A study into the use and proliferation of Lean Six-Sigma principles in the food industry.

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Signed_____Paul Mc Elroy________________Date: ___16/11/2022_______

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2 Abstract

Ever since the time when the hunter-gatherers began to abandon their nomadic ways and embrace agriculture, the organised production, processing and storage of food has been one of humankind's most important endeavours. Those who remained static to till the land, and keep animals for food, began a process that remained largely unchanged until the 18th century. At this stage, the large-scale production and processing of food became a necessity in the then-developing world, to feed the populations who had migrated from the land to operate the new processes brought about by industrialisation.

In this manner, food production and food processing also became industrialised. While continuous improvement (CI) methods began to creep into the non-food sector of industry around the commencement of the 20th century, it was much slower to take off in the food industry.

Since the onset of the 21st century, the CI concepts of Lean and Six Sigma have taken more of a foothold, Lean more-so than Six Sigma. These sets of tools, which endorse the benefits of reducing waste at all stages of processing, can currently be witnessed playing catch-up across the industry, and are gaining ground. CI is not, however, as universally applicable to the food industry as to other sectors, due to the unique set of quality requirements in food production, where food safety, food hygiene and security of supply are more highly prized than are absolute-precision factors, such as perfect product size, shape or weight.

3 List of Abbreviations

Abbreviation	Meaning
CI	Continuous Improvement.
CTQ	Critical-to-quality.
DMADV	Define, Measure, Analyse, Design, Verify.
DMAIC	Define, Measure, Analyse, Improve, Control.
FMEA	Failure Mode & Effect Analysis.
JIT	Just in Time.
NPD	New Product Development.
OAC	Operator Asset Care.
PDCA	Plan-Do-Check-Act.
RCA	Root Cause Analysis.
SIPOC	Supplier, Input, Process, Output, Customer.
SMED	Single Minute Exchange of Die.
SOP	Standard Operating Procedure.
SPC	Statistical Process Control.
TPM	Total Productive Maintenance.
TPS	Toyota Production System.
VM	Visual Management.
VOC	Voice of the Customer.
VSM	Value Stream Mapping.

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8 Glossary of Terms

Term	Meaning
5S	A principal tool of Lean - a clean clutter-free work environment.
Andon	A sign, light, or signal used to flag the presence of a problem.
Cause and Effect Diagram	See Fishbone Diagram.
Checklist	A listing of the correct method and order of tasks, checked off as completed.
Continuous Improvement	An ongoing strive for perfection.
Fishbone Diagram	A tool used in Root Cause Analysis.
Gemba	Japanese for 'real place', denotes the location of activity.
Genchi Genbutsu	Japanese for 'go and see'; suggests that the appropriate place to view an issue is where it occurs.
Heijunka	Production levelling.
Ishikawa Diagram	See Fishbone Diagram.
Jidoka	"Autonomation" - automation with a human touch.
Kaizen	Continuous improvement.
Kanban	A signal indicating that product or parts are required - a key component of Just-In-Time.
Lean	A set of tools used for continuous improvement.
Lean Six Sigma	A set of tools used for continuous improvement.
Muda	A general term for non-value-added activity.
Mura	Unevenness, where workload is unevenly spread against available time, or other available resources such as machinery or operators.
Muri	Overburden, where too great a workload is applied to available resources.
Overall Equipment Effectiveness	A metric for establishing what proportion of the time a device is producing saleable items.

Pareto Analysis	Separating the 'significant few' issues from the 'trivial many'.
Poka-yoke	Mistake-proofing.
Pull production	Producing or processing an item only when the demand is present.
Right-first-time	Endeavouring to eliminate scrap and rework.
Root cause analysis	Examining a problem until the actual cause is found.
Six Sigma	A set of tools used for continuous improvement.
SMED - Single Minute Exchange of Die	A system of improving on machine tool change-over downtime.
Takt time	Production rate to meet customer demand.
Toyota Production System	The fore-runner of Lean.

INTRODUCTION

9 Introduction

9.1 Reason for conducting this work

The author has chosen to conduct this work for the following reasons:

The author first became aware of the concepts of Lean and of Six Sigma while studying engineering at level 8, graduating in 2011. This was followed by the completion of the Level 6 Green Belt certificate in Lean Six Sigma, (LSS), by way of distance-learning, across the academic year 2014-2015, while working in the manufacturing industry. It became apparent that many facets of LSS were directly applicable to the manufacturing processes of the company's products, even though it was not the author's experience that management buy-in to the concept was all it might be. The business manufactured plastic containment vessels to food-grade standard – their largest customer bases were food producers and the pharmaceutical sector.

As part of the Lean Six Sigma course, participants were required to carry out a course project, preferably workplace based. In this instance, the author conducted a project based around 'single minute exchange of die' (SMED) and the reduction of machine downtime due to tool-changes. The project was conducted on one polymer extrusion blow-moulding machine (PEBMM) only, at the request of management. It proved to be a practical and financial success. However, principles formed at that time have not since been – to the author's knowledge at least – rolled out to the remaining 14 PEBMMs in the intervening years. The author can only conclude that management buy-in to the concept has yet to take hold.

Upon 're-migrating' to the food industry, the author felt that LSS principles did not seem as widely adhered to in this industry as they might be in industrial manufacturing. Across all sectors, it would appear to be something of a challenge to entice management, staff and shareholders to buy-in to sustained waste-reduction drives, unless a top-down LSS environment were instigated in a business.

The author's experience in the current workplace is that certain aspects of LSS have been established historically, and some have proven beneficial, but have not necessarily been re-visited, adjusted, tweaked, or updated – in short, the 'improvement' factors could hardly be described as 'continuous.'

The author's current employer, a well-known food producer, claims, in official company web-based material, to have a healthy ongoing Lean drive in-situ – this may be the case in other company sites, but the author has seen little evidence of continuity of improvement, other than a passing nod toward 5S and Root Cause Analysis.

9.2 Overview of Lean Six Sigma.

This work aims to examine the concept of Continuous Improvement (CI), which has, for many years, played a significant role in defining the difference between competitiveness and non-competitiveness in the manufacturing industries. It is envisioned that the study will examine whether this production mentality is as appropriate to the food industry as to other sectors such as engineering manufacturing, where the model originated.

The notion of CI first came to prominence in the Toyota Production System, (TPS) whereby the management of Toyota motors in Japan, who had studied the production processes at Ford motors in the USA, and decided that, if they were going to compete globally, they would have to do things differently to the way manufacturing had been traditionally executed.

At that time, Ford had initiated numerous innovative measures in manufacturing, and were considered state-of-the-art. They had taken Eli Whitney's Mass Production model and applied it across all their plants, using production-line technology to improve production efficiency and reduce costs.

When a Japanese manufacturer of automatic textile-weaving looms visited Ford in the early 20th century, he came away with some ideas for improving on Ford's processes. Sakichi Toyoda returned to Japan, and, over the course of the next half-century, his business had expanded to become the singular world leader in car manufacture and sales.

Toyota's TPS CI initiative, later to be called 'The Toyota Way' and eventually 'Lean', became the global innovation standard in CI – it aimed to reduce production costs via the elimination of waste.

Later in the century, Motorola, an American communications-device manufacturer, introduced the CI idea of Six Sigma, a way of working which aimed to reduce manufacturing costs by the reduction and elimination of variation. Bill Smith, a plant engineer devised a method aimed at reducing the number of defective items made during a production run, and hence, similarly to the *raison d'être* of Lean, to make savings on the cost of production of every saleable unit.

During the 1980s, these two major CI concepts became combined into Lean–Six Sigma, with businesses being able to pick a synergistic combination of the best and most effective aspects of both.

9.3 A brief history of Lean

Lean manufacturing, lean production and lean thinking are all term that have come into common parlance in industry in the last 20 years or so. They refer to a more efficient method of manufacturing, although, their principles have found their way into use in commercial, office, services, and even healthcare environments. However, the concept may not be as new and cutting-edge as may appear at first sight.

Traditionally, artisan crafts people made all parts themselves, and parts varied from craftsperson to craftsperson, from job to job, and even from part to part. Part-interchangeability was not a factor. There were several reasons for this; large-scale manufacturing was still a future concept, and also, no craftsperson wanted another cutting in on their work, therefore they kept parts-making sizes and methods as trade secrets. In the 1450's however, the Arsenal at Venice, in the north of modern-day Italy, under the direction of Galileo, shipbuilders started using standardised parts and production processes, and eventually achieved a point where a galley-ship could move through the entire assembly process in one hour.

Henry Ford employed similar standardisation of parts and assembly processes when his Ford Motor Company commenced assembling vehicles at their plant in Michigan, USA in 1910. He is largely credited, in the modern era, with initiating mass-production, with the use of a moving assembly line, and his ability to reduce costs of production meant that cars became much more affordable, and hence were no longer the preserve of the super-wealthy.

During America's involvement in the second world war, Ford's Charles Sorensen helped Consolidated Aircraft improve their production rate from one B24 bomber aircraft per day to one per hour.

Sakichi Toyoda, a Japanese inventor, innovator and manufacturer of textile looms, travelled widely in Asia, Europe and the USA, including the Ford plants, observing processing methods in manufacturing plants. When he invented the Toyoda steam-powered automatic loom, he included in its design a device which stopped the loom automatically if a thread broke. This concept of 'autonomous automation' – "Jidoka" in Japanese – would become one of the main pillars of what would become Toyota Production System, and eventually Lean. He also developed the notion of '5 whys', i.e., asking 'why' a problem occurred, progressively until the root cause of the problem was established. This could be any number of times, but notionally, was set at 5.

Toyoda's son, Kiichiro, branched out into the car manufacturing business, establishing the Toyota Motor company in 1937. In post-war Japan, Toyota were producing approximately 40 finished units per day, while Ford were making about 8,000. The country was scarce of the raw materials which allowed Ford, in America, to stock large quantities of parts, and avail of the benefits of economies-of-scale. Although marginally successful, Toyota was also riven with labour disputes in 1950.

Eiji Toyoda, Managing Director of Toyota, spent from July until September of 1950 on a tour of production facilities in the US, including Ford, Chrysler, and others, taking on-board the production methods in US car-making and similar companies. Toyoda, along with Taiichi Ohno, at that time a shop-floor supervisor in Toyota, used information and ideas so acquired, as well as the inventory-handling methods of Piggly-Wiggly, an American supermarket chain, and the world's first self-service shop, and commenced work on an operating method which would become the Toyota Production System (TPS).

The TPS method of production was aimed at reducing waste in all aspects of the business, as Toyoda and Ohno concluded that any process, or activity, that did not add value for the final customer constituted waste, and was therefore fair game for weeding out. The term "Lean" was used first in a master's thesis studying TPS, and popularised by Womack, Roos, and Jones in their best-selling 1990 book on the subject, titled 'The machine that changed the world.'

TPS/Lean is based on a number of tools used to reduce, minimise or eliminate waste within and between the processes of supply chain, goods storage, manufacture, assembly, packaging and dispatch. Another description for this type of activity is

‘Continuous Improvement’ (CI), as Lean is seen as being an ongoing process rather than a one-time event.

Lean production, Lean manufacturing, Lean thinking, are various descriptions for the phenomenon commonly referred to as Lean. Whichever description is used, all are based on the elimination of clearly defined ‘wastes’, i.e., processes or otherwise in the production cycle which do not add value for the final customer. Borrowing words from the Japanese language, wastes are defined as:

- Muda – a general term for non-value-added activity.
- Mura – Unevenness, where workload is unevenly spread against available time, or other available resources such as machinery or operators.
- Muri – Overburden, where too great a workload is applied to available resources.

Originally, 7 wastes were defined by Taiichi Ohno, and are easily remembered, in the English language, by the acronym TIMWOOD:

- T: Transportation – Refers to unnecessary or excess movement of material, work-in-process, or product at any point of the production process.
- I: Inventory – excess inventory is considered a waste, as it keeps money tied up un-necessarily in raw materials, work-in process and finished goods.
- M: Motion – this refers to un-necessary movement, reaching or walking of personnel during or between production processes.
- W: Waiting – whether this refers to personnel waiting for materials, work in process, or vice versa, it constitutes a waste of opportunity, time and resources.
- O: Overproduction – Lean considers the ideal trigger for production to be that an item, part, or finished product is required ‘downstream’ by internal or external consumers. This is referred to as ‘Pull’ production.
- O: Over-processing – often, the production process is under-thought and over-complicated. The ideal method of Lean production is with the absolute minimum number of process steps to produce a saleable product.
- D: Defects – non-saleable goods or goods requiring rework add significantly to the costs of production.

The original seven 'deadly' wastes are depicted at Figure 9-1.

More recently, the acronym has been extended to TIMWOODS:

- S: Skills – refers to the underutilisation of skills or skill-sets which production operatives or others may possess over and above those necessary for the production process, or the job they are doing.

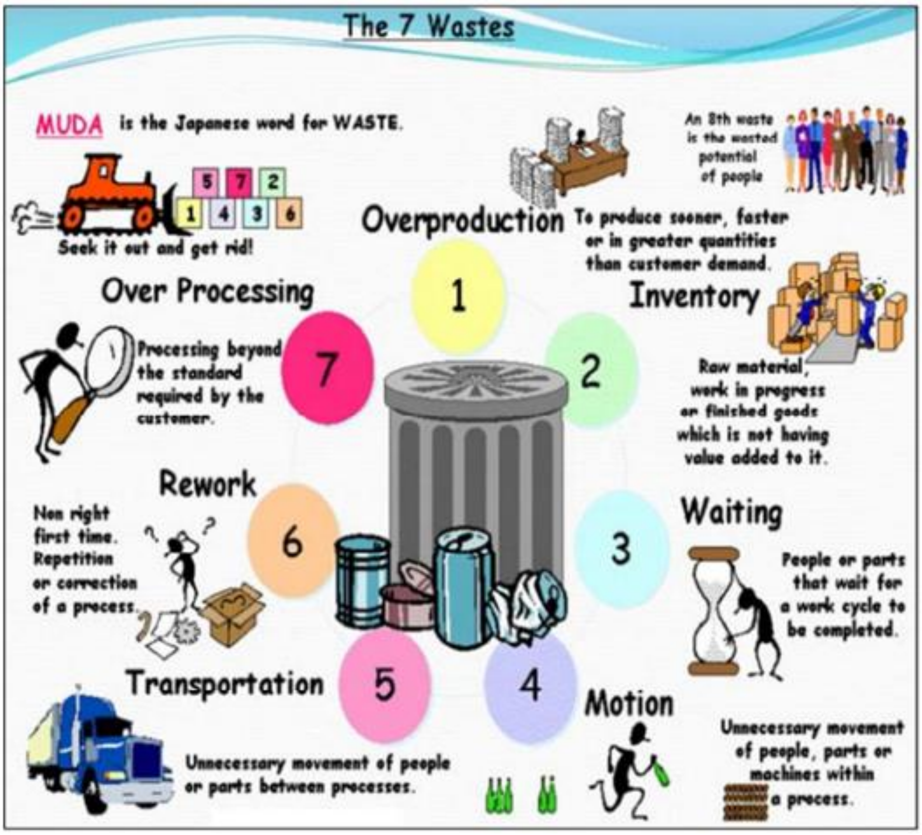

Figure 9-1 The Seven 'Deadly' Wastes

(Gbededo, et al., 2017)

9.4 Lean tools are as follows:

9.4.1 Just-in-Time (JIT)

Just-in-time is a principle first mooted as part of TPS, and introduced by Eiji Toyoda and Taiichi Ohno (hereafter referred to as Toyoda & Ohno). In order to improve efficiency and reduce the quantities of inventory held, the idea was to produce each part on a 'Pull' basis, i.e., Produce to Order (PTO) rather than Produce to Stock (PTS). This required that, in as far as possible, a part was produced just before it was required.

9.4.2 Jidoka

Jidoka – or "Autonomation" was the concept developed by the elder Toyoda, by which his automatic looms would stop in the event of a thread breakage. This meant that a machine would not continue to produce defective work, but come to a standstill and not commence work again until the situation was rectified. Jidoka is also referred to as 'Stop the line'; Toyoda and Ohno had systems in place where any employee had the power to stop the entire production process if they spotted an error.

Toyoda and Ohno considered 'Just in Time' and Jidoka to be important factors in the two main pillars of their TPS 'house', as would later become the 'Lean house' (see Figure 9.2).

Figure 9-2 The Lean 'House'

(Graphic Products Inc., 2022)

9.4.3 Takt time

Takt time is an important concept in the Lean lexicon, it may be defined as the time available to produce a product to meet customer demand. The 'customer demand' factor is all-important, as the main tenet of Lean is the provision of quality to the customer, and the elimination of anything that gets in the way of this. This is where the concept of 'Pull' production and 'Just in Time' originate. Takt time may be calculated using the formula:

$$T = Ta/D$$

Where:

T = takt time, or product assembly time to meet customer demand,

T_a = net time available for production, and

D = Customer demand

Equation 9-1 Takt time

9.4.4 Andon

Andon refers to signalling system, usually illuminated, often in the form of 'traffic lights' which indicates when a machine, process or system is running correctly, and when it is running erroneously. Andon is usually activated automatically by the machine itself, but may, in some cases, and certainly in bygone days, be activated by an operator pulling an 'andon cord.'

9.4.5 Gemba

'Gemba' is the Japanese word for 'the real place'. This, concept, in conjunction with 'Genchi Genbutsu' (go and see), refers to the greatly increased likelihood of a problem being spotted – and a solution found – by attending the location where the work is being carried out. This is also known as 'Stand in a circle', a concept devised under the TPS, where operators, management, trouble-shooters etc were encouraged to literally stand within a circle inscribed on the works floor, and observe what they saw going on around them. They would then note down what appeared to be going right, and what appeared to be going wrong. The thinking behind these concepts is that, while working policy may be set down at board-room level, those most likely to find problems are those working or observing at the coalface.

9.4.6 Genchi Genbutsu

Genchi Genbutsu, meaning 'go and see', is usually used in conjunction with 'Gemba' (Section 9.4.5 above), and suggests that the best way to identify – and solve – problems, is to observe them at first hand, and then apply root cause analysis.

9.4.7 Heijunka

Japanese term for ‘levelling’, where every effort is made to even the workload against available resources, such as time, machinery and operatives. Heijunka is the antidote to Mura (unevenness).

9.4.8 Right first time

Defects are considered one of the 7 wastes in Lean, and also in Six Sigma, (which will be addressed later). The idea of getting a product ‘right first time’ is to reduce defects to the absolute minimum. This constitutes major savings in resources and waste, as defective product can go only one of three ways:

- Disposal – a complete loss.
- Re-work – expensive, and a drain on resources.
- Sold as substandard – brings in less revenue and tarnishes the business reputation.

9.4.9 Plan-Do-Check-Act

The Plan-Do-Check-Act (PDCA) cycle was devised by American quality gurus Walter Shewhart and W Edwards Deming, and is a prerequisite for successful CI. It is effectively a method by which a proposed improvement to a process or system is trialled – if results are positive, it will be instigated – if not, it will be rejected.

Figure 9-3 PDCA cycle

(Kanbanize, 2022)

- Plan – select a proposed ‘improvement’ to be trialled.
- Do – Trial the improvement in practical terms.
- Check – check the results of the trial.
- Act – If results are positive, instigate the changes. If not, return to the drawing board – this is described as a cycle, not an event.

PDCA is quite similar to the DMAIC process (Design, Measure, Analyse, Improve, Control) promoted in Six Sigma, which will be addressed later.

9.4.10 Kaizen

‘Kaizen’ refers to the process of continuous improvement. It often follows the PDCA cycle, and can be ongoing, or in Blitz form. A Kaizen Blitz is an event, often carried out over around a week, in which brainstorming occurs around a specific area of production, in order to make as many improvements as possible. This usually commences with a 5S drive (section 9.4.13 below). All interested parties from top management to the machine operator will be invited to add their thoughts on how the process may be improved.

9.4.11 Single Minute Exchange of Die

Single Minute Exchange of Die (SMED) is something of a misnomer; one of the more time-consuming aspects of production is the change-over from the production of one product to another. This time is measured as the time elapsed between the last saleable unit of ‘Product A’ to come from the machine, and the first saleable unit of ‘Product B’ to do so. This includes the time to clean down the machine, remove the old tooling set-up, install and calibrate the new tooling setup, enter the programming for the new product if appropriate, clean down the machine again, if necessary, get the machine up and running, and get it tuned in past the attendant post-setup defects phase to producing useful product. A proportion of this work must occur while the machine is stopped. However, the more of the setup that can be don prior to stopping the machine, the less unproductive time will be clocked up. Also, the use of standard operating procedures (SOPs), jigs, checklists and poka-yoke should keep downtime to a minimum. A well-stocked stores department is invaluable in this.

9.4.12 Checklists

A checklist is a very simple but powerful tool, and can be used as an aid to conduct processes in a correct and timely manner. A list of sub-processes is written on a sheet of paper, listing the correct method and in the correct order, and these are literally ‘checked-off’ by the operator as they are completed.

9.4.13 5S

5S is a concept for keeping the workplace clean, clutter-free and clear of debris. It often heralds the beginning of a kaizen event. The five ‘Ss’ come from the Japanese words:

Seiri, Seiton, Seiso, Seiketsu and Shitsuke.

These translate, roughly, into English, as:

- Sort – Remove all items, tools etc., not required in the area.
- Straighten – Tidy up what remains, preferably with the use of shadow-boards etc, so equipment can be ‘laid hands on’ immediately, and missing items identified.
- Shine – Clean the entire area.
- Standardise – set the new standard, establish as Standard Operating Procedure (SOP).
- Sustain – Maintain the new set-up. Make the preceding ‘Ss’ the ongoing way of life.

9.4.14 Kanban

Kanban refers to a style of visual management, where flags, labels, lamps, or other physical tokens are used to denote a process being completed, component parts being required etc. An example might be where assembly personnel take parts from a tote-bin to add to the sub-assembled product. A coloured label or flag might be raised on or near the tote when it approaches empty, in order to let stores personnel know that it requires replenishing or replacing.

9.4.15 Overall Equipment Effectiveness (OEE)

OEE is an indicator of how a machine or piece of equipment is performing. Performance will be rated, either as a percentage or a rational number between zero and one, on each of three different parameters over a given timeframe:

- Availability (i.e., run time / planned production time)
- Performance (i.e., Ideal Cycle Time × Total Count) / Run Time)
- Quality (i.e., Good Count / Total Count)

OEE is calculated simply by multiplying the three factors together, and will result in either a percentage or a rational number between zero and one.

9.4.16 Poka-yoke.

This concept translates from the Japanese language as Mistake-proofing. It may refer to the condition where a sensor will stop the line in the event of an abnormality (as in Jidoka), or, in a situation where tool-changes are being performed by personnel, parts might be made in such a way that they may be fitted only in the correct orientation.

9.4.17 Root Cause Analysis

Root cause analysis comprises two different methods of identifying the root cause of a problem; either one – or both – may be used:

9.4.17.1 5 Whys.

As previously described, Sakichi Toyoda concocted this method of getting to the root cause of a problem. The question 'Why?' would be asked a number of times, until the root cause of the problem was established. Using this method, it is more likely to treat the cause of the problem rather than simply symptoms of the problem.

9.4.17.2 Ishikawa Diagram

As will be seen at Figure 9.4, similarly to 5 Whys, this instrument examines primary causes, secondary causes, and however many levels of cause are required. Additionally, it examines causes on a logical basis, looking at the problem from perspectives pertaining to what are sometimes referred to as 5Ms + 1 E. ((Man (i.e., human), Machine, Measurement, Materials, Management and Environment)).

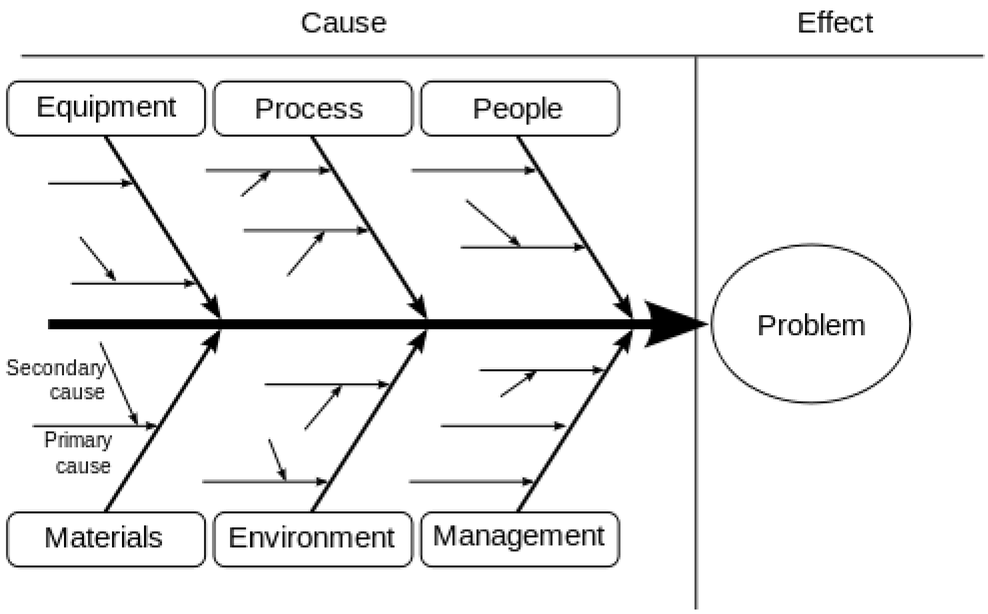

Figure 9-4 Ishikawa Diagram

(Wikipedia, 2022)

9.4.18 A brief history of Six Sigma (6σ)

In a similar way to Lean, Six Sigma was created in an industrial setting. Bill Smith of Motorola initiated the concept in 1986. However, he also was building on the work of others before him, the German mathematician and physicist Carl Friedrich Gauss had described the characteristic bell-curve of normal distribution probability in the 19th century.

Unlike Lean, Six Sigma concentrates more on statistical analysis, and aims to eliminate waste through reduction in variation. Its stated aim is to reduce, at six sigmas (sigma: σ = standard deviations from the norm) the number of possible defects to a figure at or below 3.4 defects per million opportunities for defects to occur. Variations are tracked using such statistical tools as:

9.4.18.1 DMAIC (Design, Measure, Improve, Analyse, Control)

This is quite similar in nature to the Plan-Do-Check-Act cycle routine used in Lean.

9.4.18.2 SIPOC diagrams

An examination, in pictorial form. of the route that materials take through the process:

- Supplier
- Input
- Process
- Output
- Customer.

9.4.18.3 Value Stream Mapping (VSM)

A diagram like the SIPOC, but tracing the path through the process, and noting, at all stages whether, or not, value is added. In CI, it is normal to draw a ‘Current State VSM’, which depicts, realistically how things are ‘at the moment’. This is usually followed by a brain-storming session, and a proposed ‘Future State VSM’ will be drawn up, considering all intended improvements to the setup.

9.4.18.4 FMEA (Failure Mode & Effect Analysis)

Plots the chances of a defect occurring against the potential severity of the consequences of such a defect.

9.4.18.5 Pareto Charts

Pareto charts are used to graph the significant few from the trivial many. Building on the theory by Vilfredo Pareto in the early 20th century that 80% of the land in Italy was concentrated in the hands of 20% of the population, Joseph M Juran came up with the notion of Pareto Analysis. This histogram plots, for example, the number of defects found in a given batch, by type. Typically, the most significant defect by count will number 50% - 90% of the total, with the remaining defects falling off rapidly. Clearly, in this event, finding and remedying the root cause of this particular defect, will reduce the number of defects significantly. Remedying the 4-5 most common defects will, subsequently, reduce the overall defects to almost negligible numbers.

9.4.18.6 Control charts.

A control chart plots, for example, instances of a particular aspect of production against time. Upper and Lower control limits (UCL and LCL) will be established, and a process will be deemed out-of-control (OOC) if any instance falls outside the control band between UCL and LCL. Other factors may also indicate OOC, for instance, if too many points on the graph are too distant from the line of best fit (LOBF), as established by linear regression. More than six successive points on the same side of the LOBF may also indicate a process that is OOC.

9.5 Lean-Six Sigma

Lean and Six Sigma were both 'born' in the engineering-manufacturing industries, Lean in an emerging industry – cars – and Six Sigma in the communications device industry. In Lean's original format, a Japanese company was attempting to gain competitiveness on a much larger and more competitive American business. Conversely, Six Sigma was established at an American business, as a tool to improve its competitiveness against more efficient and streamlined Japanese businesses.

The upshot is that, rather than the two systems competing against each other, a synergistic benefit is gained by merging the best aspects of both systems.

It has been said that the use of Six Sigma is, by its nature, more beneficial when applied to actual production processes, and that Lean improves efficiency at the 'spaces' between production processes.

9.6 Lean-Six Sigma and the food industry

Much available research would appear to suggest that while LSS may be deployed in the food industry, and, in many cases, has so been, it will have to jostle for position with other aspects of Quality Assurance which are deemed more crucial. These are food safety, hygiene, and adherence to food production regulations. Food quality assurance is not a new idea, Figure 9.5 depicts a quality assurance mark stamper on a surviving shard of an earthenware food container dating from the time of the Roman empire.

Figure 9-5 Food product quality stamp dating from the Roman empire.

(Domínguez, et al., 2020)

9.7 Aims & Objectives

The aims and objectives of this work were to establish whether LSS is utilised in the food industry to the same extent as other industries such as manufacturing and engineering etc. Also, if not, to ascertain how LSS might be further promoted as a concept in the food industry, from the food-processing aspect of the business.

9.8 Research Methodologies

Research for this work fell into several different categories:

- Secondary research from previously published peer-reviewed scholarly articles.
- Material in the public domain, e.g., books and websites.
- Material pertaining to the author’s past experience of conducting an LSS practical project in a workplace.
- Material garnered form the author’s current workplace.

The latter two above mentioned were used in anonymity, as the author had not applied for ethics approval due to an administrative oversight in the research proposal procedure, where approval was granted for a previously-applied research proposal, but the difference was not made known to the author until after work had commenced on this work.

9.9 Research question

This work aims to find the answer to the following question:

- Is the use of Lean Six Sigma (LSS) as prominent in the food industry as in other manufacturing industries?
- Is there scope for improving the use of LSS in the food industry?

9.10 Scope

The scope of this work was to address the questions posed at section 9.9, and no other. It aimed to examine the past state, and, in as far as possible, the current state of LSS deployment in the food industry. While speculation may occur regarding the future state of LSS in the food industry, this may not be deemed to be predictive.

LITERATURE REVIEW

10 Literature review

10.1 Lean or Six Sigma?

Lean as a concept, if not by name, has been around for considerably longer than has Six Sigma. When, upon concluding that the production process at Ford had ‘too much room for improvement’, (Mahlaha, et al., 2020) Toyoda and Ohno set about constructing the Toyota Production System (TPS) around the middle of the 20th century, several of the constituent philosophies had already been invented – or at least innovated – by Sakichi Toyoda in the early part of that century. Meanwhile, Six Sigma did not become an entity until the mid-1980s.

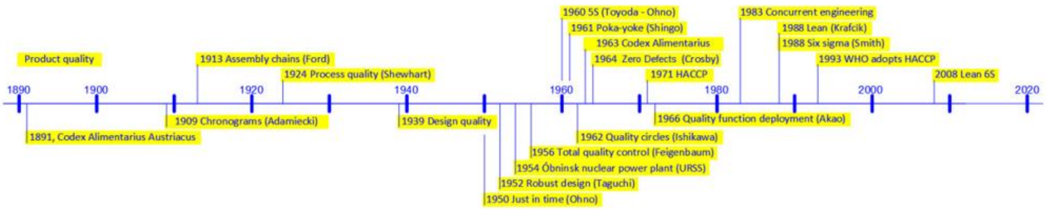

Figure 10-1 Chronology of Lean – Six Sigma

(Domínguez, et al., 2020)

It is hardly surprising therefore that, having a good chronological head start, Lean would command dominance in businesses while Six Sigma was still establishing a foothold. While researching the difference in popularity in the food industry of three different ‘iterations’ of Continuous Improvement models:

- Lean
- Six Sigma and
- Lean Six Sigma

(Costa, et al., 2018) found that, of 58 academic publications they perused, 74% pertained to Lean, 16% to Six Sigma, and only 10% to LSS. They do state, however, that Six Sigma has become more popular in recent years.

Lean manufacturing aims toward reductions in waste and product cycle-time, mostly by tackling simpler and easily remedied problems in production, while Six Sigma utilises more complex statistical analysis tools to help iron out variability in production. (Palange & Dhatrak, 2021).

This is borne out by reference to the ‘low hanging fruit’ issues tackled by Lean (Idrissi & Benazzouz, 2019), where Pareto Analysis (Zhe & Amrinola, 2022) tells us that the majority of problems are liable to be caused by a small number of issues. Therefore, it seems prudent to commence any CI drive by instigating certain Lean tools initially, and polishing off the process by applying Six Sigma.

(Costa, et al., 2021) describe Lean as a set of tools used for doing more with less, to the benefit of the final consumer, while Six Sigma, through its DMAIC methodology, aims to minimise errors and defects. The not-entirely-dissimilar PDCA cycle used in Lean, in conjunction with other Lean tools such as Root Cause Analysis and 5S, lead to reductions in non-value-adding activity (Nader, 2022). (Laureania & Antony, 2019) asserts that while Lean works on quality, speed of delivery and price, Six Sigma delivers on predictability and stability.

10.2 Benefits of LSS

Benefits of a successful and sustained Lean Six Sigma drive have been cited as including, but not limited to the following: production cycle time reduction, productivity increase, improved production lead time, smooth production flow, defect reduction, reduction in equipment set-up time, reduction in production cost, improved machine availability, improved overall equipment effectiveness, reduction in idle time, inventory reduction, waste reduction, competitiveness improvement, increased profitability, improved market position and reduction in employee overtime. (Putri & Dona, 2020), (Costa, et al., 2020), (Palange & Dhatrak, 2021).

However, (Costa, et al., 2018) point out that benefits are not the only promoters of LSS in the food industry; certain drivers exist also. These include the constant push for price reduction by the retailer chains, along with their reducing lead-time requirements and increasing credit-terms expectations.

Toyoda and Ohno, in forming the TPS, did not go all-out to improve production at all costs though, they were also all about bringing their staff along with them. The three main aims of their system were continuous improvement, respect for people and zero waste. (Domínguez, et al., 2020) This is demonstrated by (Liker & Convis, 2011) in their book “The Toyota Way to Lean Leadership”, where they state that, during the

Toyota Recall crisis of 2009, when production fell to very low levels, Toyota did not lay-off any full-time operatives at any of their production facilities globally, but sent people for training during this slack time.

10.3 Lean Wastes

Lean categorises as waste any activity, process, or factor that does not add value (Idrissi & Benazzouz, 2019) to the product for the final consumer, who pays only for the finished product (Orynycz, et al., 2020). These wastes originally numbered 7, and are easily remembered by the mnemonic TIMWOOD:

- T – Transport
- I – Inventory
- M – Motion
- W – Waiting
- O – Overprocessing
- O – Overproduction
- D – Defects

More recently, an 8th waste has been identified, Skills. This refers to the untapped skillsets that personnel may possess. The mnemonic is hence rewritten as TIMWOODS.

(Morales-Contreras, et al., 2020) single out two of these wastes for special mention; they state that the Japanese describe Overproduction as the Killer, and Inventory as the Serial Killer, as both these, more than any other, keep the most important business resource of all – money – tied up needlessly. They also cite work by (Bicheno & Holweg, 2009), in which the latter propose seven forms of waste specifically for service industries:

- Duplication,
- Delay,
- Loss of opportunity with the customer,
- Unclear communication,
- Incorrect inventory,

- Movement of customer,
- Error in the service transaction.

When conducting their study into optimising processes at a beverages production business using LSS, (Zhe & Amrinola, 2022) circulated questionnaires based on the original seven lean wastes, but also added a scoring system to denote the severity of the issue in each case. (Table 10-1)

(Omoush, 2020) states in the findings of his study into the effects of LSS on quality in food production facilities, that defects are measurable using Six Sigma tools, and, further, that if they can be measured, they can be reduced to approach a defect-free state. (Omoush, 2020) and (Martínez, et al., 2022) define a defect as being a nonconformance to product specification. (Omoush, 2020) also attributes the wastes of Waiting to one or more of the following factors:

- Poor planning,
- Inexperienced employees,
- Poor communication process between the workers,
- Poor supply chains

(Azalanzazllay, et al., 2022) also cites 'Environmental waste' as an emerging waste to be accounted for in current and future reckonings.

Waste Type	Score	Description
Over Production	0	Not Happen
	1	Happened but not distract production flow
	2	Start to distract production flow
	3	Distract production flow, and increase production cost
	4	Distract next flow of process
	5	Cause defect of product because product keep in warehouse for too long
Defect	0	Not happened
	1	Happened and cause minor rework
	2	Cause delay minor
	3	Potential to re-production
	4	Cause late for shipment and need extra inspection
	5	Defect discovered by consument and cause increase cost
Unnecessary Inventory	0	Not happened
	1	Happened but not distract production flow
	2	Need extra man to control the machine/ingredients
	3	Start to distract production flow
	4	Potential damage the machine/ingredients
	5	Need extra room and causing too much damage
Inappropriate Process	0	Not happened
	1	Happened but the effect not significant
	2	Happened and the effect significant
	3	Cause more ingredient consumption
	4	Cause duration more time
	5	Cause defect and endanger operator
Excessive Transport	0	Not happened
	1	Happened and not distract production flow
	2	Cause bad communication between division
	3	Cause more consumption of area
	4	Cause duration more time
	5	Cause damage of product
Waiting	0	Not happened
	1	Happened and not distract production flow
	2	Cause duration more time
	3	Cause bad production process
	4	Potential late for shipment
	5	Cause late for shipment
Unnecessary Motion	0	Not happened
	1	Happened and not distract production flow
	2	Added more process
	3	Potential to more duration
	4	Decrease operator productivity
	5	Potential to cause injury

Table 10-1 Score-weighted expansion on the original seven lean wastes

(Zhe & Amrinola, 2022)

10.4 5S

5S is a key concept in the Lean toolbox; it is useful across the entire spectrum of the production process. By clearing away clutter, cleaning and tidying the work area, and having ‘a place for everything, and everything in its place’, a machine or process operator’s life is made simpler. So also, are the lives of those who deliver materials to the workstation, those who receive work from the workstation, and those who maintain plant and equipment. Tooling, dies, and tools are at hand's reach when they are required, and the hazards of 'slips, trips and falls' is much reduced, improving health and safety factors for all concerned.

Indeed, this Safety aspect was suggested as the sixth 'S' in what, for a time, was mooted as 6S. (Carrera, et al., 2021) give us a roadmap for the stages of 6S (Table 10-2)

Nº	Stage	Description
1	Seiri	Remove all unnecessary tools and parts. Keep only essential items.
2	Seiton	Arrange the work, workers, equipment, parts, and instructions in such a way that the work flows free of inefficiencies through the value-added tasks with a work division necessary to meet demand.
3	Seiso	Clean the workspace and all equipment, and keep it clean and tidy ready for the next user.
4	Safety	Reduce labor risks and ensure the compliance with safety and health regulations.
5	Seiketsu	Ensure procedures and setups throughout the operation promote interchangeability. Normal and abnormal situations are distinguished, using visible and simple rules.
6	Shitsuke	Make it a way of life. This means commitment. Ensure disciplined adherence to rules and procedures.

Table 10-2 Stages of 6S

(Carrera, et al., 2021)

However, disagreement appears to exist between the works of (Carrera, et al., 2021) and that of (Mahlaha, et al., 2020) on what assignation be given to a seventh 'S' (i.e., 7S), with the latter appearing to opt for the 'S' in Team Spirit, while the former proposes the 'S' in CSR, or Corporate Social Responsibility.

In their study of Lean Management in the fast-food industry, (Orynycz, et al., 2020) suggest that implementation of 5S promotes more effective, and hence, better work, leading to overall better productivity by eliminating waste in the material stream. They found that operations times were reduced at workstations given the 5S treatment. Of course, in the spirit of CI, and in common with all LSS tools, this treatment is not a once-off project, but an ongoing process. Clearly, in the case of 5S, this continuing aspect is covered in the 5th S, Sustain. (Nandakumar, et al., 2020) suggest that, apart from regular floor inspections, periodic reviews should include those who spend their working hours at the coalface or 'Gemba'.

Clean-up kits, spill kits, machine-tooling and dies, as well as those hand-tools used by maintenance engineers are frequently stored on Shadow-boards. This is a major feature of 5S, as it satisfies all the first four Ss. This ensures that tools, brushes, dustpans etc are right at hand when they are needed, in an easily identified manner, and it can be immediately observed if an item is missing from its designated place.

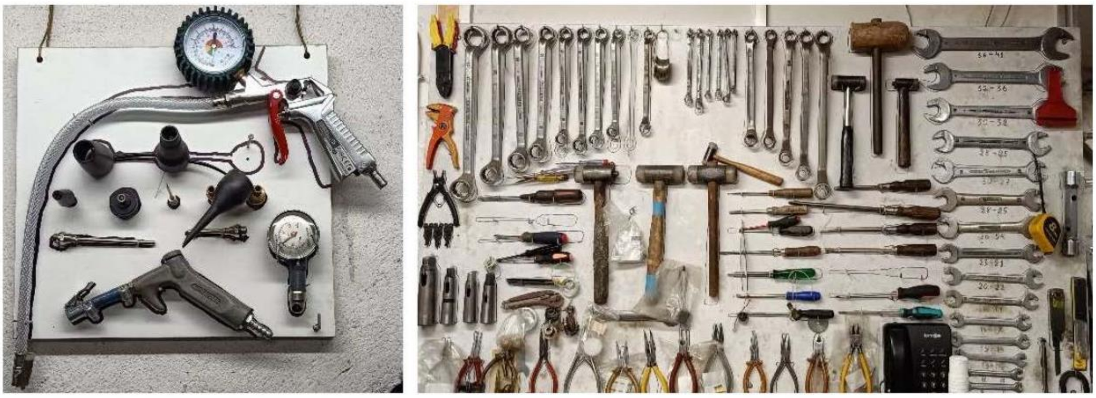

Figure 10-2 Examples of Shadow Boards for tools

(Domínguez, et al., 2020)

10.5 Value Stream Mapping (VSM)

VSM, a major Six Sigma tool, also works well with Lean tools, as seen in Figure 10-3. VSM is effectively a three-stage process.

- Stage 1 involves a group of people assessing the current setup of production processes, and drawing a depiction of it on an A3 sheet of paper, and establishes, in an honest fashion, at what junctures of the process value is added, and where waste is generated. This is called the Current State VSM
- Stage 2 entails studying the current state VSM in brainstorming sessions, and drawing up an ideal future state VSM, using Lean tools to eliminate waste.
- Stage 3 s where the actual process is altered to bring it into kilter with the Future State VSM. (Muñoz-Villamizar, et al., 2018), (Nandakumar, et al., 2020), (Putri & Dona, 2020)

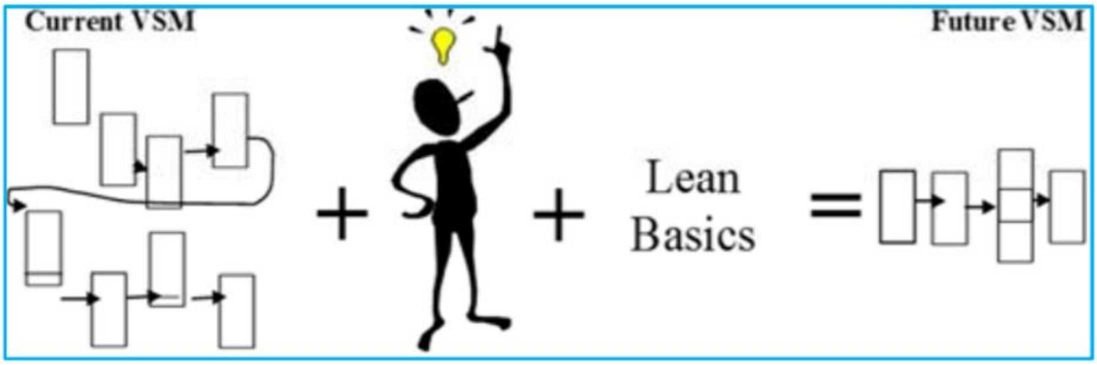

Figure 10-3 Value Stream Mapping and Lean relationship.

(Gbededo, et al., 2017)

10.6 Pareto Analysis

Pareto analysis is loosely based on the 80/20 rule (Nader, 2022). It supposes that, in most cases, approximately (very approximately in some cases), 80% of defects can be attributed to 20% of the causal factors. A Pareto chart generally consists of a histogram plotting the defects, with the largest number represented on the left-hand side, and going to the right in descending order. This will often be accompanied by a cumulative plot diagram superimposed on the histogram, as seen in Figure 10-4.

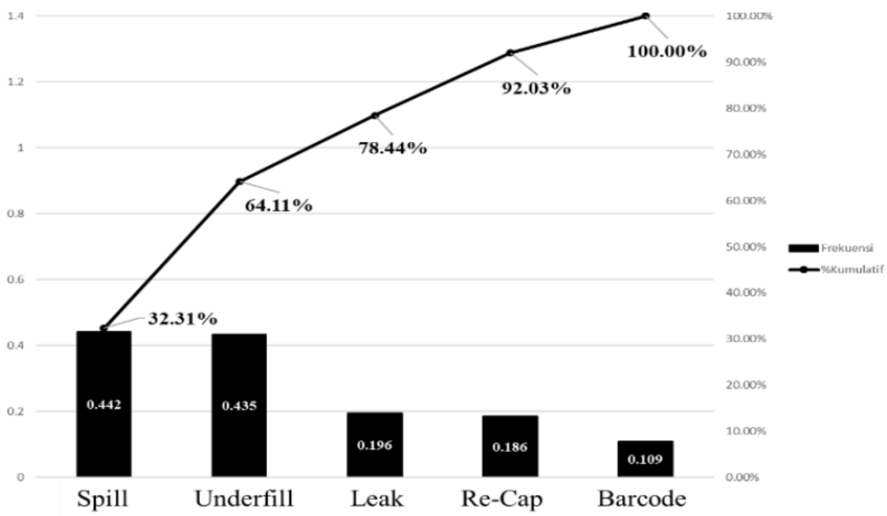

Figure 10-4 Typical Pareto Diagram

(Zhe & Amrinola, 2022)

10.7 Standard Operating Procedure (SOP)

(Putri & Dona, 2020) conducted research into the methodology of conducting commercial food production on a very small scale. But, even at this level, they embrace the notion of establishing Standard Operating Procedures. How much more important this must be therefore when producing food commercially on a large scale. When a correct formula is struck for producing a product, conducting a tool-change, dealing with allergens and / or cross-contamination, and myriad other procedures in a production facility, it is vitally important to record the correct method / order / ingredients etc Then draw up an SOP based on this, and ensure that all concerned parties have the training to carry out the procedure in the correct manner.

10.8 Single Minute Exchange of Die (SMED)

One form of production waste that has been dramatically reduced over the years, using Lean tools, is the loss of production time due to machine changeovers. When a run of one product finishes, and another is due to begin, there is normally a set of adjustments which need to be made to production equipment, recipes etc. before the new production run can commence. This usually leads to the waste of waiting, as operatives on the machine and its ancillaries must are often non-deployable elsewhere during this time.

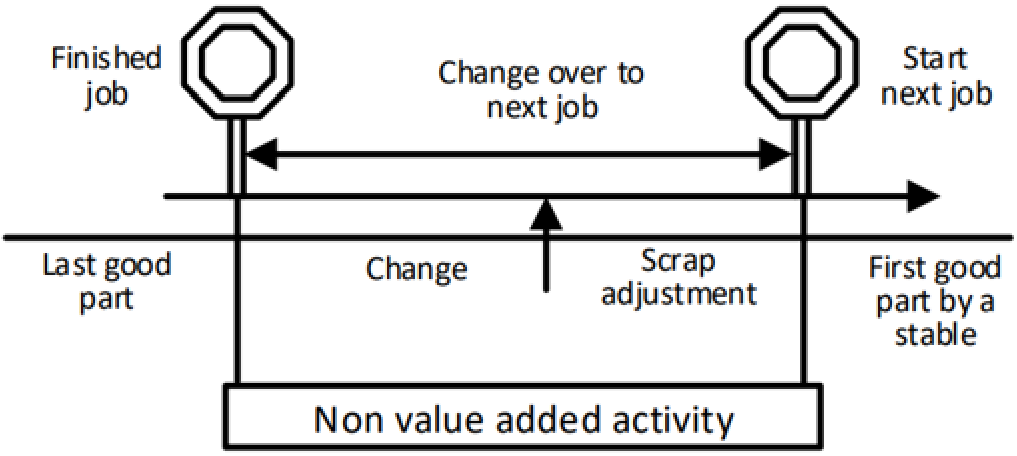

Figure 10-5 Representation of Change-over time.

(Sahin & Kologlu, 2022)

As previously described, and as depicted in Figure 10-5, the change-over time represents all that time when saleable product is not being produced due to the stripping of the ‘old-product’ tooling and fitting of ‘new-product’ tooling, also any re-programming and wash-down that must accompany this change, and any production of ‘start-up scrap’, i.e., unsaleable items usually produced while the production process is being stabilised. Dr Shigeo Shingo developed the SMED methodology while working at Mazda 1n 1950. When asked, 19 years later, and working at Toyota, to reduce the four-hour changeover time on a 1000 tonne press, he developed a system for doing it in three minutes.

A point to note is that, in the past, control-systems for machines, which were mostly timer and relay-based, often had to be practically rebuilt at product changeover. Since the invention of the Programmable Logic Controller (PLC), a type of dedicated, reprogrammable, machine-contained computer, in 1968, reprogramming a machine for a change of product usually occurs in seconds.

The actual physical changeover of the tooling, die or otherwise, can be a very different matter, but adequate preparation can reduce the downtime considerably. In as much as possible, any preparation work that can be carried out prior to stopping the machine should so be done. This is known as ‘External’ setup (Sahin & Kologlu, 2022). Having this preparation carried out prior to machine shutdown saves significantly on downtime. A planned, methodical approach to the remainder of the task, using jigs or locators to ensure correct positioning, ‘one-way-fit-only’ ensures that items cannot be fitted incorrectly. This employs another lean tool; ‘poka-yoke’, or mistake-proofing. Having – and using – accurate pre-determined measurements ensure correct positioning of equipment where the use of jigs is not possible. Following the order of a standardised and approved checklist will ensure that parts are fitted correctly, and in the correct order.

The ability to conduct fast tool changes improves production versatility, allows for reduced batch size, and renders a business more amenable to the voice of the customer (VOC), from which all pull-production flows. (Costa, et al., 2018)

Line hopping (Garcia-Garcia, et al., 2022), if spare line capacity is available, may also be used in certain situations to alleviate downtime at changeover, whereby spare capacity on an unused section of another line, or piece of equipment, might be utilised to keep the production flow going rather than incurring downtime. This is not normally possible in the food industry, though, as the danger of cross-contamination must be guarded against.

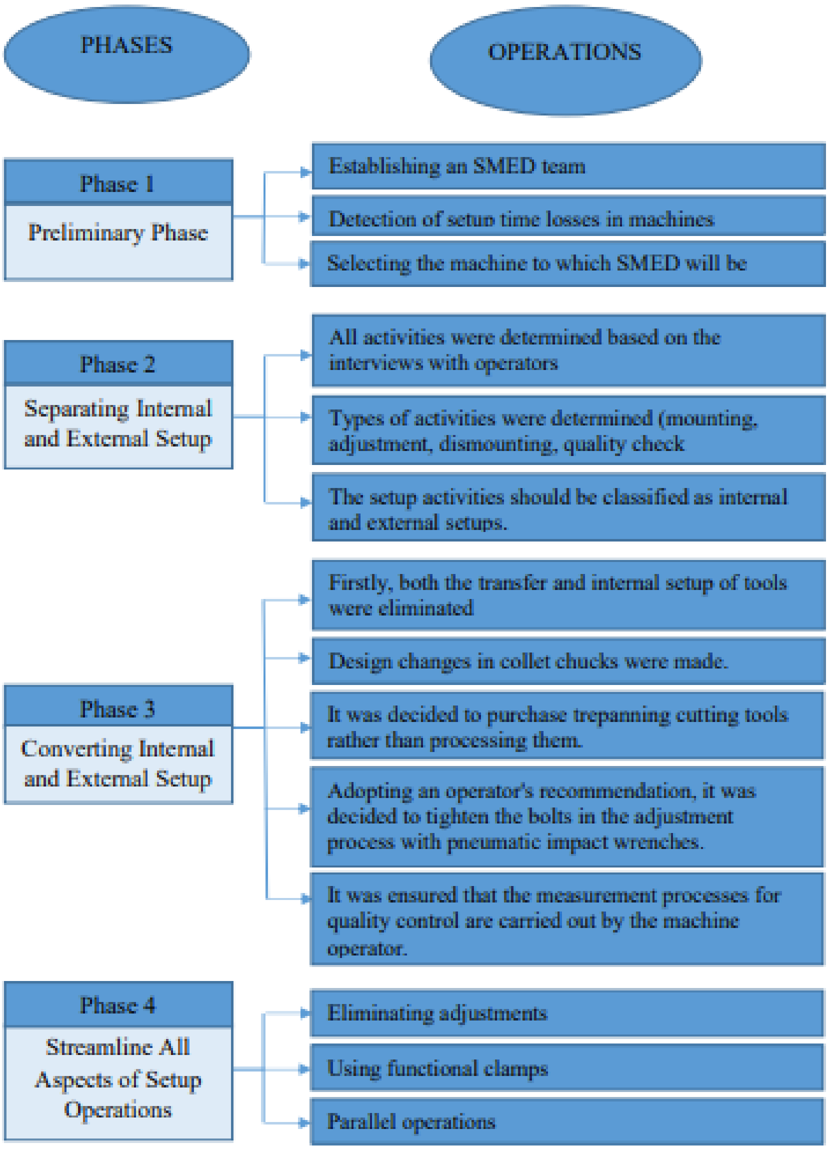

Figure 10-6 SMED conceptual stages and practical activities

(Sahin & Kologlu, 2022)

The SMED concept, as per all aspects of LSS should, ideally, be an ongoing 'journey' rather than a single event. Figure 10-6 demonstrates a plausible route through the establishment of SMED as a mindset, a way of life, and a business method.

10.9 (OEE) Overall Equipment Effectiveness

This Key Performance Indicator (KPI) takes three factors into account, and is a very useful tool for gauging the usefulness of a given item of plant on an ongoing basis. It is calculated by multiplying the available time for the equipment by the quality by the performance:

$$OEE = availability\ x\ quality\ x\ performance$$

Where:

$$availability = \frac{Total\ time\ - (planned\ downtime + unplanned\ downtime)}{Total\ time}$$

$$Total\ time\ =\ Hours\ per\ shift\ x\ shifts\ per\ week$$

$$quality = \frac{No.of\ actual\ saleable\ items\ produced\ by\ the\ machine}{Total\ No.of\ items\ produced}$$

$$performance\ = \frac{Speed\ of\ the\ machine}{Rated\ speed\ of\ the\ machine}$$

Equation 10-1 Overall Equipment Efficiency

By the author.

OEE may be expressed as a percentage, or as a rational number between 0 and 1. An effective SMED regime contributes greatly to machine availability, and hence to OEE (Garcia-Garcia, et al., 2022).

10.10 SIPOC Diagram.

A SIPOC diagram is a depiction, often a hand-drawn image, which represents the passage of materials through sourcing, acquisition, value-adding, dissemination, and dispersal. An example can be seen at Figure 10-7. SIPOC is an acronym, the letters of which stand for:

- Supplier
- Input

- Process
- Output
- Customer

It is often drawn up ‘by committee’, the product of a brainstorming session with several internal stakeholders present, and aims to render a faithful representation of the entire journey from purchasing raw materials to selling finished product. The SIPOC map may also be used as the basis image when conducting a Value Stream Mapping exercise. (Nandakumar, et al., 2020), (Vanany, et al., 2020)., but are more

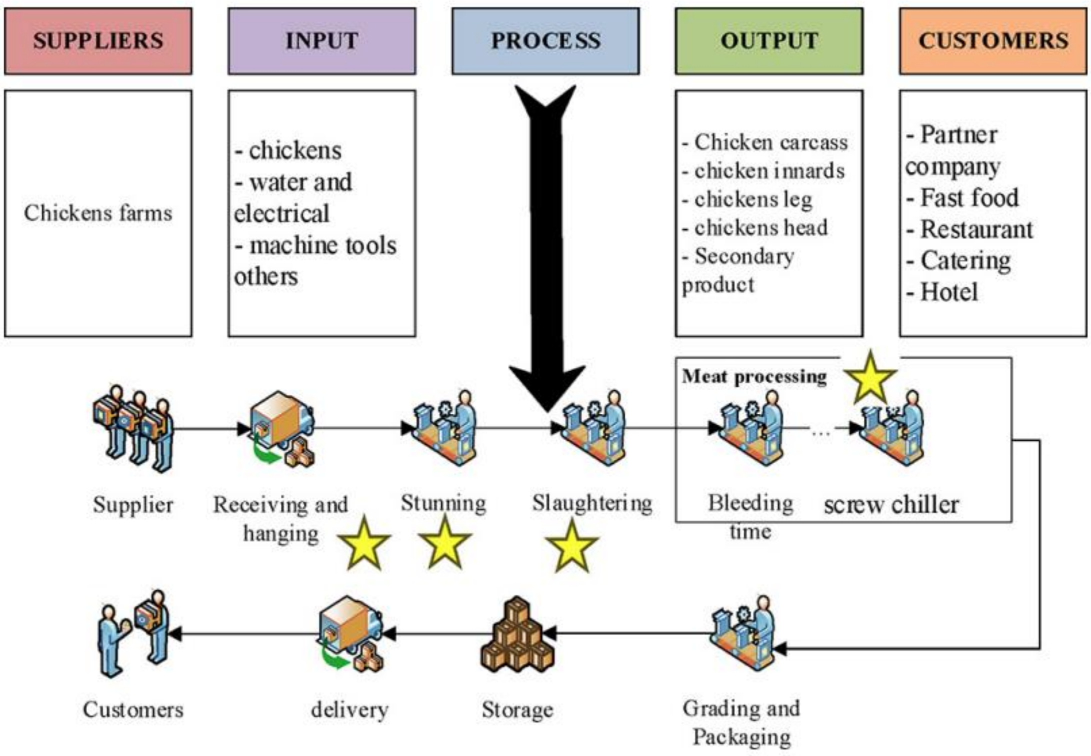

Figure 10-7 Example of a SIPOC diagram

(Vanany, et al., 2020)

often used for analysing all aspects of the business relating to the production side, and for pricing. SIPOC may be applied, not only to the day-to-day running of the business, but also to projects.

10.11 Poka-yoke

‘Poka-yoke’ translates literally from Japanese as ‘the avoidance of inadvertent errors’ or ‘fail-safe’ (Domínguez, et al., 2020); it is commonly used in the English language as ‘mistake-proofing’ (Palange & Dhatrak, 2021), or, occasionally, less politely, as ‘fool-proofing’ or ‘idiot-proofing’. The term was coined by Dr Shigeo Shingo in the 1960s, and refers to practical situations where a component, part or item may be installed in the correct orientation only, due to its design. A prime example from everyday life is the three-pin electrical plug, which is designed with one large pin on the ’Y’ axis and two smaller ones on the ‘X’ axis, in such a way as that it may not physically be plugged in incorrectly.

10.12 Just In Time (JIT)

The concept of ‘Just in Time’ forms the basis of Toyoda and Ohno’s ‘pull’ production idea; indeed, it was considered one of two main pillars of their Lean-house model (Idrissi & Benazzouz, 2019). JIT is the antithesis of ‘Just in Case’ or ‘push’ production, where product is manufactured to stock (Azalanzazllay, et al., 2022), and is considered wasteful in that it generates inventory needlessly. JIT, on the other hand, produces only what is needed ‘now’ to fulfil internal or external orders, and is governed directly by customer demand.

10.13 Right First Time

Right first time (Martínez, et al., 2022) is a concept that is almost self-explanatory, an item produced free of defects first time around is considerably less expensive to manufacture than one that must be re-worked, sold as a substandard product, or dumped.

10.14 Root Cause Analysis

Root cause analysis is used to find the actual cause or causes of a problem, so that the cause may be treated, rather than simply treating the symptoms. Usually, one or both of two methods are used:

10.15 Ishikawa diagram

Dr Kaoru Ishikawa’s fishbone diagram, also known as a “cause-and-effect” diagram (Zhe & Amrinola, 2022), is drawn on a large sheet of paper (often A3), with the problem inscribed at the end of a horizontal line, while 6 other lines radiate from above and below the horizontal, in the style of a fishbone. Each of these six lines is marked with one on of the “five Ms and one E”, which are held to be the most likely causal factors in the problem. These stand for Man (i.e., Human), Machine, Measurement, Materials and Method, as well as Environment. Primary, secondary, and however many layers of potential causes to the issue are marked along these tributary lines, in a fashion as seen at Figure 10-8, until the root cause or causes of the problem is established. Factors pinpointed in this analysis may be use as a basis for improving the process, and, in the case of the “Human” factor, for improving working conditions (Zhe & Amrinola, 2022).

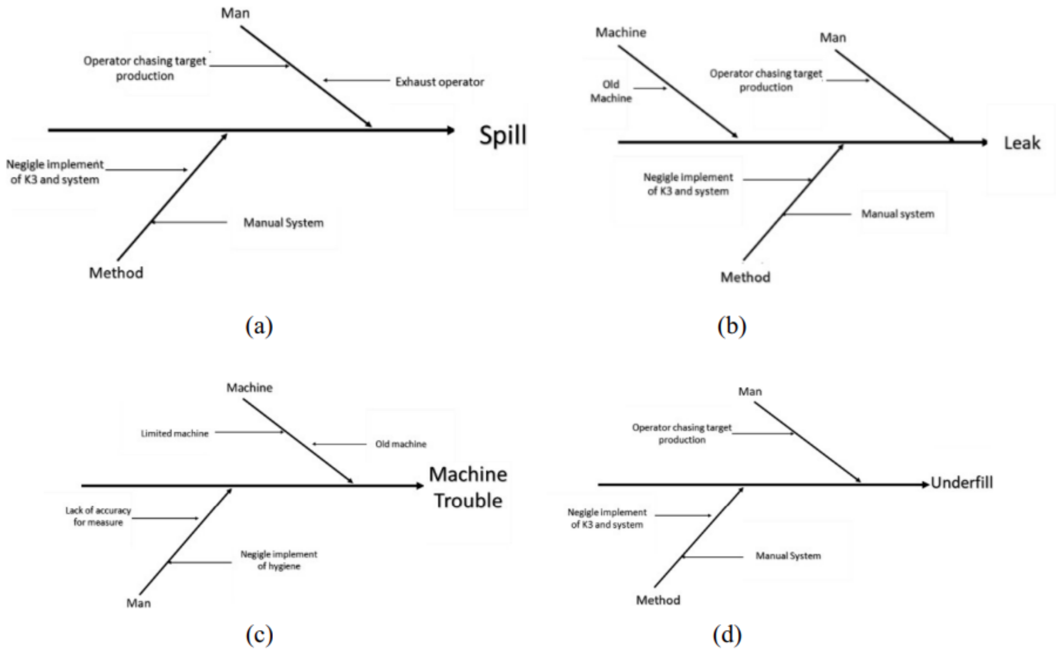

Figure 10-8 Ishikawa diagram.

(Zhe & Amrinola, 2022)

10.16 Five Whys. (5W)

Also occasionally referred to as ‘Why-Why’ analysis (Gbededo, et al., 2017) (Lim, et al., 2019), 5W was originally developed by Sakichi Toyoda, the original business ‘brain’ of the Toyoda dynasty. Toyoda’s idea of getting to the root cause; and hence treating the reason for the problem rather than just its symptoms, points toward solving the issue instead of kicking it further down the road.

Used alone, or in tandem with the Ishikawa diagram (Garcia-Garcia, et al., 2022), ‘Five Whys’ constitutes a powerful analytical tool in the Lean toolbox, and is frequently used during the ‘Analyse’ step of Six Sigma’s DMAIC programme (Vanany, et al., 2020) (Zhe & Amrinola, 2022). (More on DMAIC in section 10.23).

10.17 Voice of the Customer (VOC)

VOC represents the scope of what exactly the customer expects – and does not expect – in a finished product. In other words, that which the customer is willing to pay for. Any process or activity which falls outside this scope represents waste, and is fair game for elimination using LSS.

10.18 Kaizen

Kaizen is a Japanese-language word meaning continuous improvement (CI), and, as such, sums up both the ‘*raison d’être’* and the ‘*modus operandi’* of the entire Lean concept (Palange & Dhatrak, 2021). Kaizen promotes CI by instilling the values of continued small-scale improvements on an ongoing basis, and, ideally, becomes habitual, a philosophy of working, and a way of life (Nandakumar, et al., 2020). According to (Orynycz, et al., 2020), kaizen is less a tool of the Lean set, and more of a workstyle. Improving is everything, and everything is improving.

‘Kaizen Blitz’, on the other hand, describes a situation where a problematic area of a process is ‘taken in hand’ over a short period of time. Often a three-day or five-day event (Reid, 2019), a kaizen blitz will be operated by a hand-picked, multi-disciplinary team.

Non-value adding aspects of the process will be identified in the preparation stage of the event, new and better methods will be explored. This ties in with the ‘Plan’ phase of the Plan-Do-Check-Act (PDCA) cycle associated with Lean.

During the actual Blitz event, the new methodologies will be deployed, and the resultant improvements, or otherwise, checked. Here, the ‘Do’ and ‘Check’ phases of PDCA.

The follow-up phase of a kaizen blitz will establish what, if any benefits have accrued, and standardise successful changes on an ongoing basis. This relates to the ‘Act’ phase of PDCA. If no benefits have accrued, the PDCA cycle kicks off again, with another kaizen blitz (Gbededo, et al., 2017).

10.19 Total Productive Maintenance (TPM)

TPM incorporates a raft of concepts pertaining to equipment care, and, after pitching safety as the paramount construct, places emphasis on preventative maintenance rather than reactive maintenance. Its principal aim is to minimise equipment downtime and improve Overall Equipment Effectiveness (OEE) (Nader, 2022), (Costa, et al., 2020) (Psarommatis, et al., 2020). This entails pre-empting machine breakdowns, and their attendant expensive downtime, by carrying out all possible maintenance during non-productive time. Procedures such as oiling, greasing, changing out worn components such as bearings, bushings etc. Normally, such actions will be carried out by dedicated maintenance personnel, during scheduled downtime. However, TPM also allows for Operator Asset Care (OAC), where the machine operative will take responsibility for certain elements of machine maintenance on an ongoing basis, such as cleaning, ongoing lubrication etc. (Costa, et al., 2020) assert that the highest likelihood of TPM being instigated is in those businesses with the most specialised equipment. Record-keeping is an essential factor in the TPM process.

10.20 Critical to Quality (CTQ)

Critical to quality might be defined as those aspects of a product that satisfy the requirements of the customer. It is normally a seen as a graphical depiction, known as a CTQ tree, and will be based on the Voice of the Customer (VOC).

10.21 Failure Mode and Effects Analysis (FMEA)

FMEA is a tool used for establishing the likelihood and potential effect of failures in a system from the point of view of any stakeholder, human or otherwise, to the stated effects. This includes personnel, either employee, customers, or any others. It also encompasses harm which may befall equipment, buildings, the environment, and methodology employed in production (Psarommatis, et al., 2020). FMEA grades failure modes and effects by giving numerical rankings to the likelihood of any adverse occurrence, and another ranking to the severity of the outcome of such occurrence. Both numbers are then multiplied together, and the product is used to rank the level of energy that must be put into ensuring that such an event does not happen, and the urgency in which such an occurrence, should it take place, must be dealt. Also, according to (Palange & Dhatrak, 2021), FMEA should be used in conjunction with Root Cause Analysis (RCA) to establish the cause of the issue, and to deal with it; more importantly, to ensure non-recurrence.

An example of FMEA might be where a food production facility rates, among the possible problems which may arise, the chances of a processed meat product containing foreign matter:

- Because raw materials come packed in plastic bags, the chance of a small piece of plastic getting through undetected might be rated at 3, and the severity of the consequences of such an occurrence might be rated at 2. Therefore, the FMEA rating for this is 3 x 2 = 6.
- Similarly, the chance of a small piece of metal getting through undetected might be rated at 1, and the severity of the consequences of such an occurrence might be rated at 6. Therefore, the FMEA rating for this is 1 x 6 = 6.
- Alternatively, the production facility is very likely to have nut-free designation, so the chances of a peanut finding its way into the product might be rated at 1, while the potential severity of this happening might be rated at 10. Therefore, the FMEA rating for this is 1 x 10 = 10.

FMEA is frequently used as an analytical tool in the ‘Analyse’ phase of a DMAIC drive (Zhe & Amrinola, 2022).

10.22 Kanban

Kanban, a Japanese-language word for card, denotes a system of signalling within a production environment. Originally instigated by Taiichi Ohno, kanban were originally cards which accompanied product through its assembly process, with each operative tearing off the appropriate perforated section as an activity was completed. Kanban can be cards, electric lights, or any other method of signalling. An example of their use might be where a cellular assembly unit were using components, they might flag up a kanban on a particular component tote-bin when it was approaching empty, as a signal that it needed refilling (Psarommatis, et al., 2020).

The use of kanban facilitates Just in Time (JIT) processes associated with pull production (Costa, et al., 2020), (Costa, et al., 2021) (Palange & Dhatrak, 2021), indicating when production should proceed and when it should cease; however, this does not lend itself well to continuous production environments.

(Gbededo, et al., 2017) assert that quantities raw materials, packaging etc on the production floor may be minimised using kanban, as such items need only be supplied as required. This reduces mess, minimises the floor-space requirement, and decreases the likelihood of clutter-related accidents. It also helps reduce the ‘deadly’ wastes of overproduction and inventory, and facilitates load-levelling (Heijunka).

(Costa, et al., 2018) suggest that the use of kanban is best suited to processes where discernibly shaped discrete products are manufactured, particularly when shaping occurs early in the process. Kanban is likely to be of little benefit where continuous flow process occurs.

A supply-system governed using kanban is depicted at Figure 10-9.

10.23 DMAIC

The major tool of Six Sigma is: Define, Measure, Analyse, Improve, Control, and is commonly known by the acronym DMAIC. It is used to identify, quantify, classify, rectify, and standardise processes, to streamline production, remove all aspects that add no value, and produce that which is demanded by the voice of the customer by way of eliminating variation (Indrawati, et al., 2020). Each of the stages is carried out, in the given order, and each is not commenced until after its predecessor is completed. The Define phase was not part of the original Motorola line-up of Six Sigma; it was added later, when General Electric adopted – and adapted – Six Sigma (Sánchez-Rebull, et al., 2020). Each step of the DMAIC model is accomplished using other tools from the Lean and / or Six Sigma toolbox. Like PDCA, DMAIC is cyclical in nature, as are many aspects of Continuous Improvement. CI, as a matter of course, does not have a defined endpoint, but strives permanently for betterment. A depiction of the cyclical nature of the DMAIC process is seen at Figure 10-10. Unlike PDCA, DMAIC is deemed to be data-driven (Nader, 2022).

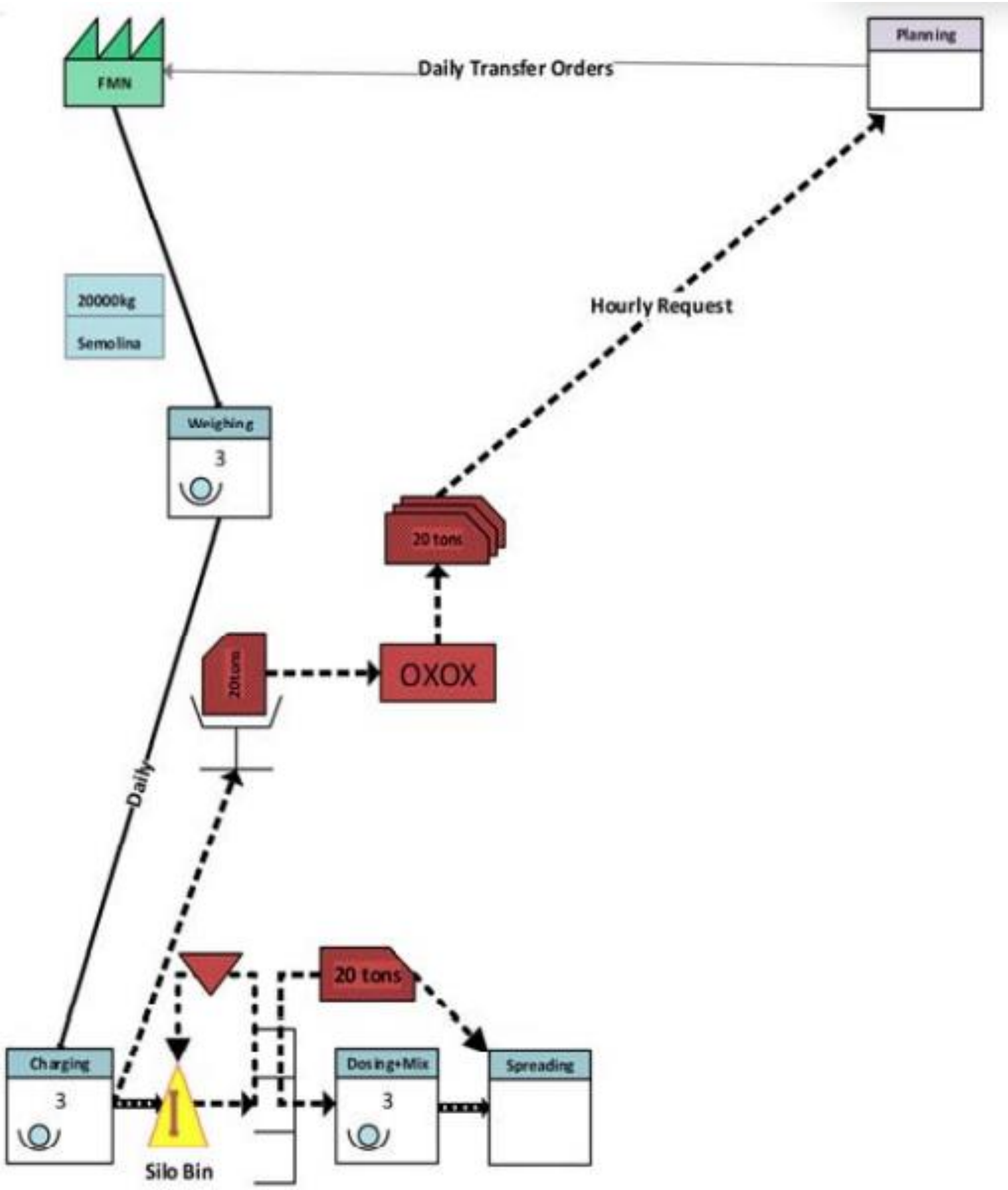

Figure 10-9 A Kanban pull system

(Gbededo, et al., 2017)

DMAIC is not so much a tool, as an apparatus for organising and controlling the individual tools used in CI (Costa, et al., 2018), (Vanany, et al., 2020). Below are listed some examples of the many permutations of LSS tools which may be used during the DMAIC programme.

- For example, when noting the current *status quo* of an existing process, i.e., the Define phase, it is likely that we will use a SIPOC map, and possibly VSM (Nandakumar, et al., 2020). The problem is defined using facts, not speculation.

- In the Measure phase, Statistical Process Control (SPC) charts may be employed to identify whether the process in in control statistically. A scatter plot's line of best fit, established via linear regression, should trace closely to all points on the graph, with no points outside the control limits, and no more than 5 consecutive points either above or below the line. SPC ensures quality items, free of defects, from one process to another, right to the end of the line (Costa, et al., 2020). Of course, 'Measure' can be as simple as using a measuring tape, vernier callipers, micrometre, etc.
- In the Analyse phase, tools such as 5 Whys (Carrera, et al., 2021), and Ishikawa diagram will be used to establish the root cause of the problem. (Indrawati, et al., 2020). We need to determine precisely what is the gap between the current process and the ideal (Costa, et al., 2021).
- In the Improve phase, issues addressed in root-cause analysis will be addressed. SPC 'after the event' charts might be drawn up again at this stage to verify the improvements made.
- In the Control phase, standard operating procedures will be drawn up to standardise the 'new' methodology (Palange & Dhatrak, 2021).

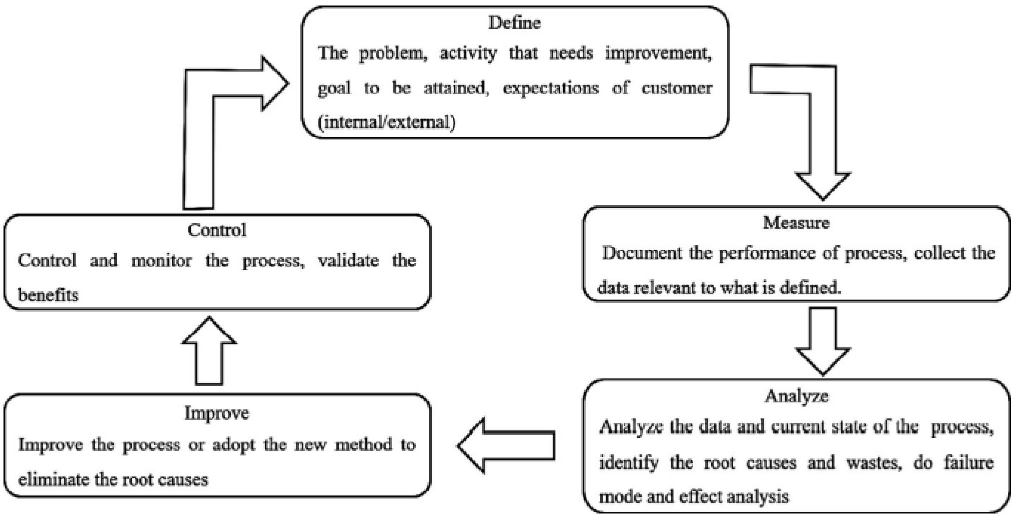

Figure 10-10 The DMAIC cycle

(Palange & Dhatrak, 2021)

DMAIC is considered an excellent tool, particularly when the cause of the problem is obscure, as its systematic nature probes to find the ideal solution (Sánchez-Rebull, et al., 2020).

10.24 DMADV

Define, Measure, Analyse, Design and Verify (DMADV) is an equivalent tool to DMAIC, but is aimed at service industries, whereas DMAIC is deemed more suitable to manufacturing industries (Psarommatis, et al., 2020). Similarly, to DMAIC, the steps of DMADV are carried out sequentially.

10.25 Visual Management

One very important LSS tool which appears notable by its absence from most papers reviewed, is Visual Management (Mahlaha, et al., 2020). This is where the mapping of a process, the method of carrying out aspects of the process, the required ‘look’ of the finished product, the positioning of labels on outer packaging, and numerous other facets of correct working will be depicted, in graphic form, at strategic points throughout the workplace. Other examples of Visual management might be Andon lights for stop/go of a process, green start-buttons, and red stop buttons on machinery, and, for example, a beacon that denotes that a safety device or critical control point, such as a metal detector, has activated.

One possible reason for the apparent absence of this factor from papers review might be that, while the data studied originates in countries all over the globe, the necessity for visual management systems may have a greater-than-usual pertinence in the case of food processing facilities in Ireland and the UK, where a sizable majority of the production operatives may not be working in their country of origin, and consequently may not have their adopted country’s major language as their first language. This situation indicates the importance of having instructions and methods represented in a visual manner.

METHODOLOGY

11 Methodology

11.1 Data collection.

The aim of this study was to establish answers to the following questions:

- Is the use of LSS as prominent in the food industry as in other manufacturing industries?
- Is there scope for improving the use of LSS in the food industry?

Data used in this study originated from several sources. These were as follows:

- Previously published peer-reviewed articles, books, and scholarly works, and websites.
- ‘Lean Business Ireland Lean Project Database’, available online.
- The author’s previous experience of conducting a workplace based LSS drive.
- Material garnered form the author’s current employer.

11.1.1 Review of available literature.

This study commenced with a trawl through academic databases to source material that might be deemed relevant to the subject matter. Search terms used were Lean, Six Sigma, Lean Six Sigma, Continuous Improvement, Food, Food Industry. It was the author’s stated intention to base the vast bulk of this work should constitute a ‘dry’ thesis, based on secondary research, indicating that data cited would be quantitative rather than qualitative. A web search conducted using the Technological University of Dublin (TU Dublin) Tallaght Library search facility yielded 39 papers that showed promise in the required field. Reading through the reference pages of the original 39 papers unearthed a further 19 potentially useful publications. Therefore, a total of 58 papers showed potential to be useful for this purpose. Searches for material were carried out using the keywords ‘Lean’, ‘Six Sigma’, ‘Lean Six Sigma’, and ‘Continuous Improvement’, all in combination with the terms ‘Food’, ‘Food Production’, and ‘Food Industry’. These searches yielded research papers from the following databases: Science Direct, Emerald Insight, Elsevier, IOP Science, IEEE Xplore and MDPI.

19 of the original 58 publications were rejected as being out-of-date, as they were published prior to 2017. Upon perusal, a further 7 papers were found to contain little

data relevant to this purpose. Material contained in a total of 32 papers was ultimately cited in the literature review section alone.

The author read the material in portable document format (PDF), highlighted sections deemed relevant, and copied the highlighted passages, figures, and tables into 66 new MS Word documents, arranged by the nature of the content.

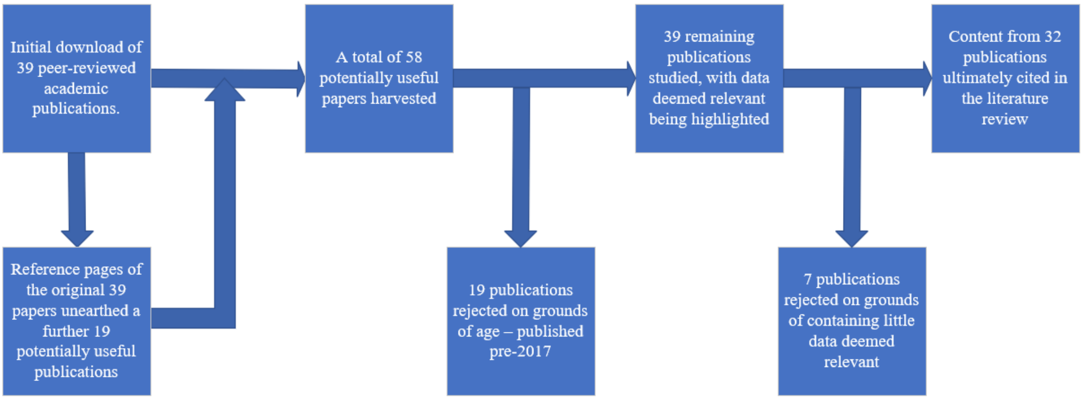

Figure 11-1 Flowchart of the process of papers selection.

By the author.

These were classified by their subject matter; each MS Word document contained material concerning one aspect of Lean Six Sigma (LSS) only. Some of these Word documents contained work harvested from a single paper, while others comprised work from numerous papers.

Having material from different authors present in a single document proved useful when it came to comparing, and contrasting, the findings of peer-reviewed work on a per-subject basis.

Work then commenced on writing the literature review, and was carried out on a methodical basis, tackling one aspect of LSS at a time.

11.1.2 Lean Business Ireland – Lean Project Database.

Enterprise Ireland offer Lean training to businesses under the umbrella of ‘Lean Business Ireland’. These are often advertised, promoted, and, in some cases financed or partly financed by local enterprise boards. Firms or individuals who deliver Lean training are matched with businesses who wish to acquire Lean skill sets. Normally, training sessions are set at a total of five days duration, but it is quite typical for a Lean facilitator to visit the business for a greater number of significantly shorter duration visits. A popular configuration is a two-hour visit, and work with an in-house potential Lean champion or a group. Training on the overall potential effectiveness of Lean may be delivered initially, and certain aspects of the lean toolkit may be delivered in greater depth on subsequent visits. As the business embraces Lean and witnesses its benefits first-hand, it is more likely that they will take on more and more aspects of Lean over the duration of the training.

11.1.2.1 Annual distribution.

Research was carried out by the author on the implementation of such Lean training initiatives in various companies in the Republic of Ireland across the years 2017 to 2022. A database pertaining to this work was prepared by Lean Business Ireland, and is available at the URL https://www.leanbusinessireland.ie/lean-project-database/ (Lean Business Ireland, 2022). The database lists a total of 331 companies of which two non-food related businesses are listed for the year 2022. With this in mind, it was intended, for the purpose of this work, to deal only with those listed in the years 2017-2021.

Between 2017 and 2021, several firms involved in LSS training and implementation each participated in delivering training and / or advice to one or more of 329 businesses throughout the country, with 65 of those companies working in one or more aspects of the food industry. Of 65 Lean-based projects carried out under this programme on food businesses, over the stated years, the annual distribution was as follows:

Year	Food-related Projects	Total Projects
2017	12	50
2018	17	78
2019	28	121
2020	3	59
2021	5	21

Table 11-1 Lean projects carried out in the years 2017-2021

By the Author, adapted from (Lean Business Ireland, 2022)

This yearly distribution is depicted in Table 11-1, with those businesses involved in food production being represented in graph form in Figure 11-2.

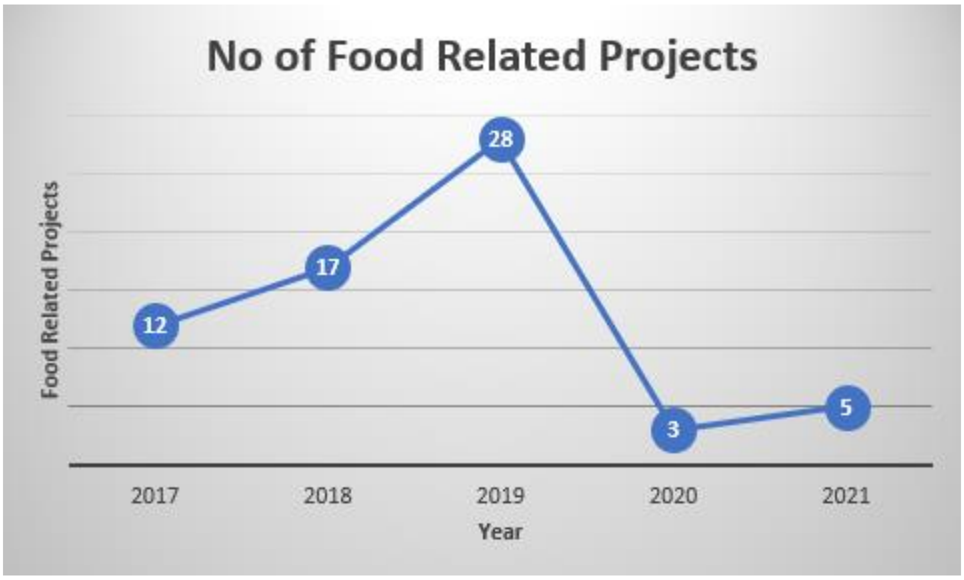

Figure 11-2 No. of Food-related Projects per year

By the Author, adapted from (Lean Business Ireland, 2022)

As will be clearly seen from the graph, the programme witnessed a significant increase in interest during the years 2017-2019, with the graph at Figure 11-2 initially tracking the beginnings of an apparent exponential increase. However, a sharp fall between the number of initiatives carried out in 2019 and 2020 apparently bears witness to the destructive affect that the enforced lockdowns associated with the Covid-19 pandemic was to have on the food industry, and, as seen in Figure 11.3, industry in general. The effects of the pandemic, as viewed in graph-form in Figure 11-3 demonstrate that, in both the food industry and industry in general, the drop-off rates in Lean initiatives delivered under this programme in the years 2019-2021 traces a much more dramatic curve than did the increase in such initiatives across the years 2017-2019. Although there is a slight 'bounce' in the number of deliveries to the food industry from 2020 to 2021, overall deliveries continued to collapse in the same period.

Perhaps the most dramatic aspect of all is seen at Figure 11-4, which plots the number of deliveries to food-related businesses over these years as a percentage of overall deliveries. In 2017, 2018, 2019 and 2021, such deliveries constitute between 21% and 25% of all deliveries; in 2020, this figure plummets to just over 5%.

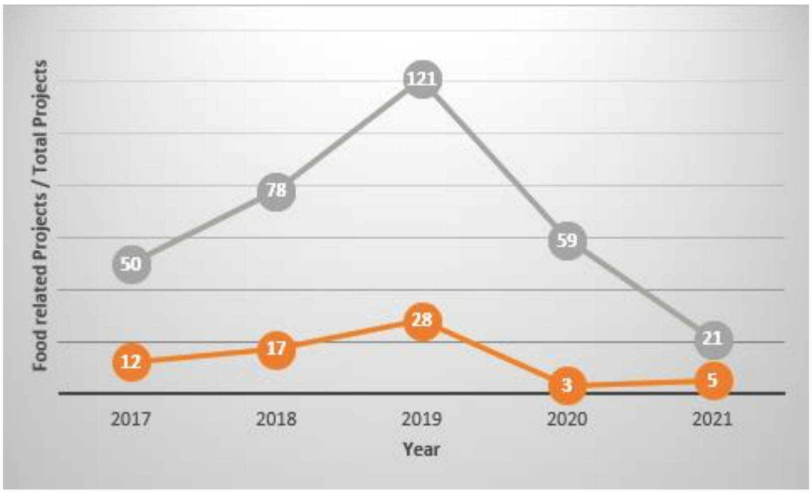

Figure 11-3 No. of Food-related projects vs Total No. of Projects

By the Author, adapted from (Lean Business Ireland, 2022)

Obviously, although food production facilities were granted something of a reprieve from the greater effects of lockdowns imposed on other workplaces, business visits and the mixing of personnel was, at different stages of the pandemic, discouraged or banned to varying degrees.

While it is difficult to pinpoint why 59 deliveries occurred at the height of lockdown in 2020 (with only 3 of those in food-related businesses), one might extrapolate that those in the food business were solely occupied with the continued and safe delivery of food, while personnel being paid furlough money in non-food industries may have continued to remain available to receive training over net-based meeting platforms such as Zoom or MS Teams.

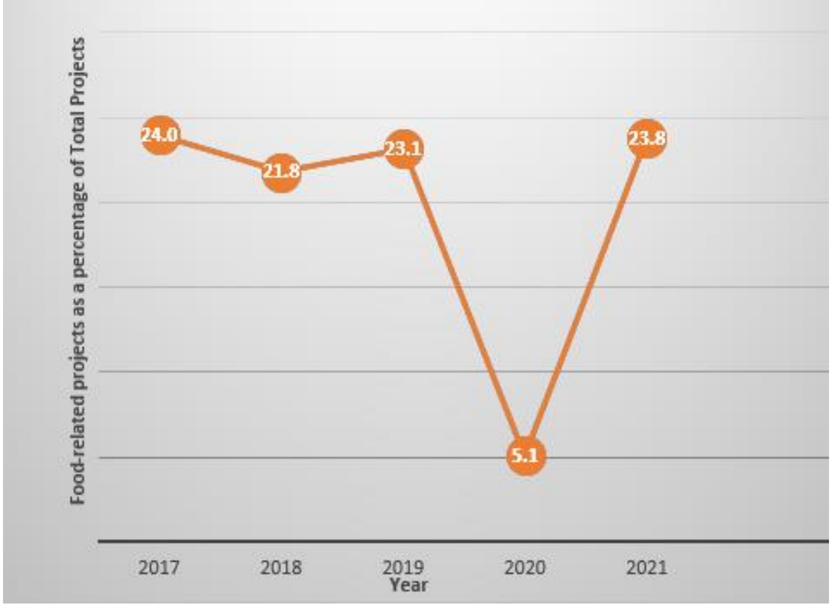

Figure 11-4 Food-related projects expressed as a percentage of Total Projects

By the Author, adapted from (Lean Business Ireland, 2022)

11.1.2.2 Regional distribution

For the purpose of this programme, Lean Business Ireland divided the territory of the republic of Ireland into 8 discrete regions as follows:

- North-West Region – Donegal, Sligo and Leitrim
- West Region – Galway, Mayo and Roscommon
- Midwest Region – Clare, Limerick, Tipperary
- South-West Region – Cork, Kerry
- North-East Region – Cavan, Louth, Meath, Monaghan
- Midlands Region - Kildare, Laois, Longford, Offaly, Westmeath
- Dublin Region – city and county
- South-East Region – Carlow, Kilkenny, Waterford, Wexford, Wicklow

These regions are depicted on the colour-coded map of the republic of Ireland shown at Figure 11-5 while the distribution of the 65 food-related businesses by region and size is represented at Table 11-2 and Figure 11-6.

	North-West Region – Donegal, Sligo, Leitrim
	West Region – Galway, Mayo, Roscommon
	Mid-West Region – Clare, Limerick, Tipperary
	South-West Region – Cork, Kerry.
	North-East Region – Cavan, Louth, Meath, Monaghan
	Midlands Region – Kildare, Laois, Longford, Offaly, Westmeath.
	Dublin - City and County
	South-East Region – Carlow, Kilkenny, Waterford, Wexford, Wicklow.

Figure 11-5 The Republic of Ireland in 8 regions.

By the author

Region	Micro	Small	Medium	Large
North-West	1	-	-	-
West	-	-	1	-
Midwest	1	5	-	-
South-West	2	4	4	-
North-East	-	1	7	4
Midlands	5	1	1	1
Dublin	-	3	1	4
South-East	-	-	1	-

Table 11-2 65 Food-related businesses – Distribution by region and size

By the Author, adapted from (Lean Business Ireland, 2022)

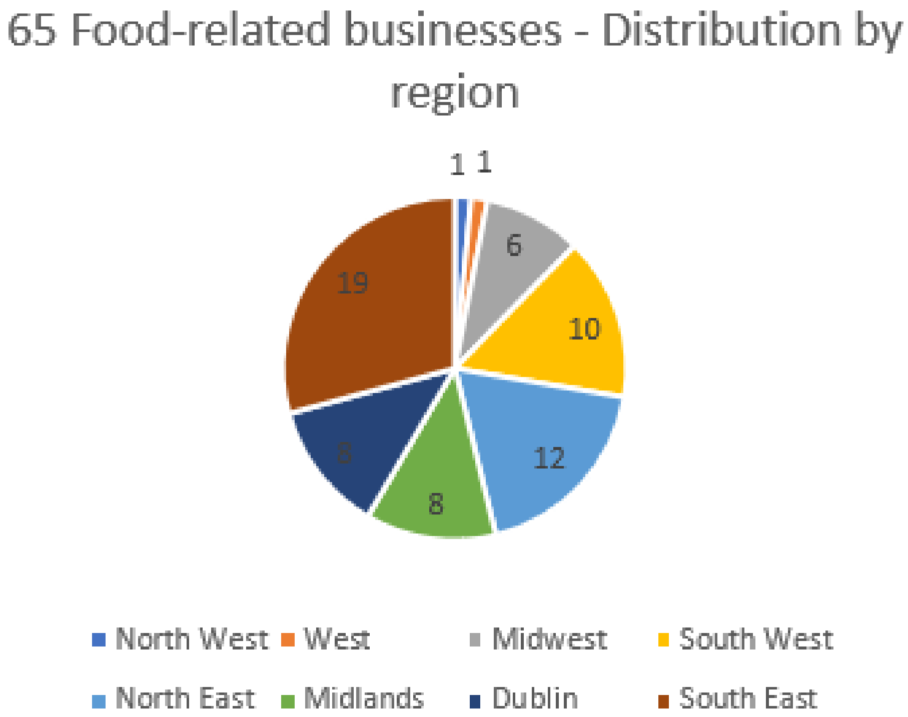

Figure 11-6 65 Food-related businesses - Distribution by region

By the Author, adapted from (Lean Business Ireland, 2022)

11.1.2.3 Size distribution

For the purposes of this programme, Lean Business Ireland classified the businesses involved by size, with the 65 food-related businesses falling into size categories as listed at Tables 11-3, and Figure 11-7.

Business Size by number of employees	Number of businesses
Micro (1-10)	19
Small (10-50)	23
Medium (50-250)	14
Large (250+)	9

Table 11-3 65 Food-related businesses – Distribution by size

By the Author, adapted from (Lean Business Ireland, 2022)

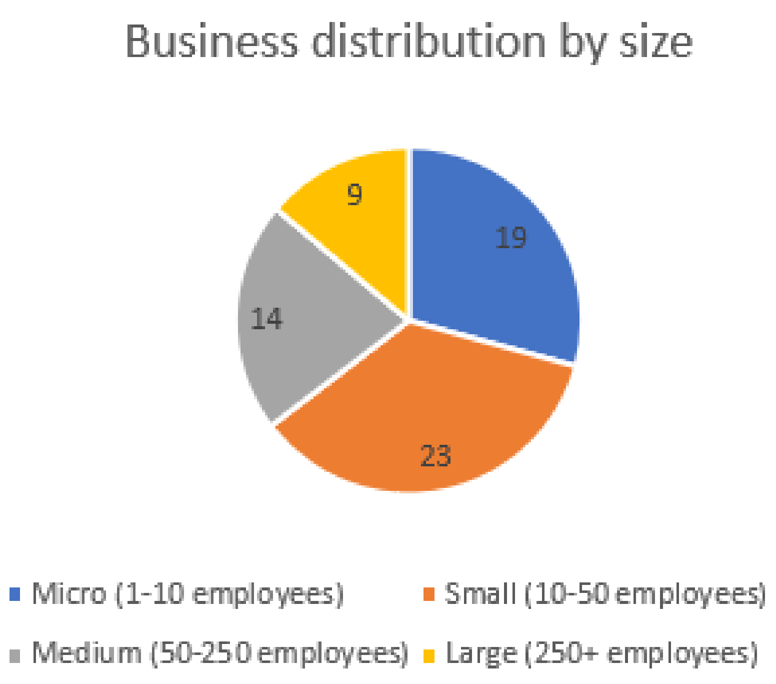

Figure 11-7 65 Food-related businesses – Distribution by size

By the Author, adapted from (Lean Business Ireland, 2022)

11.1.2.4 Type distribution

For the purposes of this programme, Lean Business Ireland classified the food-related businesses involved by type, with the 65 food-related businesses falling into type categories as listed at Tables 11-4, and Figure 11-8.

Type of food-related business	No. of businesses
Food: Dairy and Beverages	17
Food: Prepared consumer foods, Seafood, Horticulture	21
Food: Primary production and processing	25
Food: Other	2

Table 11-4 65 Food-related businesses – Distribution by type

By the Author, adapted from (Lean Business Ireland, 2022)

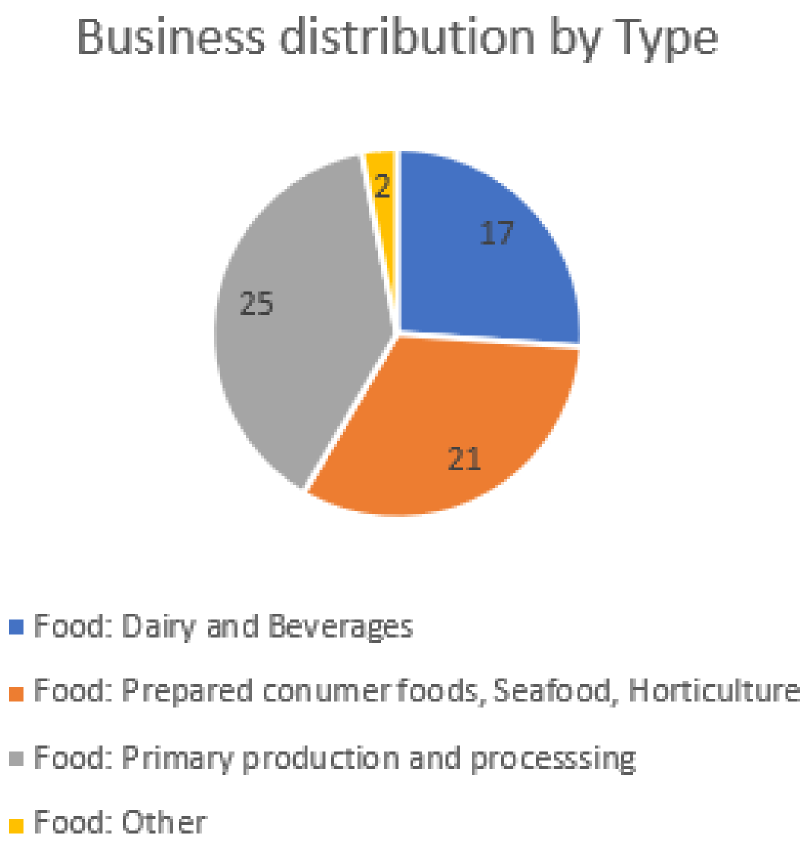

Figure 11-8 65 Food-related businesses – Distribution by type

By the Author, adapted from (Lean Business Ireland, 2022)

11.1.3 Stated aims of businesses receiving Lean training.

The Lean Business Ireland Lean Business Database (Lean Business Ireland, 2022) lists among the stated aims of businesses partaking of Lean training the following:

- Improved operations management.
- Improved layout and flow.
- Improved operational performance “Lean for Enterprise” using KPIs and scorecards.
- Creating and sustaining Lean culture and behaviours.
- Improved digital process innovation.
- Improved quality management.
- “Lean in office” – improved support functions, HR, finance, accounting.
- Improved new product development (NPD).

The above would suggest that the vast majority of participants entered into training with a goal in mind, and were not simply participating in training because ‘It seemed like the right thing to do,’ because it was available, because it ticked the correct buzzwords on someone’s list etc.

11.2 A Lean project – Single minute exchange of die (SMED).

Some years ago, the author completed the Green Belt certificate in LSS. As part of this course, it was necessary to carry out a practical project. This was to be workplace-based preferably. The author was, at that time, working as a maintenance engineer in a polymer extrusion blow-moulding facility, which made containment vessels in medium density polyethylene which were, for the most part, supplied to the food and beverages industry, and the pharmaceutical industry.

Upon broaching the subject of conducting a work-based project, buy-in from management was not immediately effusive, but the project was reluctantly sanctioned. The author set about putting plans in place for a single minute exchange of die (SMED) project, as it was apparent that tool-changes took several hours to complete.

The approach that seemed most appropriate was the Define, Measure, Analyse, Improve, Control method. To start off, a tool change was observed, with notes being taken of how and in what order the machine was prepared for the tool change, the ‘old’ components were removed, ‘new’ components were installed, and the machine was set up and running again.

At the beginning, potential benefits of the project were identified as:

- Decreased machine downtime.
- Improved product flow
- Decrease in maintenance-team hours per tool change.
- Decrease in lost machine-operator time during tool-change.
- Decrease in quantity of raw material lost to heat-degradation during down-time – leading in turn to a decrease in waste at start-up.
- Decrease in wasted electricity during downtime.
- Reduced need for inventory.
- Reduced customer delay.
- Higher productivity.
- Improved competitiveness and profitability.
- Reduced risk of injury to maintenance personnel.
- Allow shorter production cycles.
- Improve production planning flexibility.

11.2.1 Extrusion blow moulding – a brief description.

The machine in question was a ‘Fischer-Muller Blasformtechnik BFB 8-80’. The machine is depicted in the photograph below, with the split-mould shown in the open position. The head or extruder is seen at top centre, where a parison – that is, a partially molten tube - of plastic, is seen at the bottom of the head, in blue. The blow-pin is directly beneath the head. When the parison is extruded to such an extent that its end covers the pre-cooled blow-pin, the mould closes. The blow-pin then introduces air into the parison, causing it to 'balloon' out until it takes the shape of the pre-cooled mould. (The coolant pipes can be seen at either end of the mould; chilled ethylene glycol is circulated through cooling ‘zones’ in the body of the mould). Following a pre-set blowing period, the mould opens again, and the formed vessel is removed by the take-out device, which is seen just below the head.

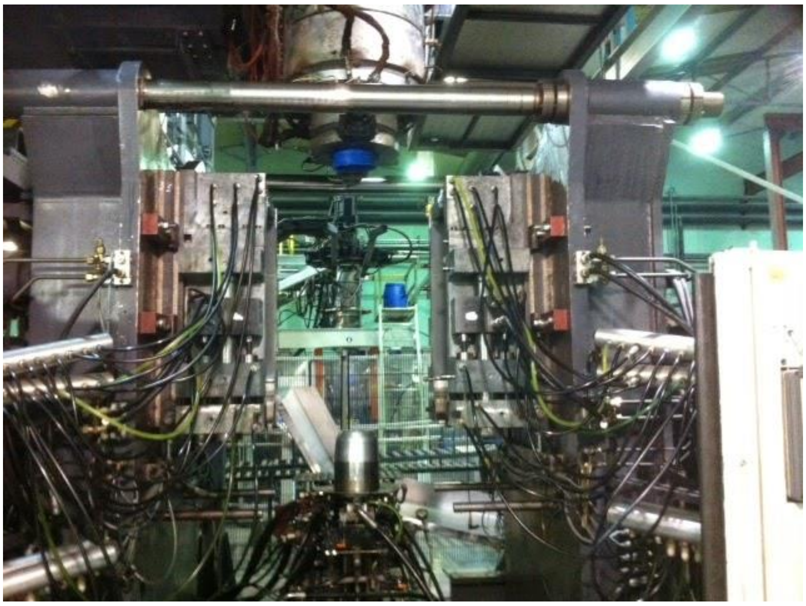

Figure 11-9 Extrusion blow-moulding machine.

© *The Author*

11.2.2 DMAIC

The DMAIC cycle for this project was instigated along the following lines:

11.2.2.1 Define Phase:

The Define phase is used to define which issues require improvement. This is best carried out by observation, by use of the Lean tool Gemba (the real place). Observation over several tool-changes, together with Root Cause Analysis by way of an Ishikawa diagram revealed several aspects of the process that could be improved upon. These were compiled into a preliminary list, using also a Critical-to-Quality (CTQ) tree diagram, as depicted in Figure 11-10, that it was felt best reflected the Voice of the Customer (VOC). During a brainstorming meeting of the project team, the project was 'scoped' with several the items on the original project charter being 'scoped-out' of the project. It was decided that those items included in the project would be:

- Mould and blow-pin positioning systems, (the major tooling)
- Pneumatic pipe and coolant circuit colour coding, (mistake-proofing)
- Individual coolant circuit valves, (previously, if a leak occurred, the entire system had to be drained down)
- Standardisation of coolant pipe/fitting size. (These varied previously)
- Assisted tool movement for heavy tooling

11.2.2.2 Measure Phase:

During the Measure phase, physical measurements were taken of various aspects of the machine that required alteration. Along with this, a timed checklist was developed to record times taken to complete various aspects of the tool-change process.

11.2.2.3 Analyse Phase:

In the Analyse phase of the project, data discovered during the Measure phase of the project was compiled into a Gantt chart. This tool, borrowed from Project Management, was used to depict the amount of time required for various aspects of the tool-change, showing projected start times, duration, and end time, and in which order tasks should occur. This data was subject to Pareto analysis, to separate those 'significant few' aspects of the process requiring modification from the 'trivial many'. This was carried out by way of establishing a 'Pareto chart', as seen at Figure 11-11.

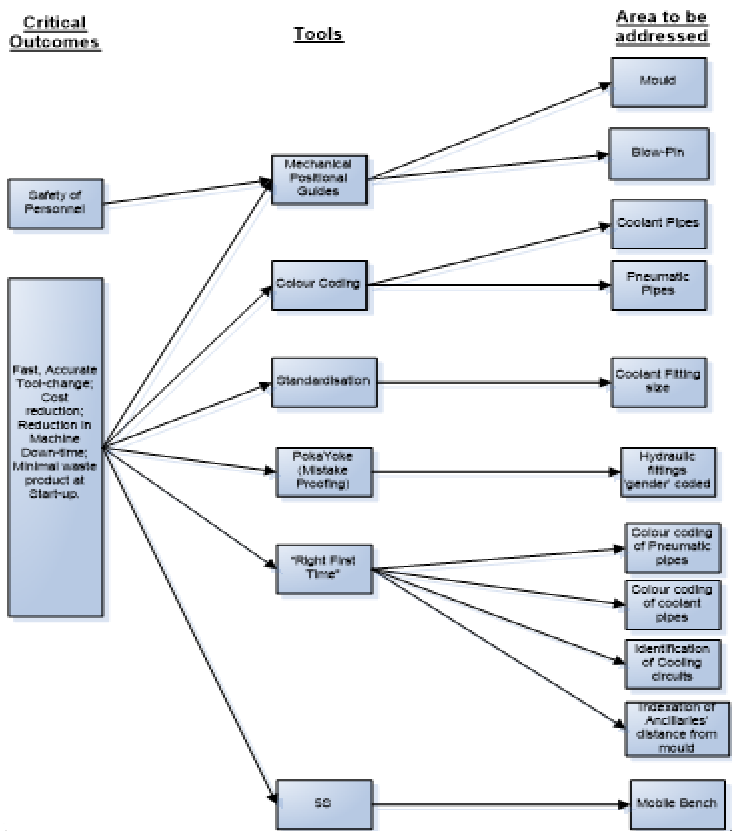

Figure 11-10 Critical to Quality tree

By the author

11.2.2.4 Improve Phase:

The improve phase of this project was largely 'Hands-on', including the physical addition of individual coolant valves, colour coding of coolant circuits by installing pairs of different coloured plastic discs at the inlet and outlet ports of each cooling zone. Colour coding of pneumatic pipes and fittings, and mistake-proofing of hydraulic fittings, by means of gender alignment – each hydraulic coupling had a pair of fittings, designated male, and female. Physical location aids were made up and fitted to ensure that the mould and blow-pin assemblies were fitted in precisely the correct position every time.

5S also became a part of the Improve phase, with trays and crates being used to 'house' components of specific tool-setups together.

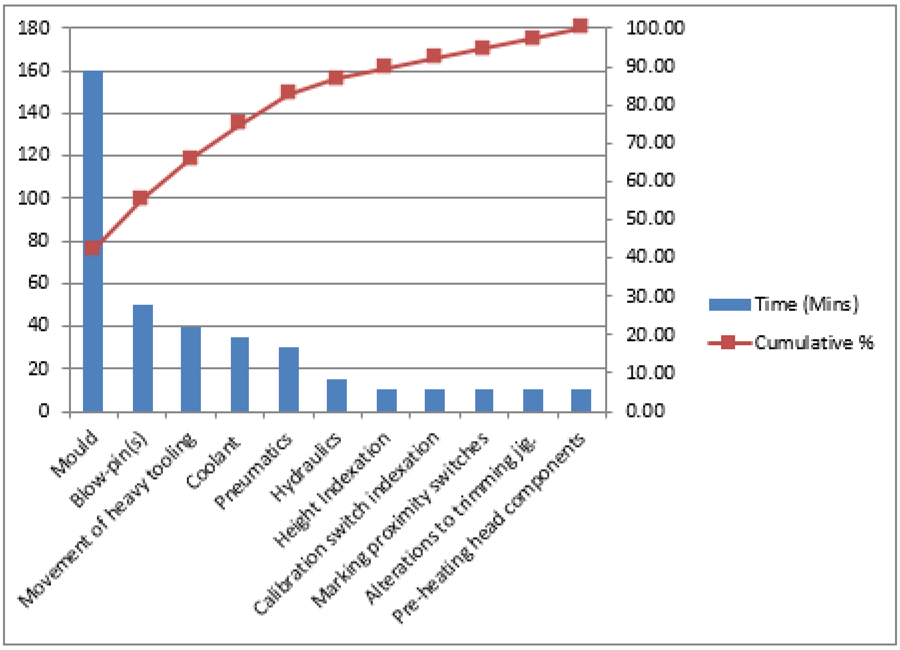

Figure 11-11 Pareto Chart for the SMED project

By the author.

11.2.2.5 Control Phase:

In the on-going control phase of this project, the following tools were used:

Process-sheets: these were individually drafted for the various tool-changes on an ongoing basis as they occurred; these detailed the tool-change process along with photographic images of the specific physical set-up. Copies of these process sheets were stowed in document-holders mounted adjacent to the machine specifically for this purpose.

Checklists specific to each set-up were also drafted; these, in conjunction with the process-sheets, ensured that each step of the tool-change was carried out, and in a timely manner. Unlike the timed-checklists used in the 'measure' phase of the project, these had the sole purpose of checking off those aspects of the tool-change were carried out, and in the correct order, and on each tool-change thereafter.

11.3 LSS in a large -scale food processing facility.

The author is currently employed by a large-scale international meat-processing organisation. The specific facility in question intakes raw materials such as fresh beef, frozen beef, beef fat, and dry goods such as rusk, soya, pea protein, chopped onions and seasonings. Output consists of a range of frozen hamburger patties for in-house brands, retail outlets and fast-food restaurants. Two production lines run parallel, with no crossover due to the possibility of cross contamination. While continuous improvements initiatives have been carried out over the years, not all these have fallen into the category of Lean Six Sigma. Most CI programmes have been project-based, and even these have been almost non-existent since the on-site project manager was re-assigned to supply-chain management and production planning in early 2020, at the beginning of the Covid-19 pandemic.

11.3.1 Project-based continuous improvement.

In 2018, several CI projects were instigated which, using the LSS DMAIC model, worked against waste, and realised substantial cash savings.

11.3.1.1 Operator Asset Care

The daily post clean-down assembly of two key items of equipment, as well as their tool-changes, dismantling, and ongoing low-level maintenance, lubrication etc, were handed over to the machine operators. These operators were given bespoke training on this work which had traditionally been caried out by maintenance personnel. The new arrangement had the effect of freeing up one maintenance person.

11.3.1.2 Stacker downtime.

Each of the two production lines contains a ‘stacker’, which is a device into which frozen burger patties fall from the end of a conveyor belt into one of four / five / six (depending on the product), drop zones and land, edgeways-on on a revolving metal worm, screw, or pigtail. These rotating pigtails cause the patties to be stacked side to side on one of the metal chutes below it. Operators lift a bundle of stacked patties from the chutes, and place them in polythene-lined packing case. An example of a stacker at work is depicted in Figure 11-12. A small amount of scheduled downtime is required to alter the stacker setup at product changes. Depending on the product size and production configuration, the stacker may be set at four lanes, five or six lanes, and this change-over falls under the remit of general maintenance.

Figure 11-12 Pattie Stacker

© *The Author*

Figure 11-13 Stacker change-over trolley.

© *The Author*

A survey in 2018 revealed that 15% of total plant downtime the previous year had been directly attributable to stacker downtime. Apart from scheduled changes, a problem existed where the stackers might come under pressure, and, but the time an operator would run to the patty extruder and alert the operator there to stop producing, the stacker in question would be completely jammed up.

A system of Andon lights and sirens was put in place, controlled with a manual switch by the stacker operators, which immediately alerts the extruder operator to cease production in the event of a back-up starting to occur.

Another system was put in place, using a purpose-made mobile trolley to hold stacker components that are not currently in use. As can be seen at Figure 11-13, this trolley has dedicated holding positions for components, and it can be readily identified if any component is missing. This 5S approach to storing the parts, along with single minute exchange of die (SMED) methods used in the tool change, and the reduction in jam-ups mentioned above, combine to result in a 50% reduction in stacker-related downtime.

11.3.1.3 Mixer operatives' partial re-deployment.

Another initiative conducted in the same year was the installation of remote-control panels close to the extruder units to control the ingredient mixers. This done away with the need for a dedicated mixer-operator on production runs of all products of 100% meat content.

11.3.1.4 Interleaving operatives' re-deployment.

Product aimed at the food-services market, such as fast-food take-aways, are packaged in polythene-lined cardboard packing cases, with greaseproof paper interleaves between layers of patties. An LSS project in the year 2018 led to the reimagining of the interleaving task, with the workload re-balancing allowing for the re-deployment two operatives.

11.3.1.5 Energy cost savings.

Savings in energy costs were made without any reduction in the use of energy. A re-evaluation of the Maximum Import Capacity level agreed with the electricity supplier from 2,000 kVA to 1,500 kVA led to an annual saving of €5,700. Meanwhile, an upgrade of power factor correction equipment reduced the reactive power draw, with an attendant annual saving of €10,000 on the electricity bill.

Another plan was at an advanced stage of preparation, but was put on cold-storage due to the outbreak of the Covid-19 pandemic. This constituted the removal of a gas-fired boiler used for water heating, at a cost of €30,000/year and replacement with a wood-pellet fired boiler instead, with an annual heating bill of €10,000. While this plan has not yet been enacted, it would raise the company's green profile, and save €20,000 per year on fuel, as well as attracting an annual green-business grant to the tune of €32,000 every year for 15 years.

11.3.1.6 Recipe change.

A slight change in the type of beef used made a sizable difference in revenue, with not more than a marginal decrease in product quality. An alteration in the ingredients used in the product led to a saving of €0.04 per kg.

11.3.2 Visual Management

Visual Management is employed to help with the correct execution of several processes throughout the business. Signs in the packaging area depict various levels of acceptability of product, rated by appearance. This allows operators to compare any given product piece with a photographic image, and decide whether the product is acceptable, borderline, or unacceptable, based on standards set by the customer. This is represented in Figure 11-14.

Another similar visual sign is erected in the area where raw material is de-boxed; a comparative visual inspection with the sign as shown in Figure 11-15 allows the operative to judge on the presence of any trimming defects or of several different kinds of contamination which may be present.

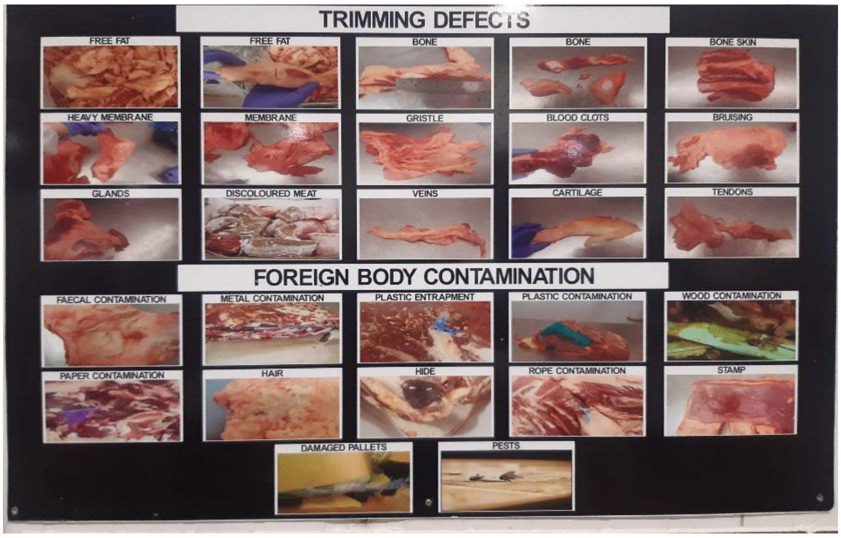

Figure 11-14 Visual Management sign depicting potential raw materials issues.

© *The Author*

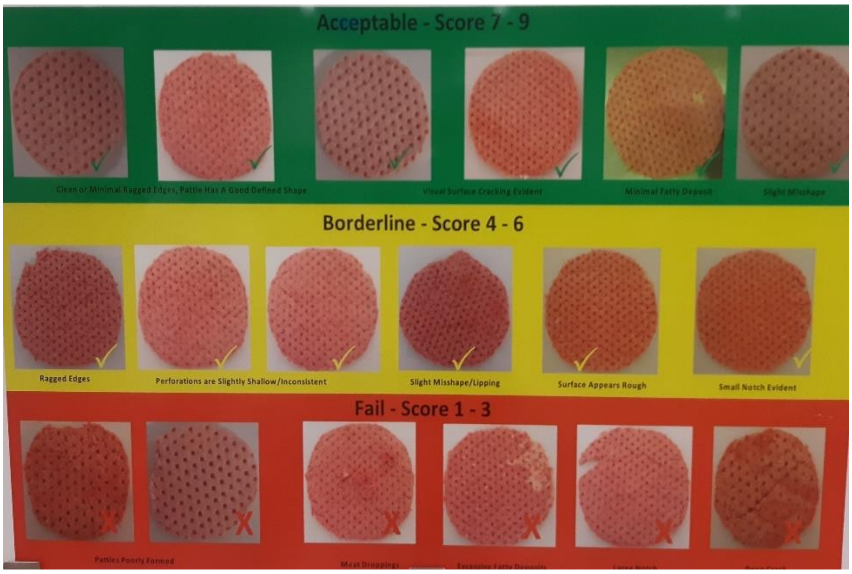

Figure 11-15 Visual Management sign depicting potential finished product issues.

© The Author

11.3.3 5S

Aspects of 5S are obvious throughout the facility; being as premier food producer, the plant is always maintained in a condition of cleanliness. Clutter is not accepted, and safety standards are kept to a high level.

Tools and tooling are stored in dedicated storage, with hand-tools being shadow-boarded in their respective toolboxes, (Figures 11-16 and 11-18), so they can be accessed immediately, and, more importantly in a food-production environment, a missing tool can be immediately identified. Also, extrusion-machine tooling is similarly stored, as seen at Figure 11-17.

Figure 11-16 Tools stored in shadow-board toolbox.

© The Author

A similar set-up is in place for storing tooling associated with the stackers, and not in use at any given time. (Figure 11-13). This system allows for immediate access to tooling, immediate knowledge of any missing part, and storage of the equipment in the most suitable orientation for washing and sanitising, as described at 11.5.1.2.

Tools, tooling, (Figures 11-16, 11-17, 11-18), as well as stores (Figure 11-20), and storage of equipment such as stepladders (Figure 11-19), are laid out in such a way so as their presence – or absence – is immediately visible, and can be accessed without clearing clutter out of the way first.

Figure 11-17 Machine tooling stored in dedicated, numbered racking.

© *The Author*

Figure 11-18 Tools stored in shadow-board toolbox.

© *The Author*

Figure 11-19 Ladders stored and locked in location.

© *The Author*

11.3.4 Reduction in the number of codes.

An initiative was carried out to reduce the number of lines (codes) of raw materials that had to be kept on site for day-to-day production. These included dry goods, such as soya, pea protein, and rusk, as well as frozen onions.

Figure 11-20 5S Stores layout.

© *The Author*

11.3.4.1 Dry ingredients

One example of a project-based CI initiative pertains to two different main types of dry goods, rusk and seasoning, of each of which several different varieties occurred. Each had been previously supplied separately under a specific product code, and the overall range of dry goods extended to over 100 different codes. One supplier was responsible for supplying the complete range of rusks, pea-starch, and seasonings, all of which were delivered in 20 kg paper bags.

After substantial in-house research, a meeting was held with the supplier of these goods, and a plan was established to trial the blending, in appropriate ratios, of rusk and seasonings in one bag, also pea-starch and seasoning in one bag. The pilot trial proved successful, and ever since, these products have been supplied pre-blended.

The positive effects of this initiative were as follows:

- A reduction in the number of codes for these products from >100 to 26.
- A concomitant reduction in inventory required on a day-to-day basis.
- Poka-yoke: this initiative points toward goods being pre-blended in the correct ratios, and has the effect of promoting mistake-proofing, as it cuts down the number of potential errors in weighing and adding dry goods to the product.

11.3.4.2 Meat

Fresh and frozen beef (and occasionally fresh and frozen pork) are the main ingredients used in the production of the product. The beef is sourced from the company's own abattoirs and boning-halls at different geographic locations, and from those of other companies. These are supplied sealed in polythene bags, in the case of fresh meat, and in cardboard cases in the case of frozen. Frozen fat is added in the recipe of one particular product.

Prior to a CI initiative similar to that for dry goods (section 11.5.4.1) being carried out on the main ingredient lines, numerous codes existed for these also. Two codes existed for each of four different categories of fresh meat, based on lean meat percentage, and a similar number of frozen meat categories, Codes also existed by breed, with four for Hereford, and six for Aberdeen Angus. One code existed for the Feather blade cut of meat, one for brisket steak and one for Chuck steak. One large customer also required three specific codes of meat, and one existed for fat. This added up to a total of thirty-three different types of beef that were required in a given week's production.

In a similar way to the CI exercise carried out on the number of codes of dry ingredients, the number of codes of meat/fat were cut from 33 down to 12 by conducting a re-assessment the recipes by the new product development (NPD) team, in conjunction with the customers.

While a similar tonnage of beef is required on a weekly basis as before, the reduction in the number of lines has led to a major enhancement in logistics, movement and storage of raw materials, and greatly improved the drive toward Just in Time (JIT) supply of materials, cutting down on the need to hold inventory.

RESULTS & DISCUSSION

12 Results

12.1 Lean Business Ireland – Lean Project Database.

12.1.1 Savings, cost reductions and percentage improvements.

Enterprise Ireland's initiative of Lean training to businesses under the umbrella of 'Lean Business Ireland' has been, to date, according to Lean Business Ireland's Lean Project Database (Lean Business Ireland, 2022) quite successful. Despite encountering a substantial lull in the years 2020 and 2021, the initiative has helped more than 330 businesses throughout the republic of Ireland to adopt Lean as a way of work, and embrace Lean manufacturing as a method of delivering better value to their customers.

According to the database, 19 out of the 65 food-related businesses who partook of lean training in this period, were willing to place a specific cash value on the effects of their continuous improvement (CI) drive. Among others, annual savings of €200,000, €173,000, €90,000, and €393,000 were reported, with one business reporting savings of over €500,000. Others referred to 'significant cash savings".

One business reported a saving of 95% in the time required to generate management reports, another a 15% decrease in maintenance downtime, another a 25% increase in revenue plus a 50% increase in profits, while yet another stated that streamlining due to Lean had led to a reduction of 50% in floor-space required, freeing up effectively ½ of their production space. Product changeover waste reduction of 80% and changeover time reduction of 66% were also mentioned. One business reported a 100% increase in output capacity. Significant percentage reductions in costs and increases in productivity and profitability were specifically mentioned in reports from 28 of the 65 businesses involved. While not all percentage improvements were as impressive as others, every saving is a step in the right direction.

12.1.2 Other improvements

Other, perhaps less-tangible benefits reported included: reduced human error, more projects, greater training compliance, better alignment, time savings, better staff morale, improved accountancy efficacy, reduced waste, energy savings, reduction in staff illnesses and accidents, improved flow, reduced overtime payments, increased new product development (NPD), better audit-ready status, business growth, regain of lost market share and the ability to re-assign staff, among many, many others.

12.2 SMED Project

The following constitute the results from the author's SMED project (described in section 11.4, carried out on one polymer extrusion blow-moulding machine:

12.2.1 Overall benefits:

- Decreased machine downtime.
- Improved product flow
- Decrease in maintenance-team hours per tool change.
- Decrease in lost machine-operator time during tool-change.
- Decrease in quantity of raw material lost to heat-degradation during down-time – leading in turn to a decrease in waste at start-up.
- Decrease in wasted electricity during downtime.
- Reduced need for inventory.
- Reduced customer delay.
- Higher productivity.
- Improved competitiveness and profitability.
- Reduced risk of injury to maintenance personnel.
- Allow shorter production cycles.
- Improve production planning flexibility.

12.2.2 Revenue savings due to SMED programme

The average revenue generated per hour on this machine was €549.34 This hourly rate also applied for loss of revenue when the machine had down-time, and was also applied as a saving to any hour by which the tool-change process is shortened. The mean average pre-improvement time per mould change was 7.1 hours, while that, post-improvement was 5.5 hours. This constituted an overall mean average reduction in downtime due to tool change as 1.6 hours. With four maintenance operatives involved, at an average pay-rate of €20.82 per labour hour, the average labour cost per mould change was €591.00.

(1.6*4=) 6.4 hours * €20.82 + 1.6 hours *594.34 = €1084 savings per tool-change

€1084* 35 (tool-changes/annum) = annual saving of €37,950.00 / annum. This figure is for one single machine in a facility with 17 such machines, some larger, some smaller. Clearly, a similar plant wide SMED drive would realise significant savings each year.

12.3 LSS in a large -scale food processing facility.

12.3.1.1 Operator Asset Care

The Operator Asset Care programme as described at section 11.5.1.1 led to an annual saving of €35,000.

12.3.1.2 Stacker downtime.

The 50% reduction in stacker-related downtime, described in section 11.5.1.2, realised a saving of €45,000 for the remainder of 2018, with a projected annual cash saving of €90,000.

12.3.1.3 Mixer operatives' partial re-deployment.

The partial re-deployment of mixer operatives, as described in section 11.5.1.3, resulted in an annual cash saving amounting to €60,000.

12.3.1.4 Interleaving operatives' re-deployment.

The re-deployment two operatives due to the work-rebalancing initiative around the interleaving of the product gave an annual saving of €40,000.

12.3.1.5 Recipe change.

The recipe change, at section 11.5.1.6, led to a saving of €0.04 per kg of ingredients, realising a saving in the remainder of 2018 of €142,000, and an ongoing annual saving of €300,000.

13 Discussions

13.1 Overview of the use of Lean Six Sigma

Lean Six Sigma (LSS) is a fusion of Lean, a system of tools whose primary aim is increased efficiency through the elimination of waste, and Six Sigma, a method of increasing efficiency through the elimination of variation. Lean is made up of a set of tools which can be used, discretely or severally, to initiate and sustain a continuous improvement (CI) drive. As Lean is very much easier to initiate, it is usually the first step in an LSS Lean tools, particularly those generally used in the early stages of a CI initiative, such as 5S, SMED and root-cause analysis, which are practical and straightforward to uses, and will usually yield good results by remedying ‘low-hanging fruit’ issues. Pareto analysis would generally suggest that identifying and tackling the ‘significant few’ problems ahead of the ‘trivial many’ will result in substantial improvements in efficiency, solvency, and profitability. The remaining tools in the lean toolkit will generally be used further down the line to begin tackling the least trivial of those ‘trivial many’.

The Six Sigma aspects of LSS, being based more-so on complicated statistical analysis, will habitually be initiated at a much later stage in the LSS journey – often several years later. When used in conjunction with Lean, as LSS, it generally has the effect of ‘polishing up’ the process after Lean has been used to tame it.

Lean, Six Sigma and LSS have been used with varying degrees of success in manufacturing and engineering industries for many years – some of the successes have been extraordinary. The level of success will depend on numerous issues, not least of which being the level of buy-in for the concept at all levels in the business. If management do not embrace CI because they are too busy doing the business of doing business, or because they consider it a challenge to the way things have traditionally been done, if floor-level operatives do not embrace it because they consider improved efficiency to be a threat to their jobs, or because someone has not taken the time to explain it to them in a language they understand, then the chances of success are severely diminished.

13.2 LSS in the food industry

13.2.1 Overview

Research and experience would suggest that, while Lean, Six Sigma and Lean Six Sigma (LSS) have, for many years, been mainstays in the battle for continuous improvement (CI) in the traditional engineering manufacturing industries; the volume of research carried out in this field would suggest that the food industry has, in general, been well behind the curve in embracing its benefits. This is amply demonstrated in

(Costa, et al., 2018), who found relevant research papers being available over much of the first decade of the 21st century averaging around two per year. This number increases significantly across the years 2011-2017.

LSS would appear to be a misnomer for the CI activity that occurs in much of the food industry – Lean is much more used than is Six Sigma. The advantages of Lean, i.e., the elimination of waste, is greatly beneficial in this field. It represents a reduction in wasteful processes, scrap product, and re-work, often through little more than the application of common sense, and occasionally a small cash outlay. For any food business starting out on the LSS journey, two aspects of Lean, namely 5S and SMED, are strong, cost-effective initiatives which will usually tackle the lowest of the low-hanging fruit, and realise savings in waste, resources, money, and time.

In the food industry, the elimination of variation associated with Six Sigma will not, however, pay the same returns on the time, energy and resources invested, certainly not before the greater bulk of the issues which can be sorted using Lean are so achieved. The reason for this, as compared to a similar return on investments in, for example, an engineering business, come down to how much quality is the customer willing to pay for. If we compare, for example, the necessity to have a size tolerance applied to products, then obviously, that for the diameter of a hydraulic ram which controls the rotor pitch of a helicopter is going to be considerably tighter than the tolerance for the diameter of a sausage. This draws a strong distinction between the usefulness of Lean in the food industry and that of Six Sigma, particularly in the earlier stages of CI.

Added to this is the fact that the food industry faces stringent food safety regulations, and food hygiene conditions, both of which are likely to feature more prominently in a quality control (QC) department's workload and list of priorities than is CI (Costa, et al., 2020). (Azalanzazllay, et al., 2020) (Azalanzazllay, et al., 2022) also suggest that the food industry is, in general, more conservative in nature than other manufacturing industries, and indeed service industries, and (Costa, et al., 2020), for this reason, have traditionally been more reticent to embrace CI. All also cite the necessity for cleaning between batches as an impediment to the implementation of LSS, with particular emphasis on the set-up and changeover time cleaning regimes not being conducive to SMED techniques being utilised.

(Costa, et al., 2020) also stress the point that the seasonal and perishable nature of raw materials to the food industry severely curtail the capacity for Just in Time (JIT) supply, and lend themselves better to the practice of manufacture-to-stock. Here, for example, the notion of Takt time may not be as readily applicable to the production of oven-ready turkeys as it is to that of passenger aircraft.

13.2.2 Business size.

Allied to the above, is the fact that many small and artisan food businesses are springing up globally, and, in many cases, the owner is also the only employee. In other cases, these businesses employ a small number of people. While the notion of LSS might hold great appeal, it is often not practical for those producing to a small scale to add Lean to their already overwhelming list of tasks.

At first sight, Lean would appear much more likely, for this reason, to appeal to larger businesses, who are more likely to have spare person/hours to devote to such a programme. It is worth pointing out, though, that most production staff of many large food-processing businesses – particularly in the case of Ireland and the United Kingdom – may not have fluency in the vernacular language, as many will have travelled from abroad for work. With this in mind, it has been suggested that management may not see a clear path to the introduction of LSS on a top-down basis, if they believe that the nuances may not penetrate all the away to those at Gemba. If these, and other management-staff difficulties, can be surmounted, (Azalanzazllay, et al., 2020) suggests that team building is the secret to overcoming the 'resistance to change' that naturally accompanies the introduction of any new ideas or concepts in the workplace. They suggest that empowering employees to take ownership of these concepts is normally more productive than imposing them as a *fait accompli*. (Azalanzazllay, et al., 2022) suggests that the probable most successful approach is to appoint an LSS champion, who will form teams for each aspect of the CI initiative, and bring employees at all levels along, getting programme buy-in from everyone concerned.

(Laureania & Antony, 2019) cite the quality guru W Edwards Deming, in that quality is ultimately the responsibility of senior management, and this opinion is shared by (Vanany, et al., 2020), while (Reid, 2019) suggests that a top-down approach is slow, costly and inefficient, and that, ideally, every employee must be taught to have a lean mindset and be a lean-thinker.

Information garnered from the Lean Business Ireland Lean Prject Database (Lean Business Ireland, 2022), however, would suggest that, of 65 food businesses to whom Lean training was delivered between 2017 and 2021 under this programme, almost two thirds fell into the ‘Micro’ or ‘Small’ categories, i.e., having 50 employees or less. Of the remainder, approximately 21% fell into the medium-sized category (50-250 employees), while only around 13% were deemed large businesses (over 250 employees).

While this data would suggest a greater interest in LSS tarining in smaller businesses, this may be due to the fact that, as stated previously, a smaller business is less likely to have spare personnel capacity, and may draft in training from external sources. Another probable reason is that, in many cases, smaller organisations may be unable to afford such training, but that it may be subsidised or fully covered by local enterprise boards. Often, the enterprise boards will be the bridging step between small and emerging businesses and the notion of LSS.

13.2.3 Business ownership profile.

LSS programmes appear to be more readily embraced, as a percentage, in the major dairy processing facilities throughout Ireland than in meat/fish processing plants. This may be because the dairy industry operates on significantly fewer sites, and is in the hands of fewer organisations. However, it seems more likely that, being co-operatively owned, the dairy sector is more open to early innovation of novel business practices than might be the meat-processing industry, which is almost exclusively family owned. In many cases, the traditional family-run businesses are still managed in a traditional way, where the age-old mantra of ‘I’ll tell you what to do, and you will do it’ would appear to achieve immediate, if not necessarily optimum, results.

13.3 Statistics.

It is impossible to state with accuracy when Lean, Six Sigma or LSS were first utilised in the food industry, to what extent they are currently used, or what might be their expected level of application in the future. This is due, not only to the extremely heterogenous nature of the food industry itself, but also to the infinitely variable number of ways in which these tools may be applied, the dearth of published data stating benefits directly attributable to such CI drives, and also the unpredictability of just how continuous will be the nature of continuous improvement in an organisation into the future. It is also not possible to gauge the level of commitment that any specific business has invested or is willing to invest in their CI on an ongoing basis without being in possession of their records. As with so many concepts, CI often drives tend to be shelved if returns are not seen early, if the business is very busy, or if management buy-in is insufficient.

13.3.1 Previously published work.

It is, however, possible to state known statistics regarding the numbers of scholarly publications on the subject found in searches over a number of years. It is also possible to furnish known data regarding training uptakes in CI matters, and publicly-stated benefits returned by the implementation of the outcome of such training.

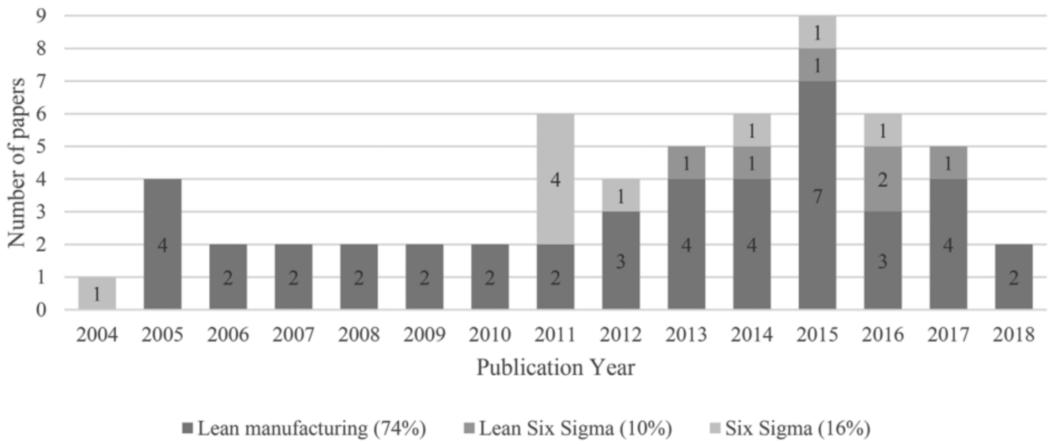

Figure 13-1 Growth of Lean, Six Sigma and LSS publications pertaining to the food industry

(Costa, et al., 2018)

When (Costa, et al., 2018) were searching for published material to cite in their work, they found that there had been a sizeable increase in the number of published, peer-reviewed works in the years leading up to that time (2018), from a very low base in the earlier part of the century. (Figure 13-1)

This is also depicted, with the addition of a cumulative line-chart at Figure 13-2, which illustrates the year-by-year publication of the aforementioned papers, and demonstrates the sharp rise in the availability of such material across the years 2004 to 2018. As the (Costa, et al., 2018) work was originally submitted in early April 2018, it is a fair assumption that further publications, including their own, were available before year-end.

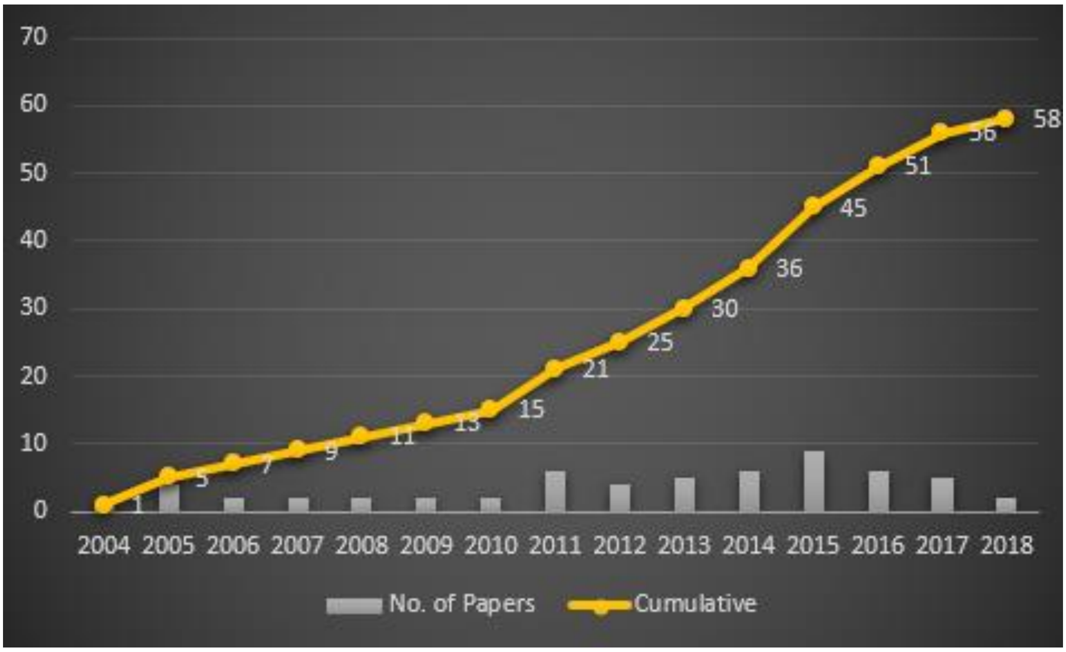

Figure 13-2 58 papers cited by (Costa, et al., 2018), by year, and with a cumulative line chart.

By the Author, adapted from (Costa, et al., 2018)

Figure 13-3 Distribution of 58 pertinent papers by geographical location.

(Costa, et al., 2018)

(Costa, et al., 2018) also categorised the 58 available papers that they found pertinent to their subject matter, by geographical origin (Figure 13-3). While this in itself does not in itself implicitly signify that CI is used in the food industry in the same proportions, it is interesting that, while 30% of papers originated in Asia, the ‘spiritual home’ of Lean, only 2% originated in North America, where Six Sigma also has its roots, and greater than 50% of papers originated in Europe.

Similarly, (Muñoz-Villamizar, et al., 2018), while researching for their work on combining Lean concepts with sustainability, searched for articles under four headings. Using the specific search terms listed they found the following number of papers pertaining to each.

- 66 papers under ‘Lean and green’
- 27 papers under ‘Green in agri-food sector’
- 20 papers under ‘Lean in agri-food sector’
- 4 papers under ‘Lean and green in agri-food sector’

Figure 13-4 charts the frequency of these publication by year from 1995-2017.

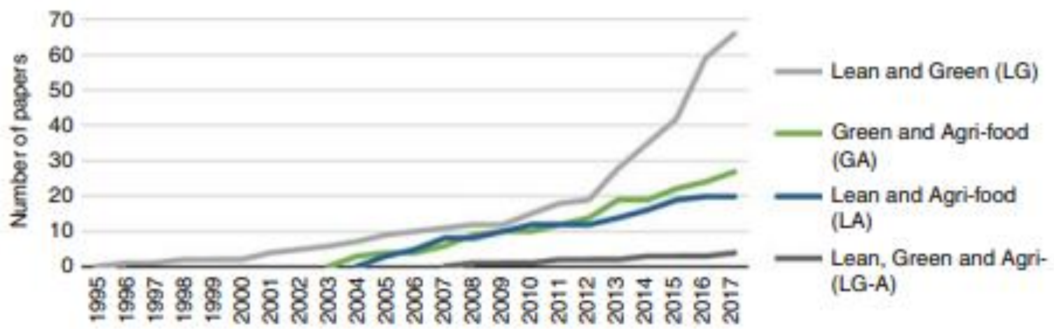

Figure 13-4 Cumulative frequency of the number of published articles

(Muñoz-Villamizar, et al., 2018)

This shows that published work found by them pertaining to Lean in the Agri-food sector only begins in the year 2004, but plots a reasonably steady increase for most years since that time up until the year prior to their own work’s publication. They do not specify in the text of their work precisely how many publications appeared in which year, but a trawl through their reference section yields this information.

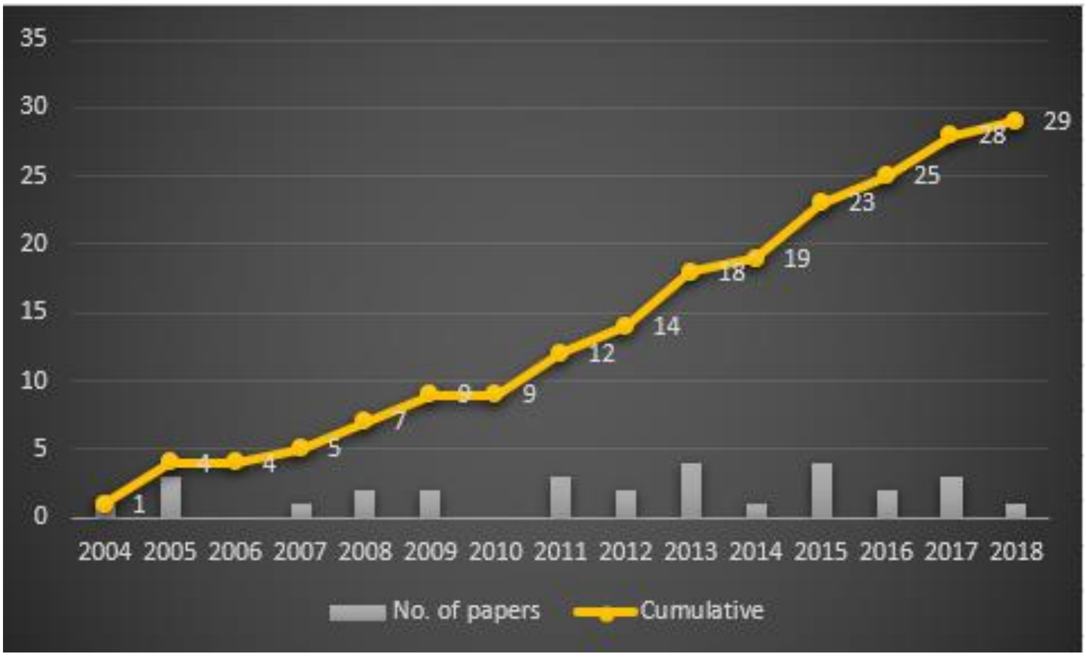

Figure 13-5 29 papers specific to the food industry cited by (Muñoz-Villamizar, et al., 2018), by year, and with a cumulative line chart.

By the Author, adapted from (Muñoz-Villamizar, et al., 2018)

In actual fact, 29 publications cited by them contains the word 'food' or similar in the title. These have been noted by year of publication, and been plotted into a chart, as seen at Figure 13-5. This, again, demonstrates that, starting form a low base in 2004, there has been no massive increase in the number of publications year on year, with none of the cited papers published at all in two of these years, and a maximum of four in any of the years named.

13.3.2 Lean Business Ireland initiative

Statistics regarding the benefits derived from this initiative are listed in section 12.1

13.3.3 SMED project

Statistics regarding the benefits derived from this project are listed in section 12.2

13.3.4 CI initiatives at he authors place of employment.

Statistics regarding the benefits derived from this project are listed in section 12.3

CONCLUSION & FUTURE WORK

14 Conclusions

14.1 Summary

Research carried out during the progression of this work consisted of examination of previously published and peer-reviewed work, as well as a database of lean training in businesses in the republic of Ireland over several years. Added to this was information regarding CI initiatives carried out by the author’s current and previous employers; one involved in the food industry and the other manufacturing food-grade containment, largely to the food and pharma industries.

Between the 1920s and the 1950s, the Japanese developed that which would become ‘Lean’. Their reason for doing so was so they might compete with much superior business models in the USA.

In the 1980s, the Americans developed Six Sigma. They did so in order that they might compete against much superior business models in Japan.

In the early 2000s, it became apparent that, rather than having two competing CI approaches, it was more effective to combine both into one synergistic strategy. Hence, the notion of Lean Six Sigma was born.

While Lean, Six Sigma or LSS have become pillars of CI in many manufacturing businesses globally, it has been a long slow slog to induce food producers to take these concepts on board. However, over the course of the last decade-and-a-half or so, interest in the concept has taken wings. But while Lean tools have come to the fore in many food-related businesses, and with very good results, of the Six Sigma tools in use in this sector, only the ‘define, measure, analyse, improve, control’ (DMAIC) cycle and ‘value stream mapping’ (VSM) tools appear to serve a useful purpose. This is because the more statistics-based tools are used in other industries to hone precision, which is largely superfluous to requirements in this field of production. DMAIC and VSM can be quite readily used in conjunction with some or all the items in the Lean toolbox as required.

In practical research, the author found that using Lean tools such as 5S, single minute exchange of die (SMED), Just in Time (JIT) delivery, visual management, DMAIC, Pareto analysis, Root Cause Analysis, check-lists and improved automation could all be used, and all in a hands-on, practical sense, to reduce waste, and remove, improve or streamline processes, ultimately aiming toward eliminating anything that did not add value for the final customer.

The JIT – pull production – production levelling facets of Lean do not lend themselves readily to all aspects of the food industry, however. Unlike in, for example, engineering manufacturing, it is not possible to kill a pig in response to the demand at supermarket level for a pack of rashers. A certain amount of market anticipation must be factored. This is true across the food industry, and all the more-so in the case when raw material supply and/or markets are cyclical or seasonal. A turkey producer is unlikely to rear and slaughter as many birds in February as in December or the run-up to Easter. Similarly, as a beer brewer might not try to purchase barley from the original supplier in April, storage will have to occur at some point in the production cycle. The grain will need to be dried and stored until it is required, or the beer will have to be produced in large quantity when the grain is available following the harvest, or both.

While beef-on-the-hoof may be available all year round, the laws of supply and demand make the price cyclical. Grain, fruit, potatoes, certain vegetables etc are available ex-field at only a short window of the year, and must be stored at some point in the production process, or between the field and the final consumer if no processing is occurring. Meanwhile meats such as pig meat and chicken, and foods such as milk and eggs, are generally available all year-round, and can be processed at a rate something closer to Takt time than can many others.

In general, due to seasonality of both supply and demand, food production 'levelling' will never be fully suited to pull-type production. There will always be a necessity for either produce to stock or stock to produce in many food lines.

The author concluded that, while LSS, or elements thereof, may play a good, useful, profit-boosting, quality inducing and even essential role in improving the food industry up to a certain point, it will never be the close fit for this industry as it is for other manufacturing industries.

14.2 LSS in the food industry.

The purpose of this work was to investigate, through research, the answer to the following questions:

- Is the use of LSS as prominent in the food industry as in other manufacturing industries?
- Is there scope for improving the use of LSS in the food industry?

The research suggests that, compared to other manufacturing industries, the food industry was somewhat 'late to the ball' regarding these forms of CI for the reasons as listed:

- Any food business' Quality Control (QC) department, the traditional home of CI, has normally been heavily occupied with other aspects of quality, namely food safety regulation conformity, food hygiene, microbiology, HACCP (See Appendix B), and protection against cross-contamination and allergens.
- Food businesses remain largely privately, often family, owned, except for the dairy processing plants, which are largely co-operatively owned. Traditional methods tend to lend themselves less to new work methods.
- Much of the meat-processing sector in Ireland, and indeed the UK, is staffed at process level largely with personnel who don't have English as their first language. Some may barely speak English at all. This is largely seen as an impediment to initiatives with a 'top-down' structure, unless management are prepared to invest significantly in multi-lingual training.

Therefore, it is fair to say that, while CI initiatives in the food industry have traditionally been project-based, there has been a sizeable increase in the instances of Lean training carried out with food-processing businesses over the last 15 years or so.

LSS, is, by definition, comprised of both Lean and Six Sigma. While Lean tools are commencing to take root in the food-processing industry, and are helping to reduce wastefulness and save money, a few elements of Six Sigma such as 'define, measure, analyse, improve, control' (DMAIC) and value stream mapping (VSM) are also useful tools. However, the more 'statistical-control' based lean tools such as statistical process control (SPC) charts probably constitute a drive towards more perfection than the customer is willing to pay for. In an industry where the quality, safety, hygiene, traceability, and appearance of the product far outstrip the necessity for absolute precision in shape or weight, the more statistics-heavy aspects of Six Sigma are unlikely to carry as much importance. It is probably accurate to state therefore, that, while Lean is only in its infancy in the food industry, and has a considerable future therein, only certain elements of Six Sigma appear relevant, and LSS 'as a whole' is unlikely to become as prominent in the food industry as they currently are in many other manufacturing industries.

However, the second question is aimed at present day circumstances, and not attempting to predict the of the future. As things currently stand, it is fair to say that CI aspects of Lean, and some of Six Sigma, have considerable scope for future expansion in the food industry.

As for how the future unfolds, that is yet to be seen. It is probably fair to extrapolate from experience that, as continuous improvement remains continuous, there will be cash savings to be made. According to Pareto principles, these savings, coupled with increase in quality, initially large, should be ever-diminishing, and, although CI is touted as a never-ending phenomenon, the law of diminishing returns states that the required input to an improvement will, realistically, at some stage, exceed the expected output.

For any business involved in CI, it remains a learning process.

And, to quote the American quality guru W Edwards Deming, "Learning is not compulsory……. neither is survival." (The Deming Institute, 2022)

14.3 Further work.

There would appear to be considerable scope for further work in this subject area. While the notion of continuous improvement (CI) is not, by any means, a new one, considerable progress has been made since Sakichi Toyoda first asked his five whys, and applied Jidoka to his automatic weaving looms. While CI has gone from strength to strength in engineering manufacturing, and has slowly followed suit in the food-processing sphere, academic work specific to Lea Six Sigma (LSS) in the food industry has been in less than plentiful supply until very recently.

While Lean has commenced to bloom, if somewhat belatedly, in the food industry, there is much apparent scope for a tailored version of Six Sigma which might be specifically fitted on a product-by-product basis. This suggests that further work in this area needs to be carried out at a practical level, and peculiar to the product in question, prior to being logged at an academic level.

Undoubtedly, just as success breeds success, as more and more academic research is conducted in this field of study, that will lay the foundations for yet more of the same. It seems likely also, that, just as the numbers of food – and non-food – businesses in Ireland which were embracing Lean training, under the Lean Business Ireland scheme, were on a skyward trajectory, at least until the Covid-19 pandemic put a blip in the graph, that this trend will continue well into the future. It also appears probable that this trend will be replicated in most of the developed world also.

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APPENDICES

16 Appendices

16.1 Appendix A – Permission regarding use of Lean Project Database.

Transcript of an email sent to Enterprise Ireland dated 09 October 2022, on foot of the fact that the data contained in the document was in the public domain, but with the caveat that material may not be altered, published or reprinted in any form without written permission from Enterprise Ireland:

Dear Sir / Madam,

While conducting research for an MSc thesis on the application of Lean Six Sigma in the food industry, I encountered the 'Lean Business Ireland' Lean project database, Version 08/09/2022, at the URL https://www.leanbusinessireland.ie/lean-project-database/ referring to work which had been carried out with businesses throughout Ireland in the years 2017-2022.

I wish to apply for permission to use data contained therein for this purpose; obviously I would respect the anonymity of your business and the companies in question unless specifically permitted otherwise.

Thank you.

Kind regards,

Paul McElroy

==

Transcript of an email received from Enterprise Ireland dated 11 October 2022:

Hi Paul,

In respect of your email dated 09th October 2022.

My manager here in Enterprise Ireland, Ruairí Ó hAilín, has indicated his support as below.

"I am very supportive of this use of the data. I would ask him if possible if he wouldn't mind us getting access to his output for our own learning, although that is not a pre-condition for use of the data".

The anonymity of the data is important.

Regards,
Stephen

Stephen Reid
Operational Excellence & Digital
Enterprise Ireland

16.2 Appendix B – A definition of HACCP

HACCP Based Procedures

Q. What is HACCP?

HACCP stands for Hazard Analysis and Critical Control Point. A food safety management system based on the principles of HACCP is a systematic approach to identifying and controlling hazards, whether microbiological, chemical or physical, that could pose a threat to the production of safe food – in simple terms, it involves identifying what could go wrong in a food system and planning how to prevent it.

Figure 16-1 What is HACCP?

(Food Safety Authority of Ireland, 2016)