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Implementing a customised Lean Six Sigma methodology at a compound animal feed manufacturer in Ireland

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Abstract

Purpose – This study aims to propose a tailored Lean Six Sigma framework providing an accessible Lean Six Sigma methodology for compound feed manufacturers with the aim of mitigating rising costs and increasingly complex demands from customers.

Design/methodology/approach – A Lean Six Sigma framework was designed combining Lean value stream mapping and Six Sigma structured problem-solving with a case study in an Irish compound feed manufacturer.

Findings – The study found that the Lean Six Sigma implementation framework provided a simplified approach, which fitted the resource availability within compound feed manufacturing.

Research limitations/implications – The study is limited by the constraints of a sole case study in providing empirical evidence of the effectiveness of the framework. Nevertheless, a conceptual Lean Six Sigma model is proposed, which will assist compound feed manufacturers implementing a continuous improvement approach.

Originality/value – This paper proposes a simplified approach to the implementation of Lean Six Sigma in agricultural compound feed manufacturers and in small and medium-sized organisations. This is the first such study in Ireland and will add to the body of work on Lean in agriculture and aid other agri-businesses and compound feed manufacturers in understanding how Lean Six Sigma can benefit.

Keywords Lean Six Sigma, Value stream mapping, DMAIC, Compound feed manufacture, Agri-food

Paper type Case study

Abbreviations

CFM = Compound feed manufacturing;
CI = Continuous improvement;

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CSVSM = Current state value stream map;
DMAIC = Define, measure, analyse, improve, control;
FIFO = First in first out;
FSVSM = Future state value stream map;
HACCP = Hazard analysis critical control point;
IGFA = Irish Grain and Feed Association;
JIT = Just in time;
JQTM = Japanese total quality management;
LSS = Lean Six Sigma;
LSW = Leader standard work;
QMS = Quality management systems;
SIPOC = Supplier, input, process, output, customer;
SME = Small to medium enterprise;
TPS = Toyota production system;
TQM = Total quality management; and
VSM = Value stream mapping.

1. Introduction

Compound feed manufacturing (CFM) is an important part of the food supply chain and the broader agri-food industry. The sector produces functional animal feeds delivering protein, minerals and vitamins for balanced healthy diets for farm animals, and supporting farm productivity through feed efficiency. In Ireland, CFM is made up of small and medium-sized enterprises (SMEs) and co-operative societies, including many independent and family-owned rural businesses and feed mills. The sector has recorded slow and steady growth over the past decade, recording 2% growth on average per annum, and 5.6 million tons production in 2021 (Irish Grain and Feed Association, 2022). It is projected that the revenue from the manufacture of prepared feeds for farm animals in Ireland will amount to approximately 1,951.72 million US Dollars by 2025 (Statista, 2021).

However, maintaining growth is challenging due to the impact of the COVID-19 pandemic and Brexit on the industry. Disruption of transport systems through displacement of people and equipment has resulted in rising costs by as much as 300%. This situation is exacerbated by Brexit, which has contributed to increased logistics costs and extended lead times (Irish Road Haulage Association, 2022). Environmental costs are an additional consideration as government tax policy is designed to encourage sustainable operations. Lastly, energy security and costs are also challenged by complex geopolitical concerns and uncertainty due to Russia's invasion of Ukraine. The combined effect from these challenges is to add immediate costs to CFM operations categorised as increased raw material input costs, increased logistics costs both in transport and administration and increased energy costs (McQuinn *et al.*, 2022). To remain competitive, compound feed manufacturers must protect their customer value by applying improvement methodologies with the objective of reducing costs and lead times to mitigate the impact of external pressures. Many agri-food (Csikai, 2010) and food processors (Dora and Gellynck, 2015; Powell *et al.*, 2017) have started to implement Lean Six Sigma (LSS) methods. The evolution of Lean and Green in recent years has aided the improvement of environmental sustainability and sustainable performance (Antony *et al.*, 2022). Lean and Green has synergies related to waste reduction, lead time reduction, product design and the use of various approaches and techniques to manage people, organisations and the supply chain (Caiado *et al.*, 2018).

However, LSS within the food industry is still very much a growth area (Costa *et al.*, 2018). There are limited studies that have applied Lean in agri-food environments and indeed in a CFM environment. The previous study investigated various LSS methodologies to minimise waste and improve process cycle efficiency in an animal feed products business (Siregar *et al.*, 2020). Another study applied Lean tools to support a green supply chain and logistics management initiatives in a Greek agri-food manufacturing (Folinas *et al.*, 2014). To date, there have been no studies involving the application for LSS to any Irish CFM facilities. This study is based in an Irish CFM that forecasts production volumes growth by 20% over the next three years with expansion in Asian and American markets. However, the rising cost of goods had become a constraining factor for achieving growth. Having an LSS approach would deliver a competitive advantage for the Irish-based CFM in this study by reducing costs through reduced process waste and variation. Thus, the research questions (*RQs*) for this study are:

RQ1. How can LSS be successfully applied in the compound feed manufacturing SMEs?

RQ2. What is the most effective LLS tool to reduce inventory and lead times through the introduction of a continuous improvement culture in CFM?

The use of value stream map define, measure, analyse, improve, control (VSM DMAIC) for sustainable manufacturing analysis is not well defined due to the complexity of symbolic visualisation of identified criteria (Duflou *et al.*, 2012; Faulkner *et al.*, 2012). Thus, this work presents a comprehensive effort to develop a methodology for sustainable VSM to evaluate socio-economic and environmental CFM performance. To the authors' knowledge, this is the first study that considers the integration of DMAIC model with the VSM to reduce the operational complexity in the CFM SMEs. This research aims to mitigate rising product costs and optimise operational processes of the compound animal feed production to meet the increasing quality demands from customers.

The literature review is outlined in Section 2, the methodology is explained in Section 3, while Section 4 presents the case study results exploring the implementation of an LSS model at a feed manufacturing site. Lastly, Sections 5 and 6 elucidate the discussion and conclusion.

2. Literature review

Recent literature emphasises the application of Lean manufacturing practices to food processing industries to improve operational efficiencies (Trubetskaya *et al.*, 2022; Powell *et al.*, 2017). The Irish Grain and Feed Association (IGFA) confirms that companies are primarily interested in regulatory and technical product issues and have not promoted quality process improvement approaches to date (Irish Food and Grain Association, 2022). The previous work has evolved product innovation with customer requirements by moving from pure protein towards animal nutrition and welfare within the CFM sector (Csikai, 2010; Köster, 2015). However, manufacturing methods do not appear to have advanced. The previous research on LSS tools in the CFM is limited to VSM application (Utama *et al.*, 2022; Siregar *et al.*, 2020).

LSS tools could complement CFM requirements by improving the flow of bulk material through milling and blending and the precision required for product composition. LSS simultaneously provides an operations management structure, embedded problem-solving behaviour, customer-focussed quality processes with reduced cost of waste and increased efficiency (Browning and Heath, 2009). The approach advances existing innovation infrastructure familiar to CFM by broadening responsibility for quality to workers and providing training and problem-solving tools to ensure they can succeed. The focus on general material flow and precision matches critical milling and blending processes within the CFM. Therefore, LSS implementation in this industrial sector can be an effective development tool that enables operations to change from one way of working to another (Laureani and Antony, 2017). The combination of practical management and operator tools makes LSS a good choice to advance feed manufacturing and prepares mills to face new market challenges. In Ireland, CFM is predominantly the domain of small to medium-sized operations (Irish Grain and Feed Association, 2022). The lack of literature relating to LSS within CFM suggests that the predominance of SMEs in the sector could be a constraining factor. The previous research suggests resourcing and financial challenges are primary reasons for unsuccessful LSS implementations (Soundararajan and Reddy, 2019; Moya *et al.*, 2019; Stankalla *et al.*, 2018; Timans *et al.*, 2016). SMEs typical of CFM can often lack management commitment and resources, both of which are requirements for success (Reynders *et al.*, 2020; Alefari *et al.*, 2017; Dombrowski and Mielke, 2014).

Literature indicates that LSS tools can be taught, but implementations are difficult to sustain without supportive leadership (Antony *et al.*, 2022). Training can be organised to introduce concepts and tools, but Lean management is often the hardest thing to get right (Patel and Patel, 2021). LSS is about practicing systematic and continuous improvement experiments. This behaviour must be supported and resourced to sustain the approach (Moya *et al.*, 2019). LSS tools can be challenging to integrate in SMEs when the organisational values are not clearly defined (van den Berg and Wilderom, 2004). Leadership and supervision play a dominating role in the definition of organisational values (Douglas *et al.*, 2017; McCaffrey *et al.*, 1995). A blueprint of tiered management meetings and visual controls that integrates LSS tools can create a system that is focussed on process improvement (Mann, 2010). The successful Lean practitioners should use a concept of teamwork by consensus (*nemawashi*) to build continuous improvement and learning into day-to-day activity (Liker, 2004). The idea of using simplified LSS methodology where appropriate in food industry SMEs through basic training, simple tools and laser focusing in projects and methodology stages has been unanimously supported by academics (Nabhani and Shokri, 2009).

3. Methodology

The study is a conceptual real-life development in the agri-food factory with responsibility for implementing a manufacturing ethos of quality and continuous improvement in the Irish facility. The company produces 80,000 tons of compound feed products annually. The company has a mature quality management system (QMS), is licenced by the Irish Department of Agriculture, Food and Marine and is certified by the Feed Materials Assurance Scheme and GMP+ Feed Assurance Scheme. The business had aggressive expansion plans, and there was a need for a robust manufacturing methodology to underpin quality, staff competence, continuous improvement and regulatory compliance. The group has an established Quality Management Systems (QMS) and as food producers all facilities operate Hazard Analysis Critical Control Point (HACCP) plans, with prerequisites such as training, site standards, and quality procedures. However, the QMS functions are siloed and do not operate as a holistic approach to manufacturing (Dubé and Paré, 2003). Thus, this case study implies a combination of strategic and tactical methods providing middle managers with a robust method to enhance their effectiveness and create completive advantage. Middle managers are often considered as a missing link in the information flow between senior management and workers (Herzig and Jimmieson, 2006). Moreover, implementation of LSS methodology would involve new ways of working and changes to responsibilities. As there are dozens of LSS tools, organisations should be trained to apply

LSS tools in SMEs efficiently. Prior to this case study, the CFM enterprise implemented a programme to deliver LSS Green and Yellow Belt training to managers and supervisors. This led to the team restructuring and changes in role profiles to incorporate value stream management and leader standard work (LSW) routines.

A case study was selected to demonstrate the effectiveness of the customised integrated VSM DMAIC model at an Irish based CFM through illustration of the practical value of the LSS approach to company strategy and middle management practices. Furthermore, this study is an example of the combined application of VSM with three separated DMAIC improvement projects. Whereas the planned LSS transition has been scheduled to run from January 2022 to December 2023, the case study reports on the first two months of the implementation and is followed up with a survey of senior management reaction to the initial implementation phase. Prior to commencing this project, the various phases with the potential benefits of the LSS implementation using an A3 event were outlined to senior management. Periodic weekly meetings were done with the entire working group, including senior management, to exchange feedback on the project development. Participant observation activity was triangulated with secondary data, such as company reports, customer feedback and blogs on the company website. JMP 15.0 statistical analysis software was used to describe and summarise the data that was collected during the project and shown in the result section. The detailed VSM DMAIC methodology, including LSS Phase 1 and Future Expanded Toolkit, of this case study is described below.

The *define* phase of this project starts with the development of a current state VSM (CSVSM). The model integrates the VSM process as a strategic project selection tool. With a door-to-door overview of the operation, management can develop a cohesive improvement strategy. The map focusses on the current flow of information and material so that potential improvements can be visualised.

In the *measure* phase, the team collects available data by observing and recording the selected processes. As data is collected, it allows the team to develop descriptive statistics of the actual performance in the area. For the case study, warehouse stock movements, production cycle times and information flow were measured.

In the third phase, *analyse*, a future state VSM (FSVSM) highlights improvements and acts as a project selection process. The case study FSVSM identified three areas for improvement: excess warehouse inventory, production lead time and production scheduling. Data collected in the previous phase is analysed to determine the root causes leading to excess inventory and long lead times. Applying LSS tools such as the 5 whys, cause and effect and brainstorming, the team defines the areas that need to be addressed in the improve phase and the tools that will be deployed. A pull production system, standard work and visual controls with 5S are selected as LSS tools that can achieve the project objectives.

The *improve* phase sees real change at the Gemba as process improvements are implemented. Implementation of standard work, 5S and visual controls and pull production are prioritised during the implementation and quick wins provide momentum and mitigate resistance to change. These tools provide the structure for effective Lean management and will become the source of future improvement suggestions as the VSM DMAIC model is embedded.

Control is the final phase of the framework designed to ensure that improvements are sustained. Process performance is monitored through the application of Lean visual controls and Six Sigma statistical tools. Improvement projects identified from the FSVSM are confirmed, and this VSM becomes the new CSVSM. The improvement cycle can be repeated with further LSS tools introduced as practitioners gain confidence and competence. As workers gain respect and see the commitment to implement improvements along this project, a collective approach will be developed with the concurrent establishment of a continuous improvement culture.

4. Results

4.1 Define phase

A project charter was developed to document objectives, customer and business benefits, background issues, stakeholders and an outline schedule. The project charter was revisited during each tollgate review to ensure that the project remains focused and is proceeding is the right direction.

After agreeing the charter, the team prepared an action plan to schedule the VSM DMAIC steps. The project charter outlines the challenge for business growth due to rising cost and mentions the potential change to pull production as a way of removing waste and bottlenecks and increasing the flow of materials. With this agreement, the team was able to develop a schedule as shown in Table 1.

A VSM will focus on products that follow the same process steps and can be grouped into families that would be impacted by changes to their processes. Using a suppliers, input, process, output, and customers (SIPOC) diagram as a guide, the team verified the different product families produced in the process *(supplemental material, Figure S-1)*. This analysis showed that 85% of the products belong to the factory processes. The CSVSM was focussed on these products to ensure the maximum return.

The SIPOC that was prepared to validate the process steps, inputs and outputs. The diagram provided an end-to-end overview of a process in preparation for the define VSM phase *(supplemental material, Figure S-2)*.

4.2 Current state value stream map (CSVSM)

Table 2 shows how the team set out to develop a CSVSM using the available data.

This step creates a map that can be analysed to identify surplus inventory and process bottlenecks. Customer orders were stable and averaged 1,500 tonnes per week. Feed products are packed in 25 kg or 1,000 kg bags with a split of 2:1 between the small and large bags. Two shifts of 39 h operate from Monday to Friday, giving a total of 78 h operating time. The factory is located in a coastal port, and 3,500 tonnes of primary raw materials are shipped directly from a sister factory in Iceland at three-week intervals. The factory uses approximately 1.7M bags annually and packaging is ordered monthly. Developing a CSVSM provided the team with a visual data-rich source to use as a strategic "improvement" selection tool. The top half of a VSM represents information flow, and the bottom section shows material flow.

Figure 1 illustrates the CSVSM and identified three areas for potential improvements:

- Inventory: There was excess inventory with no obvious flow between *marshal* and *blend* and *qc/assemble* to the warehouse. In total, 300 tonnes were continuously pushed into the *blend* step, and finished goods were stacked high in the warehouse. There was a small amount of inventory between *blend* and *assemble*, but the warehouse was consistently storing 1,760 tonnes finished goods representing 5.8 days of stock. The surplus indicates wastes of overproduction, transportation, motion and waiting. There was no production levelling planned in the schedule, resulting in frequent emergency orders for stockouts despite the large inventory holding.
- Lead time: The team assessed that there was an opportunity to reduce overall lead time from 19 days. The 11.6 days raw material stock level was set by marine

Project step	Jan	Feb	March	April	May
VSM DMAIC	Define and create a CSVSM	Measure by going to the Gemba	Analyse and create a FSVSM	Implement improvements	Control and repeat
Training	Green Belt	Yellow Belt	Yellow Belt	Yellow Belt	1:1 assessment
Leadership	Communicate change	Initiate tiered meeting	Increase delegation	Focus of visual control	Recognise and reward

Table 1. Transformation schedule

shipping contracts and provided a buffer against a six-day transit time from Iceland. However, with a process lead time of only 12.5 min, the team saw room to improve the overall lead time, which would still meet customer expectations.

- People: There is a top-down system of production scheduling with limited operator involvement or visual controls. The production manager operates a schedule for each area of the factory. The result is little communication between teams in different areas. For example, *blend* and *packing* produce a maximum of 25 tonnes per hour yet *Intake* routinely pushed 300 tonnes into production silos. In the past, when information was displayed, it was historic and overly focussed on production targets. Inventory between process steps, cycle times and change overs were not routinely monitored in the current process. The team saw an opportunity to introduce meaningful process measurements, creating an agenda for tiered production meetings.

Suggestions are taken forward to the measure phase where data collection and process measurements were gathered to validate improvement opportunities. The output from the define phase and CSVSM exercise is a decision to introduce a pull system as a

Table 2.
CSVSM data

Product	Approximately 1,000 tonnes of small bags pro 500 tonnes of bulk bags
Standard batch	22 tonnes
Rostering	2 shifts × 39 hours per week
Production schedule	Weekly
Raw material order	Weekly forecast
Packaging order	Monthly
Dispatch schedule	Weekly

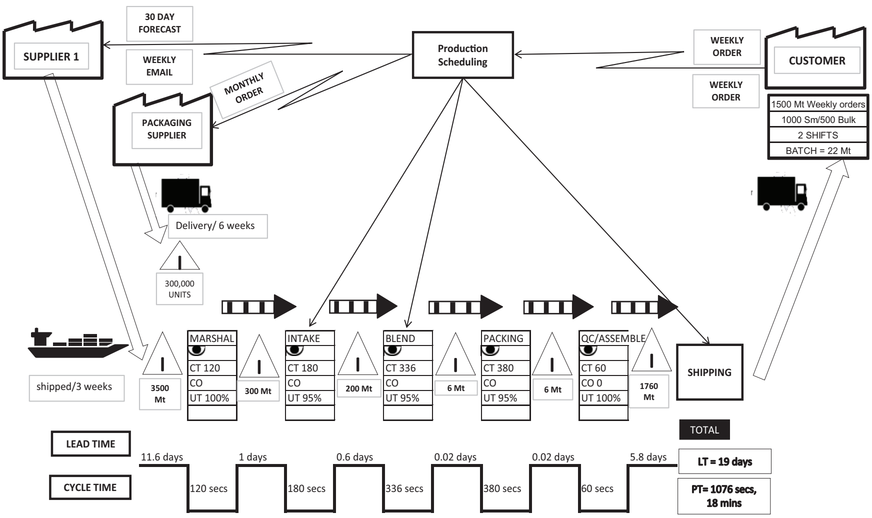


Figure 1.
CSVSM of the CFM process

countermeasure to overproduction and extended lead times. The objective was set to reduce warehouse inventory by 25% and process lead time by 10%.

4.3 Measure phase

During the measure phase, detailed information is gathered relating to the current state of a process. The CSVSM integration provides data on material and information flow for the *measure* step, highlighting existing blockages and process variation. To justify and baseline any improvements activity, it is important that the CSVSM is accurate and well defined. Deciding on key metrics at this point will ensure that the project can be sufficiently monitored through the remaining steps. The project team moved to include all operators in the DMAIC process through daily tiered meetings. Whereas recorded data was mainly used in the *define* phase, the *measure* phase involved the team gathering measurements directly from the process areas. This real-world performance data is essential for the next analyse phase. Going to the Gemba is a significant element of the LSS philosophy, ensuring accurate data and operator involvement in the improvement process.

Figure 2 illustrates a spaghetti diagram that was developed to measure distances and routes that are travelled by operators in the current state process. The diagram shows the distances and times travelled by forklift operators to deposit finished goods in the warehouse. Over 5 min could be spent transporting a pallet of goods between production and stores. With no immediate link to the dispatch schedule, this often resulted in more recent production blocking orders that were due to leave. Consistently storing 1,760 tonnes was choking the limited time and space available. CFM customers consistently request shorter lead times as on farm requirements change from season to season and day to day, so too, do their feed requirements. Transport arrangements in this context required multiple daily calls between the customer, customer support and logistics teams. A brainstorming session with logistics produced a Pareto chart characterising customer support calls that related to warehouse congestion.

Figure 3 shows the chart that could demonstrate the level and nature of change requests that were received in Q1 2022. Each change request would result in excess movement of goods as warehouse batch orders were repositioned, which could mean 30 min driving time per change request. A significant improvement would be achieved with the introduction of a

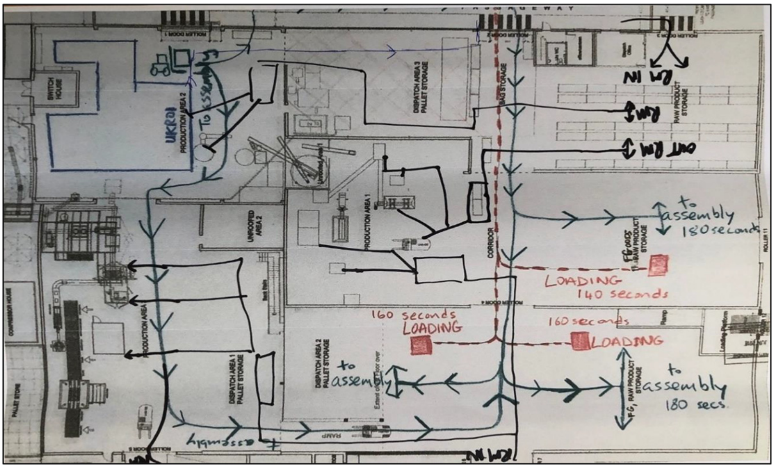


Figure 2.
Spaghetti diagram

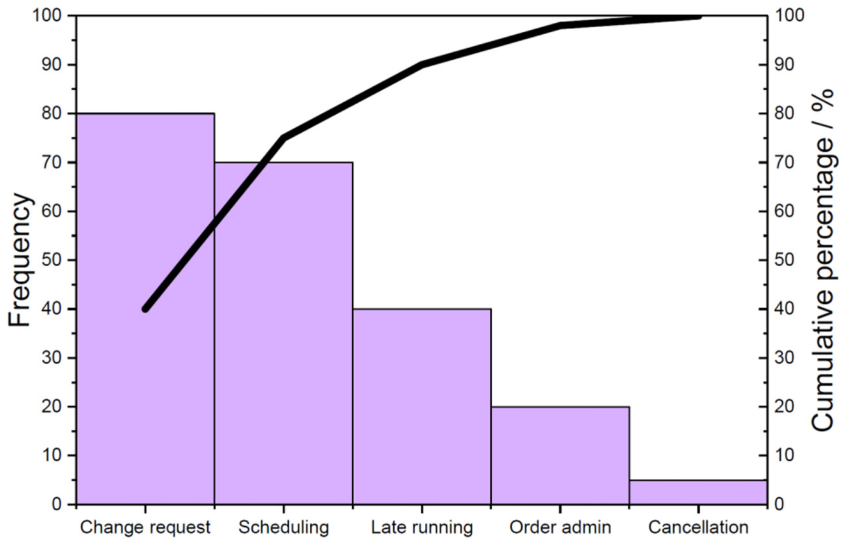


Figure 3.
Customer support calls in the measure phase

Note: Customer change requests result in up to 30 min of stock repositioning in the warehouse

pull and Kanban supermarket system linked to batch orders at the point of dispatch. This would facilitate shorter customer lead times, and products could be replaced by production once dispatched. During the measure phase, inventory and lead times were verified:

- Cycle times for each process step were measured. Process lead time was verified as 12.5 min.
- Inventory was observed and counted between each process step. Finished goods inventory was calculated as 1,760 tonnes, giving an overall lead time of 19 days.

4.4 Analyse phase

The team used data collected in the *measure* phase to develop an understanding of the process bottlenecks and potential for improvements. LSS tools were applied to identify sources of waste and variation and look at potential root causes. Combining VSM with DMAIC ensured that issues were not analysed in isolation as knock-on effects of changes in a particular area would be seen on the map. The analyse phase is the point where solutions start to be discussed with all relevant data now available.

A team brainstorming event used the 5 whys to examine the CSVSM. During the analysis, the stock buffering from push production was determined as the root cause for inventory levels *(supplemental material, Figure S-3)*. This is due to the operators buffering against customer requirements and throughput metrics. Excess inventory and transportation were observed both from the production line to stores (1,740 tonnes), and from raw material into production (300 tonnes). The conclusion was that the push system and lack of production levelling was adding to excessive inventory. Because if this, orders could remain in the warehouse as subsequent orders of the same product were produced and shipped.

Additionally, peaks and troughs occurred at workstations as warehouse lanes would frequently be overfilled. A health and safety issue would then arise as surplus product was stored in passageways and pedestrian walkways. A brainstorming event with line operators worked through a cause-and-effect diagram *(supplemental material, S-4)* and developed a Pareto chart to understand the root causes for variations in flow at workstations as shown in Figure 4.

Rating the impact of each heading from 1–10, the team identified *measurement* and *methods* as the primary causes for contributing to push production. Factors that led to over-production included use of volume metrics, which sought to maximise throughput without inventory control, and changes to schedules as different orders were prioritised ahead of shipping FIFO.

As a result, the factory was overproducing to buffer against demand instead of focussing on the real customer value, lead time. The team decided that a warehouse Kanban supermarket was the best tool to introduce a pull system. The pull of required product would reduce lead times and allow the business to concentrate on sales support over logistical firefighting.

4.5 Future value stream map

Following the *measure* phase, management made a strategic decision to switch production from push to a pull system. A FSVSM was developed with a pull system identified as the key strategic improvement. The team suggested process improvements that would deliver a pull system, and these were added to a FSVSM with actions and tools to be applied shown as Kaizen star bursts on the map, as shown in Figure 5.

A Kanban was introduced to control bulk raw materials that had previously been pushed through *intake* as fast as possible. The Kanban system was based in filling a space for 40 × 1 tonne bulk bags at intake, which was replenished by 20 bags every time 50% was used. The spectacles on the FSVSM indicate that supervisors and operates should "look and see" what is required. This simple visual control reduced inventory in this step by 260 tonnes and freed space and time for operators to focus on the bag filling cycle. At each process step, a standard work exercise was applied to improve cycle time, consistency and reduce waste at each step. For example, operators at the intake area had been working with *ad hoc* methods of breaking bulk bags into the production hoppers. The standard work process

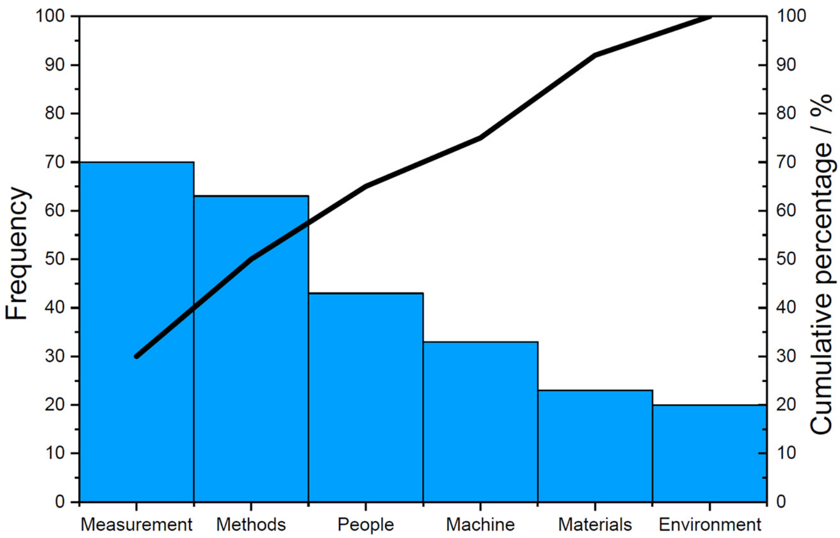


Figure 4.
Pareto root cause chart

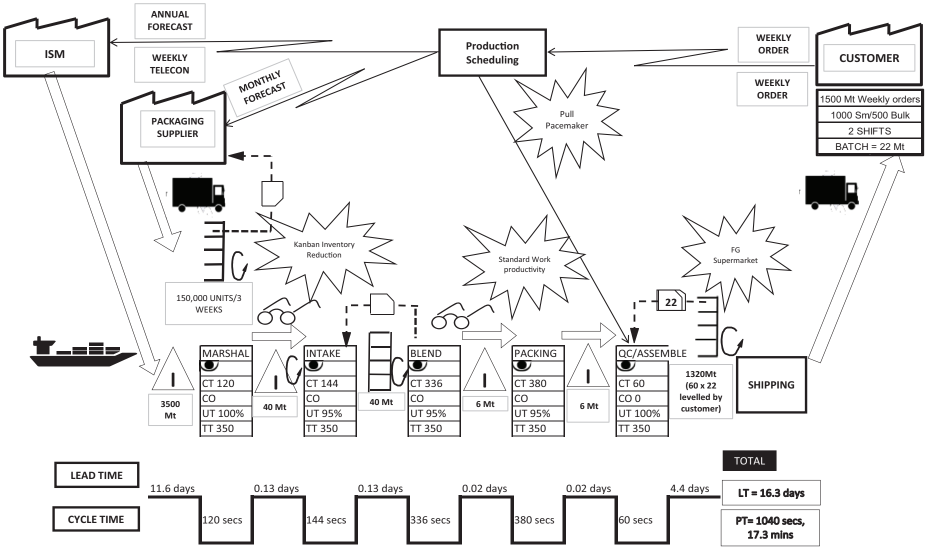


Figure 5.
FSVSM of the CFM process

introduced a single method and takt time that increased the average throughput per operator from 15 to 21 bags per hour. As a result, the operator requirements at this station reduced from 7 to 5 h. Operators were transferred to support a separate packing line.

Improvements implemented at each process step were combined into a new pull production system to manage work in process inventory achieving a reduction of 25%. Product levelling, Heijunka, was introduced to provide a small buffer of stock per customer per product. Batches would only be replaced once they were dispatched, breaking the link between production and order receipt. The warehouse was split into definitive lanes, and empty lanes became a physical Kanban signalling to supervisors that a product should be produced. The pull system ensured the immediate order fulfilment, whereas Heijunka maintained the Kanban supermarket inventory product mix. The factory was able to reduce the warehouse lead time from three to one day through elimination of the requirement for emergency order and change management.

The FSVSM objective was to reduce identified process wastes and variation leading to reduced cost of goods, process time and customer lead times. For SMEs with limited resources continuing the VSM process by designing a future state map is an efficient and effective tool, a sheet of paper and ink is all that is needed. Within the pull system, the team were able to introduce production takt time of 350 s based on the available process time divided by customer order quantities. The takt time, standard work and order levelling would allow the factory to meet customer requirements and eliminate the warehouse bottleneck.

4.6 Improve

The *improve* step of the VSM model was focused on the implementation of changes that were made in the FSVSM. As with the other steps, there is a range of LSS tools that can be applied in the *improve* step. The team's objective was to ensure that the Lean concept of standard work could be used as a basis for a sustained transformation. Closely aligned with 5S (sort, set, shine, standardise, sustain), the standard work tool seeks to design processes in the safest, easiest and most effective way. Figure 6 illustrates details of the standard work chart for the intake area to improve the process controls and visual aids.

The process is controlled to deliver three bulk bags in 339 s, comfortably within the 350 s production takt time. The factory team had identified clear objectives to achieve pull. Introduce a supermarket Kanban with production levelling for orders to reduce inventory and reduce waste of waiting and motion by cutting transportation due to overproduction. A Kanban card was sent from *assemble* once a space was vacated in the warehouse alerting *packing, blend* and *intake* to stock the supermarket with the required product, maintaining a minimum buffer for each product and customer requirement. Production scheduling switched from order receipt times to a Kanban signal from the warehouse. In total, 1,320 tonnes were established as the required stock holding.

Figure 7 illustrates a comparison of the process times by analysing the rate of intake and truck loading times. The results indicate that the end-to-end process seems to be well balanced to the intended takt time for material flow. The chart shows a 75% reduction in average transport times with the minimised inventory at intake. Moreover, the warehouse eliminated the requirement for constant material movement.

Tiered meetings underpinned the *improve* phase and critically allowed supervisors who themselves were completing Yellow Belt courses to introduce 5S and standard work into each process step. The change in emphasis for all operators in terms of process ownership was critical to the success of the project. In this study, process ownership was shown to be not just focused on the production. The successful validation of the VSM DMAIC frameworks became a driving force in the process ownership. As a result of this interlink, visual controls had to be developed, which are further discussed in the *control* phase.

4.7 Control

The *control* step aims to sustain, improve and validate the FSVSM. For the VSM DMAIC model to be transferable, the learnings from the process improvement should be visible to share with other industrial stakeholders and governmental institutions. Tiered meetings allowed the team to establish more meaningful visual controls within the factory. Previous efforts had focussed on results-driven culture focussed on volume, whereas the VSM DMAIC project focused on detailed process measurements. The cause-and-effect diagram from the analyse phase revealed a dependency on historical metrics related to maximising throughput and saw this as a root cause for the push system. Factory management applied LSW at the process level. Being present at tiered meetings and using LSS tools in real time helped to develop a more trusting partnership between management and operators. Mann (2010) describes the importance of daily tiered meetings underpinning a Lean culture. Through these meetings, staff were involved with the project and able to highlight issues and opportunities for future improvements in the new system. LSW delivers the principle of respect for people by inviting all levels to participate in improving their work processes and extending the improvements the customer value.

Visual controls include controls and process levelling charts, which provided critical metrics at hourly intervals. The ability to respond quickly to unplanned problems identified by the metrics meant that the visual controls became a centre point. This allowed the factory to deploy LSS tools and problem-solving in a controlled environment. As an example of the visual controls, bag fill control charts were used to gauge the status of the main packing equipment. Two packing machines operated each with a capacity to fill a 25 kg bag every 15 s. The factory has a capacity to produce 16 tonnes per hour in 25 kg bags.

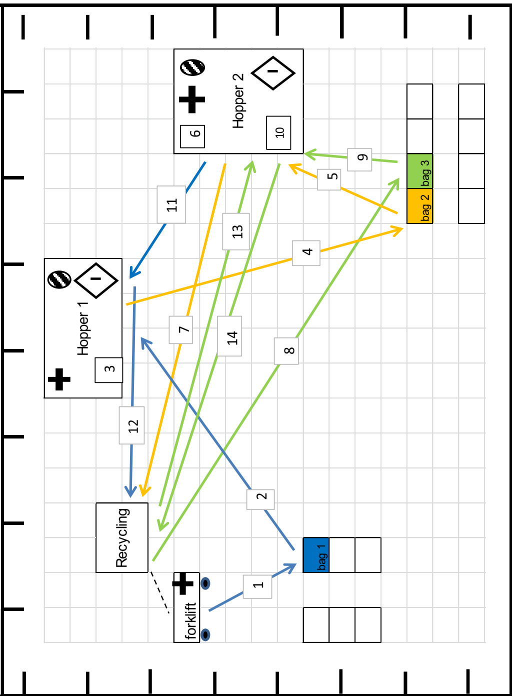
Control charts provided the team with basic statistical process control capabilities. Operators were trained to recognise if the process was in control by monitoring the data

STANDARDISED WORK CHART

Sheet	1 of 1	Chart Date	SWC 15.01.22

AREA	INTAKE
PROCESS	BREAK BULK RAW MATERIAL
Takt Time	350 Sec 3 BAG Cycle Time 339
Approved By: Padraig Brophy	Date: 14.03.22 Rev: 2
Checked By: NM	Date: 14.03.22

SEQ #	MAJOR OPERATION STEPS	Time Manual	Time Auto	Time Walk
1	Pick up Bag 1 with stronga	6	-	0
2	Present to bulk bag Hopper1	11	-	0
3	Break, Check, Release to Sit at Hopper 1	28	240	0
4	Pick up bag 2 with stronga	10	-	0
5	Present Bag 2 to Hopper 2	14		0
6	Break, Check Empty at Hopper 2	72	144	0
7	Remove bag to Recycling	25	-	0
8	Pick up bag 3 with stronga	12	-	0
9	Present bag to Hopper 2	13	-	0
10	Break, Check , Release to Sit at Hopper 2	12	144	0
11	Collect Bag 1 from Hopper 1	44	-	0
12	Remove to Recycling	38	-	0
13	Collect Bag 3 from Hopper 2	29	-	0
14	Remove to Recycling	25	-	0



		Safety Precaution	SWIP	Quality Check
————	Walking between Operations	✚		◇
- - - - -	Return to Start			

Figure 6.
Standard work chart – RM intake

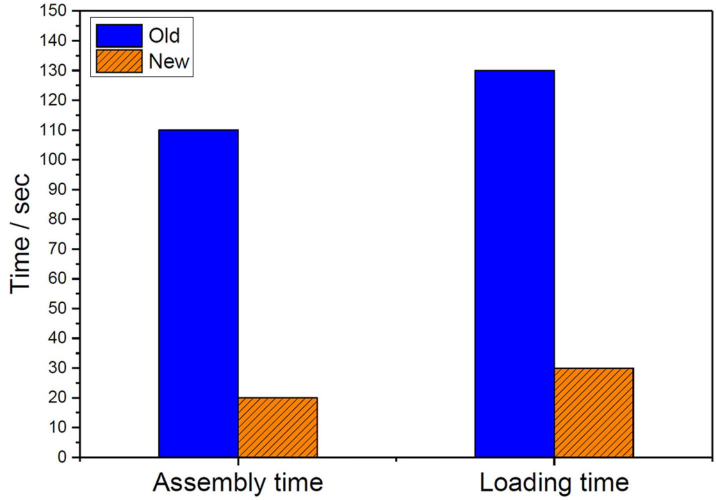


Figure 7.
Comparison of transportation time

points on the control chart relative to the process *mean* and the upper and lower controls limits (UCL and LCL). Control limits are set three standard deviations either side of the overall process mean. Figure 8 illustrates a control chart that monitors hourly bag fill rates. The process is seen to be in control as the data points are falling randomly, either side of the mean and within the UCL and LCL, with no recognisable pattern. Investigations are conducted where data points fall outside the control limits or display definite patterns on one or other side of the centreline. The preference is to minimise variation with most data points falling close to the mean/centreline. Operators investigate where the rate moves

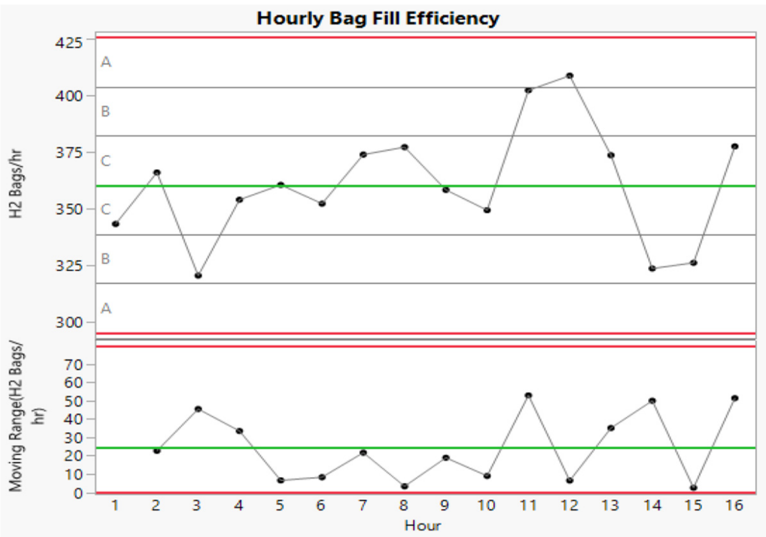


Figure 8.
Bag fill control chart showing a stable process

beyond two deviations into Zone A. In practice, a fill rate above 400 would indicate a significant change in the product bulk density. A fill rate below 325 indicates potential mechanical issues with automatic bag placement, fill lines or bag sealing equipment.

Figure 9 illustrates a QC control chart to ensure consistent formula composition.

The percentage of the primary ingredient in powder products is monitored by routine sampling in the on-site laboratory. In the example shown, the product specification is 26 (+/−5). Signs of special causes are investigated, with a focus on results that move into Zone A. The marked result would be investigated to ensure weigh cells, and in-line feed augers were free of blockages. The output tracks process performance independent of customer specification. It is essential that the addition of more expensive raw materials is minimised while still meeting customer requirements. This chart enables operators to gauge usage and minimise costs.

Table 3 shows the results three months after the VSM DMAIC model was integrated into the CFM enterprise. The results demonstrate that the methodology was proven to deliver in a CFM environment.

5. Discussion

The study has demonstrated that some challenges in the CFM industry can be solved through effective allocation of resources and integrating learning and leadership within a tailored methodology. The successful implementation of LSS for process improvement

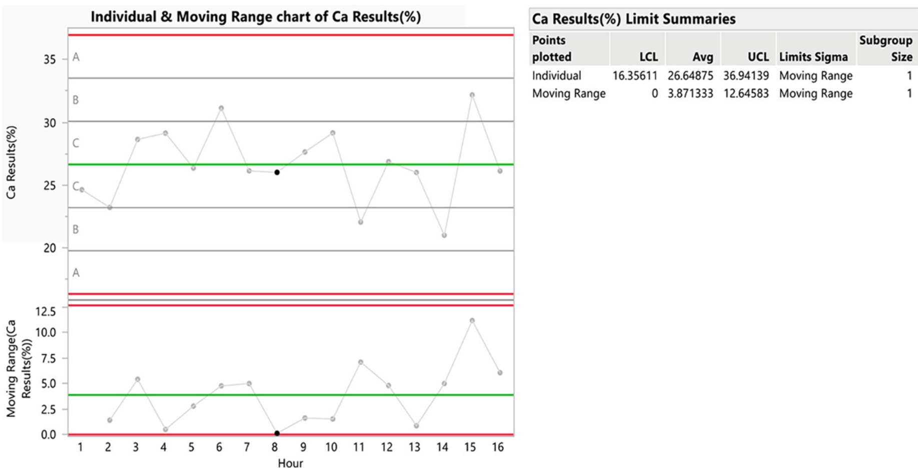


Figure 9.
QC composition control chart

Table 3.
VSM DMAIC results

Objective	Metric	Baseline	Result	% Improvement
Inventory: reduced finished goods stock and waste of overproduction	Tons	1760	1320	25
Customer lead time: reduced customer lead time	Days	3	1	66
VSM lead time: reduced waste of waiting and process variation	Days	19	16.3	14

requires an integrated training approach and early adaptation of LSW (Hackman and Wageman, 2007). Progressive VSM DMAIC cycles ensure waste elimination and continuous process improvement. Compared to previous studies, this work has shown that continuous process improvement can be achieved over a short period of time that is less than three months with a tailored VSM DMAIC model. Melin and Barth (2018) describe a Lean trial at 34 Swedish farms over 18 months and conclude that only six of the farms studied reached the desired final phase of "thinking lean". This study suggests detailed tailoring LSS to client/customer requirements improves the potential for a successful implementation.

The one-off improvement in previous studies is not an option in the present study when the methodology is applied due to the cyclical VSM model, which returns to the beginning after each cycle. The cycle is promoted by adhering to the concept of standard work for staff and leaders. Sisson and Elshennawy (2015) include training, standard work and developing leaders as essential propositions for change and further identify value stream mapping as the key tool to focus improvement activities. However, the scale of the conceptual framework proposed by the authors would be overwhelming to a small CFM manufacturer. A simplified model of the type suggested in this study is required. Likewise, Csikai (2010) describes how CFM manufacturers can start to understand the factors that influence continuous improvement by simply getting started, applying Six Sigma tools, and growing more proficient as the process moves forward.

The implementation of the LSS makes effective changes in the organisation productivity as part of the continuous improvement process, reducing costs and increasing customer value at a time of political, environmental and economic upheaval. This study showed that deploying the VSM DMAIC methodology succeeded in replacing a traditional push approach with pull production. This served as a foundation for success using a three-pronged change management approach that combines LSS tools, training and leadership, as discussed previously (Muellers and Trubetskaya, 2021). The outcome of this study is related to the waste elimination by reducing inventory and improving material and information flow. Integration and participation were identified as the key drivers of success, whereas leadership and training were the drivers of change to a continuous improvement process (supplemental material, Figure S-5). The initial precautions of senior management had to be overcome with the development of an integrated approach that demonstrated the importance of management commitment. Integrating training and leadership created routine monitoring of requirements, tool selection, practice, and application.

The VSM DMAIC model is limited by the need for an LSS champion to initiate and drive change. SMEs often have one leader, informal structures with few hierarchical levels and so centred on one person (Loefving *et al.*, 2021). The change agent needs time and resources requiring a trusted interlocuter between staff and senior management. Within CFM, this is achievable through existing operational production managers. However, the speed and quality of implementation remain largely dependent on a single individual, and that is seen as a limitation. This study notes the importance of the change agent by observing a drop in momentum when meetings were skipped by managers, whereas short, tiered sessions on the factory floor resulted in focussed problem-solving and immediate decision-making. A pre-implementation assessment was proposed to identify strengths and weaknesses of the project prior to implementation (Moya *et al.*, 2019). In this work, a rigorous assessment was suggested to improve the VSM DMAIC model by aiding resource allocation and early identification of training requirements.

The VSM DMAIC cycle can be characterised as an integration of change management, training, leadership and continuous improvement. In the review of critical success factors for implementing LSS, management commitment was given the highest priority, whereas training was seen as low priority, remaining outside the top ten success factors (Stankalla *et al.*, 2018; Albliwi *et al.*, 2015). In the current study, the successful transformations are underpinned by training, at least according to the yellow belt standard, alongside the VSM DMAIC implementation. The current results underline that training should provide a competence to use LSS tools, whereas LSW could support the licence to apply VSM DMAIC framework. Compared to previous research, the study clearly demonstrated how effective tactical day-to-day process management tools can be combined with training and leadership to produce a meaningful strategic management approach for use in CFM and other industrial sectors.

6. Conclusion

The novelty of this research relies on the tailoring of LSS (VSM and DMAIC) methodology into CFM to increase process efficiency. By delivering a transferrable template for other group businesses to follow, the initiative will demonstrate how CFM can actively promote strategic and tactical objectives and create competitive advantages in the face of challenging business conditions. The results showed that the combination of LSS tools, Lean standard work and training can establish an efficient and transformative manufacturing framework in SMEs *(RQ1)*. The established DMAIC model showed limitations, which are related to the need of time and resources. Despite model limitations, the innovative approach from this study is to make LSS accessible and achievable for small business units seeking to establish a continuous improvement methodology. Visual control chart framework developed within a course of this study can be used as an effective platform to upscale the model into larger industrial platforms of the visual management. The study provides a new approach towards structuring LSS transformation as a recurring VSM DMAIC cycle with increasing layers of competence within CFM and similar SMEs *(RQ2)*. Future research study will explore the methodologies and improvements by transferring them across other CFM sites within the case study organisation. As this is the first study involving LSS deployment in an Irish CFM and adds to the limited published work available on thus area.

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Supplementary material

The supplementary material for this article can be found online.

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