Title	Implementing a customised Lean Six Sigma methodology at a compound animal feed manufacturer in Ireland
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Publication Date	2023-01-27
Publication Information	Trubetskaya, Anna, McDermott, Olivia, & Brophy, Padraig. (2023). Implementing a customised Lean Six Sigma methodology at a compound animal feed manufacturer in Ireland. International Journal of Lean Six Sigma, 14(5), 1075-1095. doi: 10.1108/IJLSS-08-2022-0169
Publisher	Emerald
Link to publisher's version	https://doi.org/10.1108/IJLSS-08-2022-0169
Item record	http://hdl.handle.net/10379/17991
DOI	http://dx.doi.org/10.1108/IJLSS-08-2022-0169

Implementing a customised Lean Six Sigma methodology at a Compound Animal Feed Manufacturer in Ireland

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Abstract

Purpose – This work proposes 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 – 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 & 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.

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 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 5.6M tons production in 2021 (Irish Grade and Feed Association, 2022). It is projected that the revenue of manufacture of prepared feeds for farm animals in Ireland will amount to approximately 1,951.72 million U.S. 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. Finally, 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 which have applied Lean in agri food environments and indeed in a CFM environment. For example Erwin *et al.*, (2020) described the minimising of waste and improved process cycle efficiency in an animal feed products business, while Folinas *et al.*, (2014) applied lean tools to support a green supply chain and logistics management initiatives in a Greek agri-food manufacturer. To date there have been no studies involving the application for LSS to any Irish CFM facilities. This study is based in an Irish CPM who have growth forecasts that indicate production volumes will grow 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 a Lean Six Sigma (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 question (RQ) for this study is to:

- Implement a customised approach allowing LSS to be effectively implemented in CFM operations and mitigate cost increases by reducing inventory and lead times.

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 a LSS model at a feed manufacturing site. Finally, sections 5 and 6 elucidate the discussion and conclusion.

2 Literature Review

LSS systems bring both Lean and Six Sigma together in a single business improvement approach centred on creating value for the customer (Gaikwad et al., 2019; Gaspar and Leal, 2020; Chay et al., 2015; Gijo and Scaria, 2014).

There is little known in relation the application of continuous improvement methodologies within CFM. Although significant research exists in relation to product innovation within the sector (Csikai, 2010; Köster, 2015), limited research on the application of process improvement methodologies is available. Within the limited literature available on LSS application in CFM in the literature that is published Value Stream Mapping (VSM) has been extensively utilised to improving the sustainability performance of animal feed and CPM production processes. For example Putri and Hartini (2021) conducted a case study in large animal feed company in Indonesia utilised VSM to eliminate waste and improve financial performance, while Erwin *et al.* (2020) enhanced process cycle time.

Whereas product innovation has evolved with customer requirements to move from pure protein towards animal nutrition and welfare, manufacturing methods do not appear to have advanced. The 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 & Grain Association, 2022). LSS tools would complement CFM requirements by improving the flow of bulk material through milling and blending and the precision required for product composition. Lean developed from the Toyota Production System (TPS), whereas Six Sigma was first developed at Motorola and focussed on increasing value by reducing process variation (Antony *et al.*, 2022). Together they have developed into an operations management system (Burneo-Celi and Temblador-Perez, 2018; Dora and Gellnyck, 2015; Thomas et al., 2009). LSS evolved from quality movements that gained prominence in the 20th century such as Total Quality Management (TQM), Just in Time (JIT), Deming's Wheel of Quality, and LSS (Sreedharan et al., 2018; Chiarini, 2011; Naslund, 2008). The LSS methodology merges previous continuous improvement (CI) methodologies into a single systematic approach (George, 2002). Lodgaard et al. (2016) cite the need for CI approaches as essential tools for developing a competitive position. The combination of Lean Management and Six Sigma advances previous approaches from a tactical quality methodology on to a holistic strategic management philosophy (Albliwi et al., 2014). 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 material flow and precision matches industry critical milling and blending processes. LSS implementation 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 & 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. 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 (McDermott *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 in order 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 Lean Six Sigma where appropriate in food industry SME's 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

A case study was selected to demonstrate the effectiveness of an LSS implementation using the customised integrated VSM DMAIC model at an Irish based CPM. The company was established in 1991 and produces 80,000 tons of compound feed products annually. The company has a mature Quality Management system, 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. This research was undertaken in a CFM SME and the case was critically chosen because it was revelatory (Dubé & Paré, 2003).

The case study explores the implementation of a transferrable VSM DMAIC model with objective of reducing inventory and lead times and introducing a culture of continuous improvement. The case study approach is suitable for an empirical study when there is scarce body of knowledge on the subject (Yin, 2016) as there is in the case of literature related to LSS implementation within the CFM area (McDermott *et al.*, 2022). The case study approach is most suitable when information is about the object under study is not widely available (Eisenhardt and Graebner, 2007). A case study approach also aids the documenting of contextual setting for better understanding of the phenomenon under study (McDermott *et al.*, 2022) in particular when it unique, critical, and revelatory (Dubé & Paré, 2003).

VSM DMAIC model (Figure 1) provides a strategic and operational approach to production management, quality, safety, and continuous improvement. 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.

VSM acts as a project selection and improvement roadmap. The initial implementation of VSM seeks to establish key LSS tools to provide a foundation for CI activities. The LSS toolbox can be further expanded as practitioners are trained and gain competence. By concentrating on perfecting two to three LSS tools CFM can more quickly implement both practical and strategic elements of the model. With experience a broader range of LSS tools can be introduced as shown in Table 1.

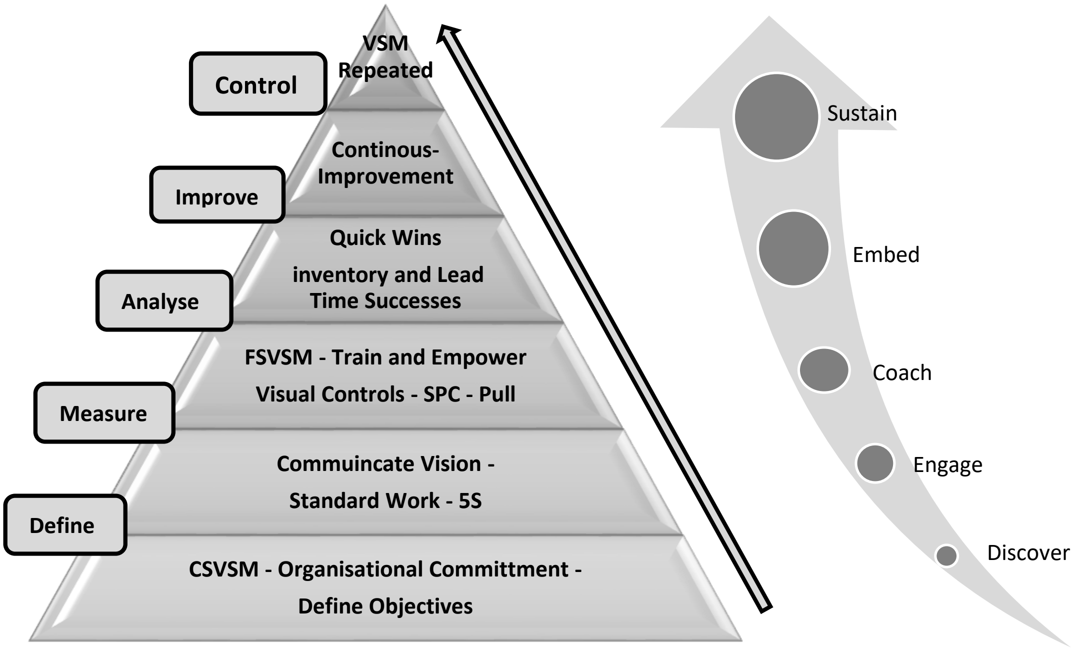


Figure 1: VSM DMAIC implementation model.

Table 1: VSM DMAIC model that includes LSS phase 1 toolkit and expanded toolkit.

VSM DMAIC MODEL	LSS Phase 1 Toolkit		Future Phase Expanded Toolkit	
	Define	• Value Stream Map • Project Charter • SIPOC	Define	• Value Stream Map • Project Charter • A3 • Kaizen event • 5 Whys
	Measure	• Value Stream Map • SIPOC • Data Collection • Brainstorm • Spaghetti Diagram • 5 Whys	Measure	• Value Stream Map • SIPOC • Pareto • Descriptive Statistics • Brainstorm
	Analyse	• Value Stream Map • 5 Whys • Cause & Effect • Brainstorm • Pareto • Regression Analysis	Analyse	• Value Stream Map • 5 Whys • Cause & Effect • Brainstorm • Decision Tree • DOE • Inferential Statistics
	Improve	• Standard Work • 5S • Visual Controls • Pull	Improve	• Value Stream Map • Lean Management • 5 S • Standard Work • Visual Controls • Pull • A3 • SPC • DOE
	Control	• Standard Work • 5S • Visual Controls • Control Charts	Control	• Value Stream Map • Lean Management System • Visual Control • Leader Standard Work • Gemba walks • Control Charts

The concept and principle of value runs throughout the LSS philosophy and is central to the VSM DMAIC implementation. VSM focusses on removing non-value-added activities, or waste, from the manufacturing process to mitigate or eliminate costs by shortening lead times and reducing inventory (Sisson and Elshennawy, 2015). Control charts monitoring process variation apply analytical Six Sigma tools at an early stage. Once implemented the VSM DMAIC framework can be scheduled as an annual (or more frequent) strategic process for identifying and managing improvement projects aimed at reducing process waste and variation. With practical tools and an emphasis on lean management culture the framework is accessible and can be transferred other organisations (Cadden et al., 2020).

VSM provides a framework for systematic process improvements and can visualise a door-to-door product life cycle or zoom into a process with internal suppliers and customers. The case study is an example of the later. Evolving from a Toyota material and information flow process, Mike Rother and John Shook developed the VSM process so well known today in “Learning to See” (Rother and Shook, 2003). VSM provides large volumes of process information in a highly visual and concise format allowing the identification of value added, non-value added, and necessary but non-value-added activities (Ohno, 1988). Processes can be improved by eliminating examples of the traditional seven non-value adding wastes of Transport, Inventory, Motion, Waiting, Over-production, Over-processing, and Defects and including the 8th waste of underutilisation of employee skillsets (McDermott, Antony and Douglas, 2021)

The *Define* phase starts with the development of a Current State Value Stream Map (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 collect 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 Value Stream Map (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 define 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 now be repeated with further LSS tools introduced as practitioners gain confidence and competence. As workers gain respect and see the commitment to implement improvements, a collective approach develops, and a continuous improvement culture is established.

4 Results

VSM promotes systematic process improvements which when combined with Six Sigma's DMAIC methodology creates a structured and systematic improvement process. The team followed the steps on Table 2, starting with the Define phase and progressing through the VSM DMAIC methodology.

Table 2: VSM DMAIC correlation.

Step	**VSM**	**DMAIC**
Step 1	Identify a product family	DEFINE
Step 2	Create a current state value stream map	DEFINE
Step 3	Evaluate the CSVSM	MEASURE
Step 4	Create a Future State Value Stream Map	ANALYSE
Step 5	Implement the improvements identified on FSVSM plan (Kaizen events)	IMPROVE
Step 6	Return to the start as the FSVSM becomes the new CSVSM	CONTROL

3.1 Define Phase

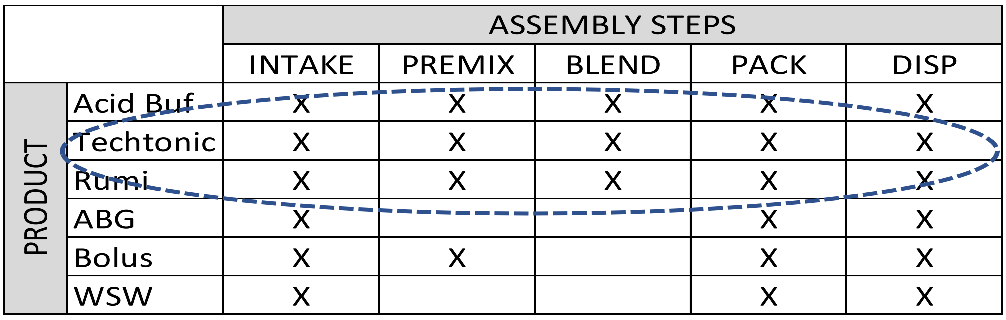
A project charter was developed to document objectives, customer and business benefits, background issues, stakeholders, and an outline schedule. The project charter that was revisited during each tollgate review to ensure that the project remains focussed and is proceeding is the right direction.

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 3.

Table 3: Transformation Schedule.

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

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 SIPOC diagram (Suppliers, Input, Process, Output, and Customers) as a guide the team verified the different product families produced in the process. Figure 2 illustrates that 85% of the products belong to the factory processes. The CSVSM was focussed on these products to ensure the maximum return.



		ASSEMBLY STEPS				
		INTAKE	PREMIX	BLEND	PACK	DISP
PRODUCT	Acid Buf	X	X	X	X	X
	Techtonic	X	X	X	X	X
	Rumi	X	X	X	X	X
	ABG	X			X	X
	Bolus	X	X		X	X
	WSW	X			X	X

Figure 2: Product family verification.

Figure 3 illustrates 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.

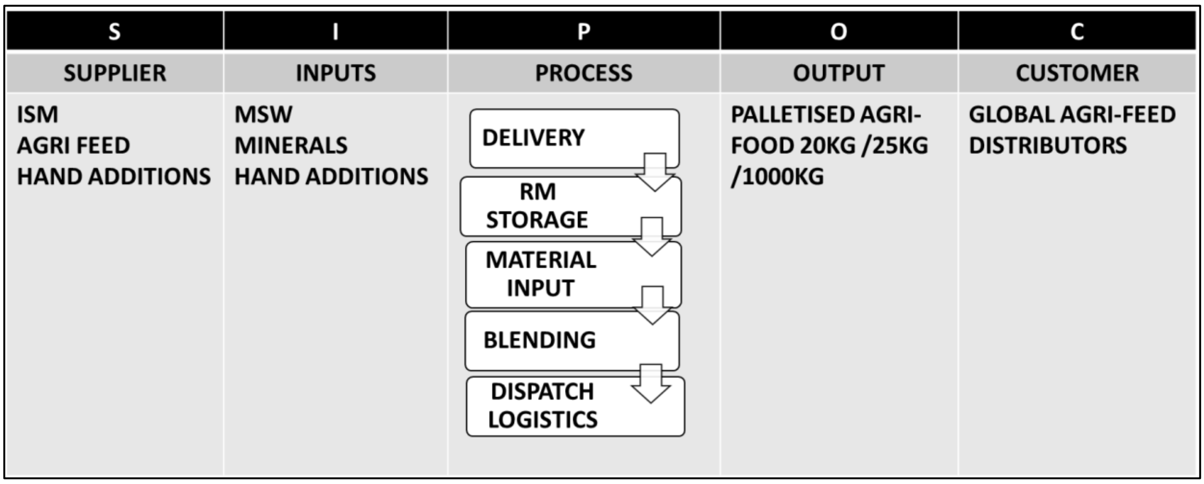


Figure 3: SIPOC Diagram for an animal feed production line.

3.2 Current State VSM (CSVSM)

The team set out to develop a CSVSM using the available data as shown in Table 4. This step creates a map that can be analysed to identify surplus inventory and process bottlenecks. Customer orders were stable and averaged 1500t per week. Feed products are packed in 25kg or 1000kg bags with a split of 2:1 between the small and large bags. Two shifts of 39hrs operate from Monday to Friday giving a total of 78hrs operating time. The factory is located in a coastal port and 3500t 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.

Table 4: CSVSM data.

Product	Approximately 1000t Small bags/500t Bulk bags
Standard Batch	22t
Rostering	2 shifts x 39hrs/week
Production Schedule	weekly
Raw Material Order	weekly forecast
Packaging Order	monthly
Dispatch Schedule	weekly

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.

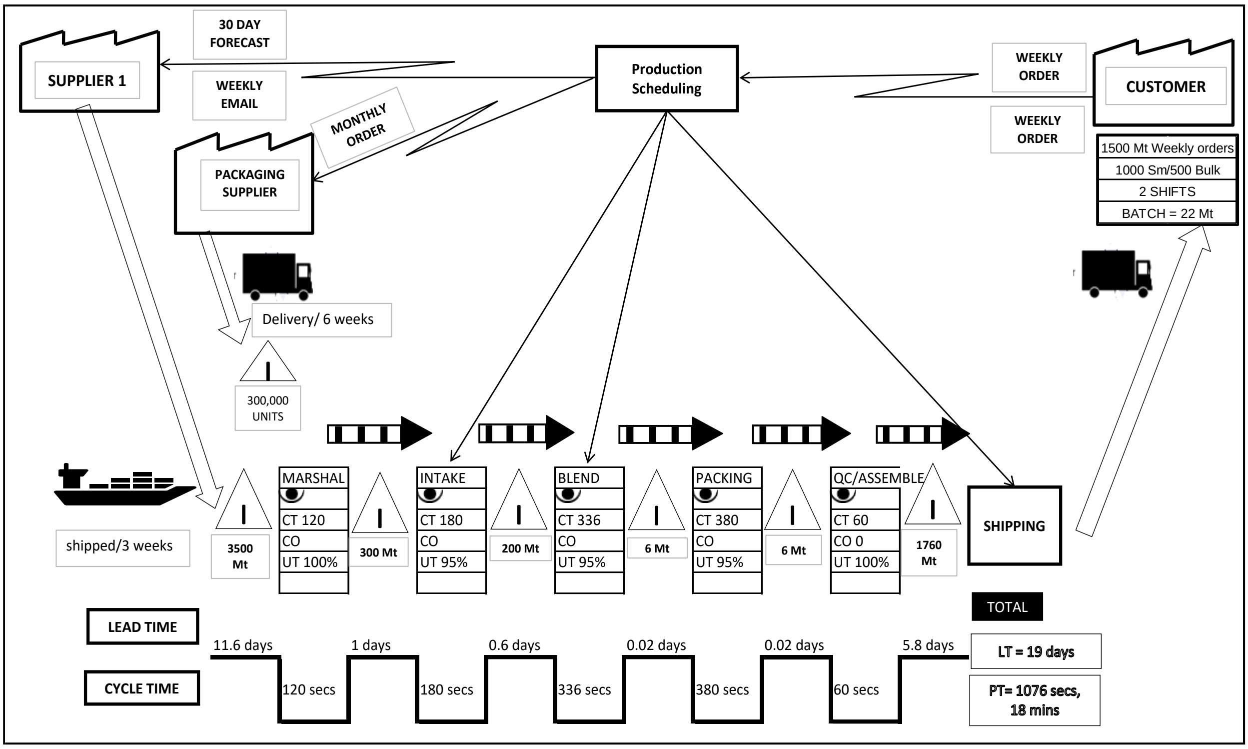


Figure 4: Current State Value Stream Map of the CFM process.

Figure 4 illustrates the current state VSM and identified three areas for potential improvements:

1. Inventory: There was excess inventory with no obvious flow between *marshal* and *blend* and *qc/assemble* to the warehouse. 300t was 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 1760t 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 stock outs despite the large inventory holding.
2. 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 shipping contracts and provided a buffer against a 6-day transit time from Iceland. However,

with a process lead time of only 12.5 minutes the team saw room to improve the overall Lead Time which would still meet customer expectations.

3. 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 25t/hr yet *Intake* routinely pushed 300t 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 countermeasure to overproduction and extended lead times. The objective was set to reduce warehouse Inventory by 25% and process Lead Time by 10%.

3.3 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 in 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.

A spaghetti diagram in Figure 5 was developed measuring the distances and routes 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 minutes 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 1760t was choking the limited time and space available.

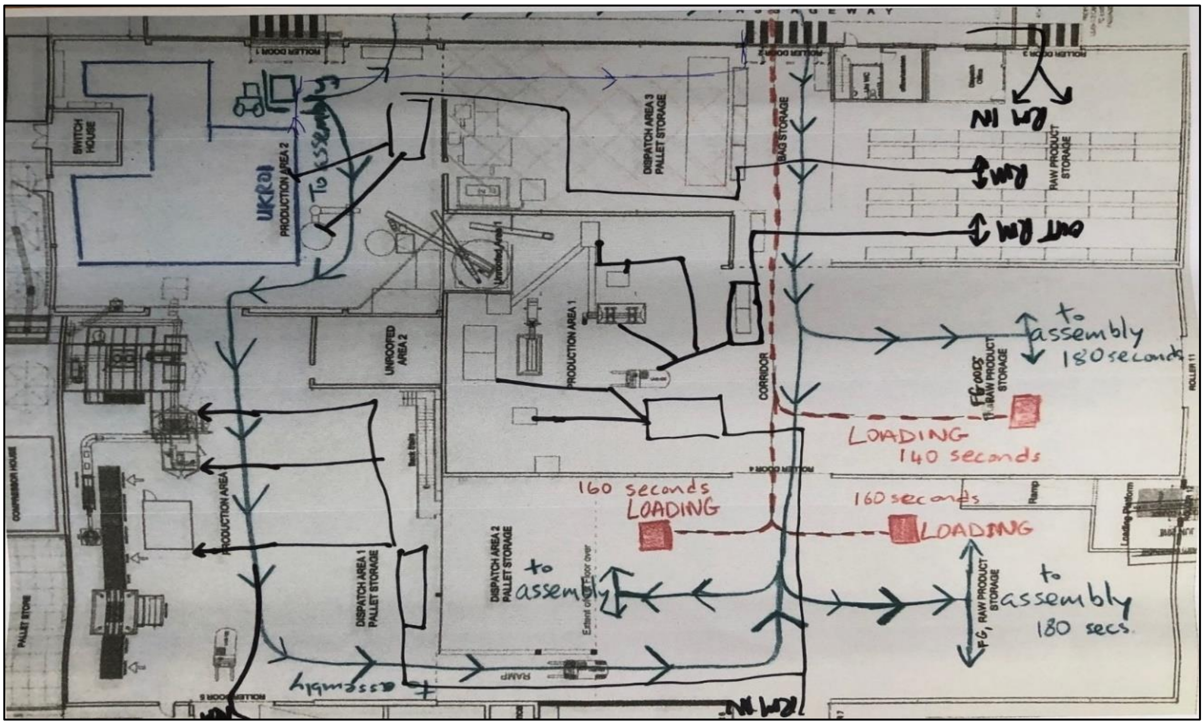
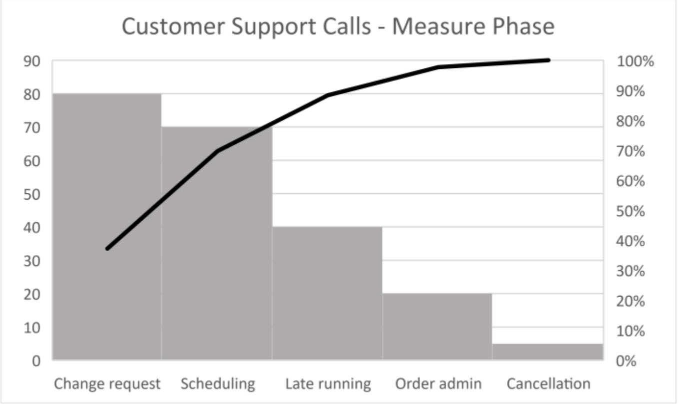


Figure 5: Spaghetti diagram.

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 6 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 minutes driving time per change request. A significant improvement would be achieved with the introduction of a 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.



Customer change requests result in up to 30 of minutes stock repositioning in the warehouse

Figure 6: Customer support calls in measure phase.

During the Measure phase inventory and lead times were verified:

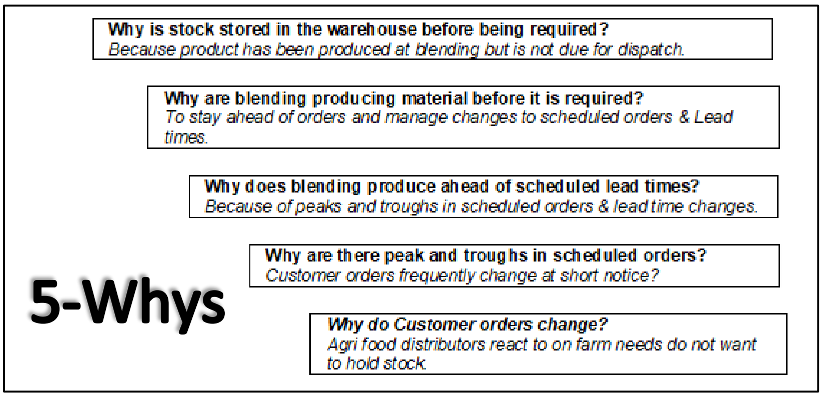
1. Cycle times for each process step were measured. Process lead time was verified as 12.5 minutes.
2. Inventory was observed and counted between each process step. Finished Goods inventory was calculated as 1760t giving an overall lead time of 19 days.

3.4 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 as shown in Figure 7. 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 (1740t), and from raw material into production (300t). 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.



Why is stock stored in the warehouse before being required?
Because product has been produced at blending but is not due for dispatch.

Why are blending producing material before it is required?
To stay ahead of orders and manage changes to scheduled orders & Lead times.

Why does blending produce ahead of scheduled lead times?
Because of peaks and troughs in scheduled orders & lead time changes.

Why are there peak and troughs in scheduled orders?
Customer orders frequently change at short notice?

Why do Customer orders change?
Agri food distributors react to on farm needs do not want to hold stock.

Figure 7 : The 5 Whys.

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 and developed a Pareto chart to understand the root causes for variations in flow at workstations (see Figures 8 and 9).

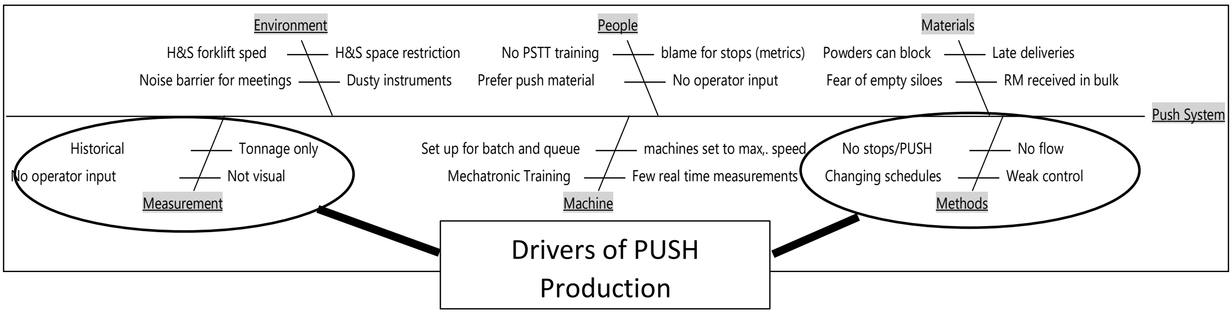


Figure 8: Cause and Effect Diagram for Push Production.

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.

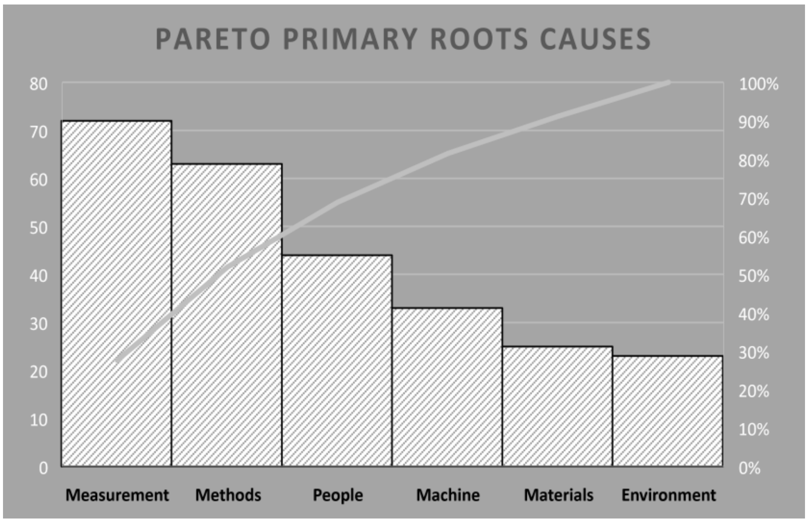


Figure 9: Pareto root cause chart.

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.

3.5 Future VSM

Following the *Measure* phase management made a strategic decision to switch production from push to a pull system. A FSVSM (Future State Value Stream Map) 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 10.

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 40x1t 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 260t 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 introduced a single method and takt time that increased the average throughput per operator from 15 to 21 bags/hr. As a result, the operator requirements at this station reduced from 7 to 5 hours. Operators were transferred to support a separate packing line.

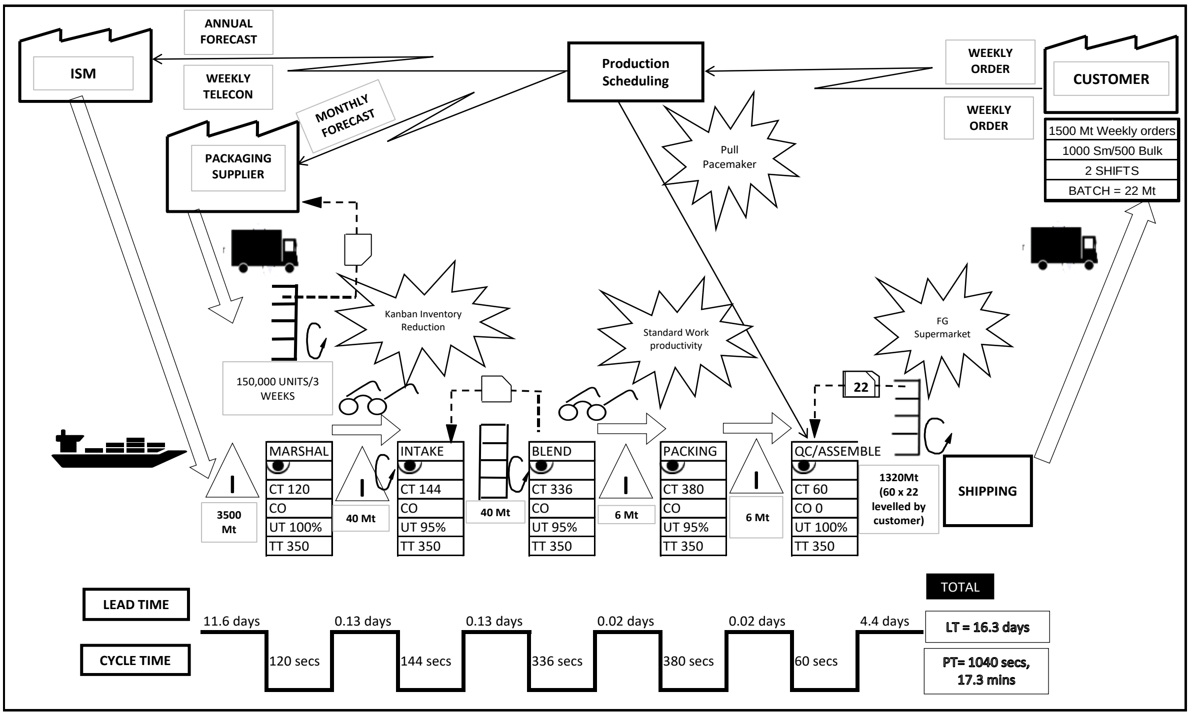


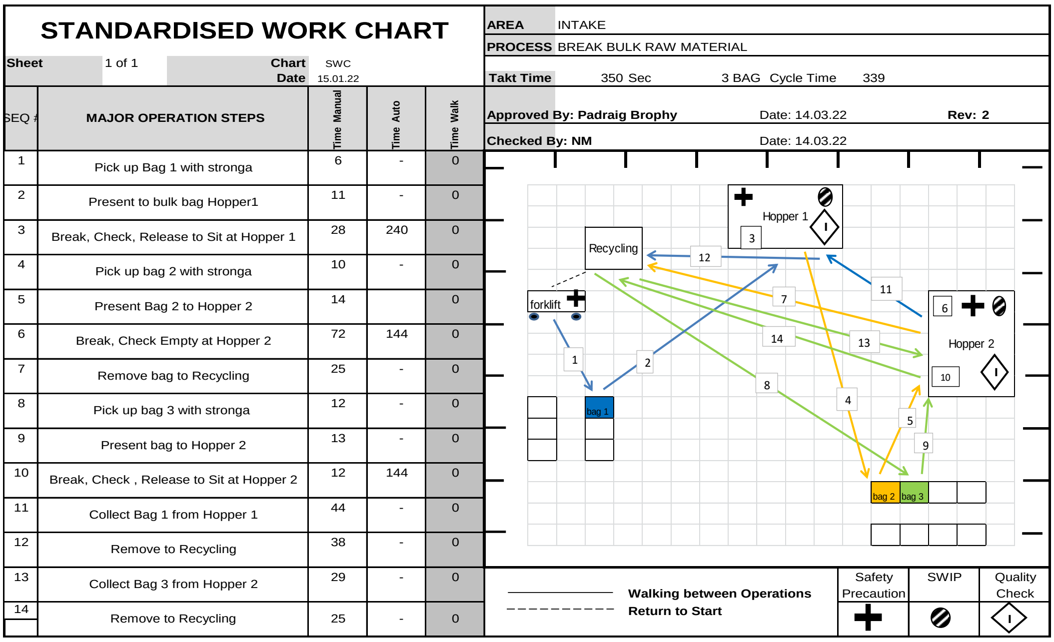
Figure 2: Future State Value Stream Map of the CFM process.

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 3 to 1 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 seconds 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.

3.6 Improve

The *Improve* step of the VSM Model was focused on the implementation of changes which 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 11 illustrates details of the standard work chart for the intake area to improve the process controls and visual aids.



STANDARDISED WORK CHART

Sheet 1 of 1 **Chart** SWC
Date 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

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

Figure 3: Standard work chart - RM Intake.

The process is controlled to deliver 3 bulk bags in 339 seconds, comfortably within the 350 second 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. 1320t was established as the required stock holding.

Figure 12 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 minimized inventory at intake. Moreover, the warehouse eliminated the requirement for constant material movement.

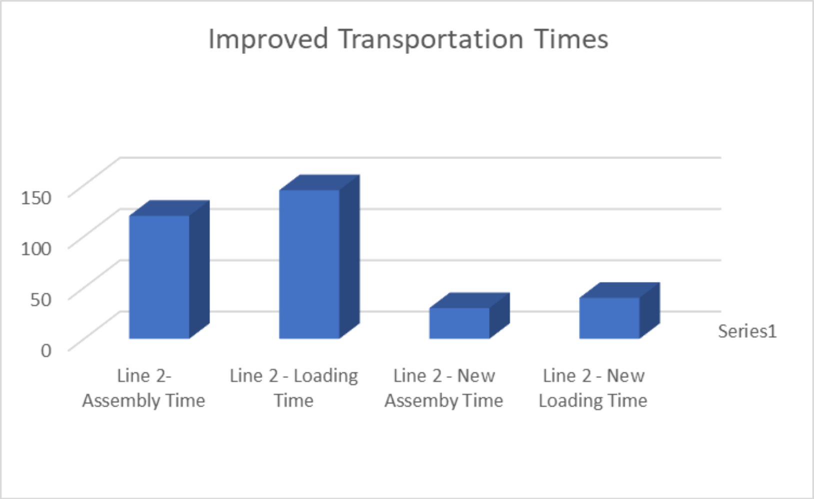


Figure 4: Comparison of transportation time.

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.

3.7 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 leader standard work (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 Centrepoint. 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 seconds. The factory has a capacity to produce 16 t/hr 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 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 13 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 centre line. The preference is to minimise variation with most data points falling close to the mean/centre line. Operators investigate where the rate moves beyond 2 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.

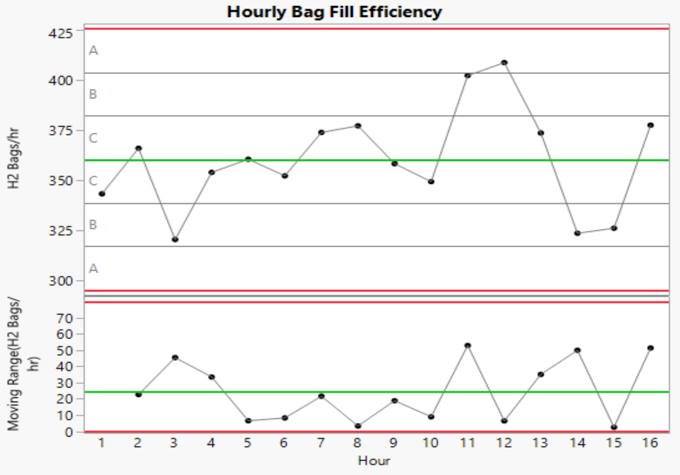
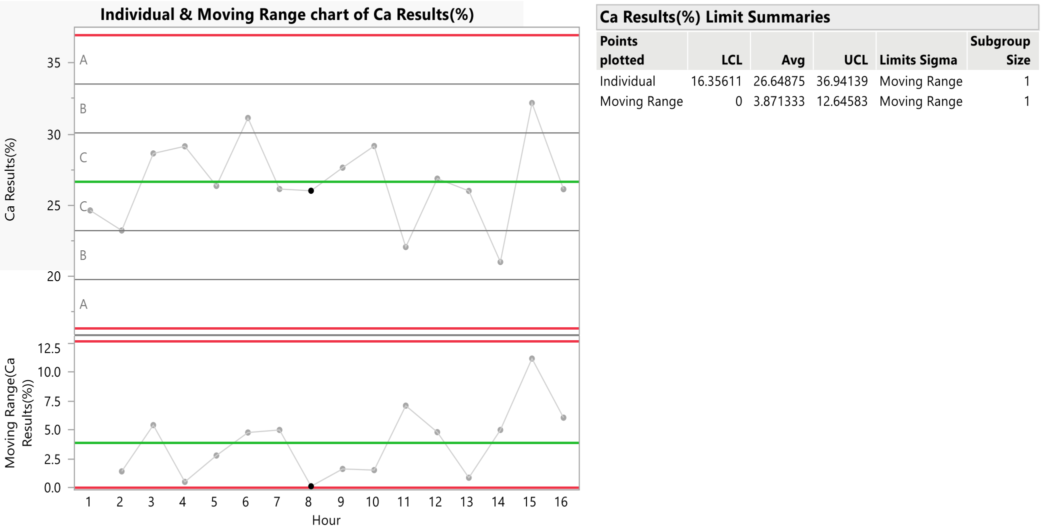


Figure 5: Bag Fill Control Chart showing a stable process.

Figure 14 illustrates a QC Control Chart to ensure consistent formula composition.



Ca Results(%) Limit Summaries

Points plotted	LCL	Avg	UCL	Limits Sigma	Subgroup Size
Individual	16.35611	26.64875	36.94139	Moving Range	1
Moving Range	0	3.871333	12.64583	Moving Range	1

Figure 6: QC Composition Control Chart.

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 5: 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%

Table 5 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 requires an integrated training approach and early adaptation of LSW. 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 thirty-four Swedish farms over eighteen 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. Developing a model that integrated staff training, leadership with a bespoke LSS methodology created an interdependence between staff and management, as shown in Figure 16.

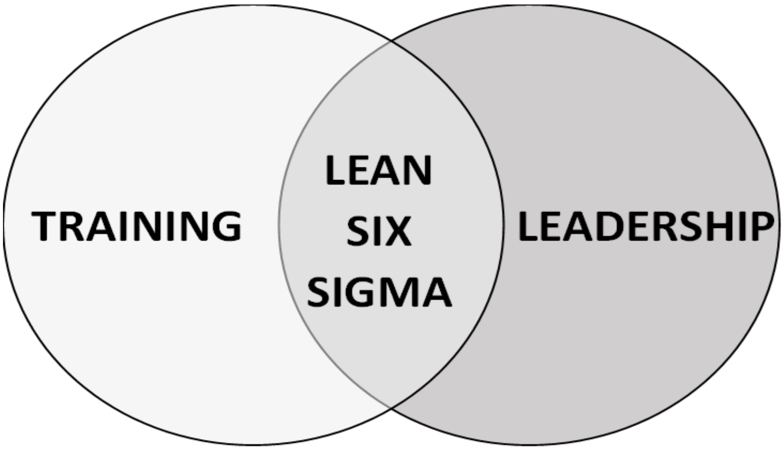


Figure 7: VSM DMAIC transferable framework.

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. 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. Leadership and training were the drivers of change to a continuous improvement process.

The VSM DMAIC model is limited by the need for a LSS champion to initiate and drive change. Löfving et al., (2021) characterised SMEs as often having one leader, informal structures with few hierarchical levels, and so centred on one person. The change agent needs time and resources requiring a trusted interlocuter between staff and senior management. Within CFM manufacturing 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. Moya et al., (2019) propose a pre-implementation assessment which identifies strengths and weaknesses prior to implementation. A rigorous assessment prior to implementation could 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., 2018). 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 leader standard work could support the licence to apply VSM DMAIC framework. Compared to previous research, the study clearly demonstrated how an 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 compound feed manufacturing and other industrial sectors.

6 Conclusion

The novelty of this research relies on the tailoring of Lean Six Sigma (VSM & DMAIC) methodology into compound feed manufacturing 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. 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 a LSS transformation as a recurring VSM DMAIC cycle with increasing layers of competence within compound feed manufacturing and similar SMEs. Future research study will explore the methodologies and improvements by transferring them across other CPM sites within the case study organisation. As this is the first study involving LSS deployment in an Irish CPM and adds to the limited published work available on thus area.

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