural dedication and continuous observation, which is consistent with the Toyota Production System's (TPS) core kaizen philosophy of continuous improvement.

Conclusion

This report expresses how the seven wastes of lean (TIMWOOD) are present in a variety of industries, such as the production of paper airplanes, baked beans, and house extensions. These industries face similar problems, including waiting times, defects, excess inventory, needless movement, and overproduction, despite having different operational strategies.

Defects, downtime, and excess stock were major wastes in the production of baked beans, which led to significant monthly financial losses. Inadequate trade coordination resulted in delays, rework, and higher material costs in house extension projects. Overproduction, waiting, and defects led to longer cycle times and lower productivity in the manufacturing of paper airplanes. When taken as a whole, these wastes led to significant time and financial inefficiencies.

Lean tools can effectively reduce waste, as evidenced by the suggested improvements, which include better maintenance, standardized procedures, better scheduling, pull systems, and workplace organization. When weighed against the possible savings, the financial analysis shows that the implementation costs of these improvements are comparatively low. In numerous instances, the investment can be get back in a brief timeframe.

Lean concepts are applicable for a wide range of industries. However, continuous monitoring, careful planning, and employee engagement are necessary for long-term success. Organizations can increase productivity, reduce expenses, and give customers more value by focusing on waste elimination and incremental process improvement.

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