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DEVELOPING LEAN SIX SIGMA FRAMEWORK FOR USE IN SMALL AND MEDIUM ENTERPRISES

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Abstract: Previous researches in manufacturing operations concluded that the best opportunities for improvement are achieved when the manufacturing system is designed from the top down and from customer to the supplier. The most effective manufacturing system designs is the one that consider the whole product value stream rather than just shop-floor activities. Although the lean deployment is a critical success factor, yet there is no holistic or a step by step approach to the deployment process. The lack of a framework that provides a systematic practical approach to lean implementation is increasingly becoming an issue for manufacturing organisations and professionals. This paper presents an attempt to develop a framework that can be used to develop a lean manufacturing system in small and medium enterprises (SME). The framework is based on lean six sigma principles of efficiency, speed, reduced waste and high quality.

1. Introduction:

In manufacturing organisations, the manufacturing function has great potential and ability to contribute to achieving strategic goals; therefore it should be given the same importance as other business functions in the organisation (Skinner, 1969). By understanding the full potential of manufacturing it can change from a tool for implementing decisions taken by other functions into a function that take a proactive role in shaping the business strategy and provide the organisation with a sustainable competitive advantage (Gilgeous et al, 1999).

2. Problem statement:

Unlike large organisations, SMEs did not get enough attention for implementation of manufacturing methodologies and technologies (Gunasekaran et al, 1998).

Although the lean transformation process is a critical success factor, yet there is no holistic approach to the lean transformation process. Henley business transformation framework was used as a frame of reference despite the fact that it is very basic, other lean and TPS researchers only provided bullet points (Ahrens, 2006).

Kilpatrick (1997) reported that despite the rich literature on lean manufacturing principles, a general lack of focus on the system level issues is visible, also there is no clear integration between the three levels of production: system, cell and machine. Kilpatrick also believe there is a need to investigate at all three levels the issues that prevent successful implementation of lean manufacturing (Kilpatrick, 1997).

Gilgeous et al, 1999; Kilpatric, 1997; Vaughn et al, 2002; Ahrens, 2006) all concluded that the lack of holistic approach or scheme to the lean transformation process has created the need to develop a framework that can be used to facilitate this process.

There is urgent need for research work in

this field to fill that gap by providing a framework for manufacturing organisations and professionals that can be used to facilitate implementation of lean. The lean six sigma methodology presented by Shamou and Arunachalam (2009) is chosen as the favourite methodology that the framework will be based on because of its advantage over traditional lean.

3. Benefits of integrating lean and six sigma:

Lean six sigma is a methodology that aims to maximise shareholder value by achieving the fastest rate of improvement in customer satisfaction, cost, quality, process speed and flexibility. Lean focus on process speed and waste removal while six sigma focuses on the removal of process variation that leads to defects (George, 2002). Lean and six sigma together provide the tools and techniques to solve problems and achieve significant improvements across the company faster.

The lean six sigma can provide benefits that cannot be secured if lean and six sigma are applied in isolation (Arthur, 2007). Examples of those benefits are:

- 1- Companies can double their speed without working harder.
- 2- Quality can be improved by 50% or more by reducing defects and variations.
- 3- Profits increase as a result of eliminating the cost of fixing problems.

Furthermore, combining lean and six sigma enables achieving improvement at lower cost (Bevan et al, 2005).

4. Small and medium enterprises:

Small and medium enterprises (SMEs) manufacturers are characterised by the following feature:

- Limited investment power.
- Low to high production volumes
- Medium to high product variety
- Use manual or semi automated equipments.
- Moderate to high operator skills.

These features are considered when the framework is designed to ensure that SMEs are able to use and benefit from the framework to improve their business prospect.

5. The lean six sigma framework features:

The framework objective is to provide a systematic step by step approach to the lean six sigma implementation process. The framework use knowledge and data collected from empirical study and literature review to formulate logical relationship between system components, show correct sequence of events and identify necessary tools and techniques. The framework process also enhances communication between company functions, prevents conflicting decisions and provides a mean for performance measurement. The lean and six sigma manufacturing concepts are used in the framework because they provide best manufacturing practices (George, 2002).

The system approach is adopted to ensure a rational link exists between system components (Monden, 1998). This is also to ensure the framework is process oriented structure that crosses the boundaries between different functions. Furthermore, it provide a link between high level strategic goals and low level activities similar to the principles of Axiomatic Design developed by Nam Suh at MIT (Vaughn et al, 2002). The framework designed to include the whole production system which is bigger

than the manufacturing system (Black, 1991).

6. Framework objectives:

The lean six sigma framework aim in providing an implementation process that can be used by manufacturing professionals to establish a manufacturing system for SMEs that is effective in achieving business objectives. The objectives are:

- Build manufacturing system that support business objectives.
- Ensures optimum manufacturing performance.
- Provide step by step implementation process.
- Show links between top level business objectives and shop floor activities.
- Emphasize importance of manufacturing operations and shop floor activities in achieving business objectives.
- Provide clear understanding of the lean six sigma process and deployment.

7. Background:

The first author had carried out an empirical study in 2008 about effectiveness of lean and six sigma implementation in SMEs, the study included 26 lean manufacturers and six sigma users from US, UK, Holland, Germany, Spain and China. The most important conclusions from the study are:

- 1- Understanding lean fundamental principles is a critical success factor.
- 2- Effective and successful lean implementation can only be achieved with a structured framework that link lean principles to business objectives, describe sequence of events and identify correct tool and techniques.

3- It is important to create a formula that links operation parameters to manufacturing performance indicators.

4- Successful lean transformation can only be achieved if support functions are fully integrated using a value stream approach.

The data analysis showed a close link between achievement of business and operation objectives. Vaughn et al (2002) also pointed to the importance of low level activities at operation level in achieving top level business objectives

The manufacturing complexity is also considered. It is obvious that manufacturing complexity increases lead time and might affect quality. To eliminate the complexity in order to improve stability and scheduling reliability, process design must be simplified to tackle static complexity, and controls measures must be applied to tackle dynamic complexity (Flowers and Cheng, 2008).

Figure 1 show the resulting new lean six sigma framework.

8. Framework structure:

Building a manufacturing system on best practice reduces the risks and instability faced by manufacturing system based on unstable market trends (Vaughn et al, 2002). With that in mind the framework adopted typical business objectives for SME manufacturers.

The framework is made up of two main phases:

Phase1: Establishing the foundation for the manufacturing system.

Phase 2: Achieving stability.

Phase one is broken down into 3 parts: prerequisites, operation strategy and infrastructure. Similarly, phase 2 is broken down into 5 stages. Each phase is broken down into sections or stages which need to be completed in the numerical order that is

also indicated by the direction of the arrows shown in the framework drawing. For phase 1, because organisation's objectives are cascaded top bottom, the framework start at the top and moves need to be completed before the ones below them. Conversely, phase 2 starts at bottom and moves upwards since achievement of objectives begins at the lowest level in the shop floor; this means activities at the bottom are prerequisite for activities above them. The framework also works from the left to the right which means Phase1 should be completed before phase2 is started. Similarly, for phase2, stage 1 must be in place before stage 2 is started and so on. The most popular tools and techniques used at each sub stage are shown at the bottom.

8.1. Business objective:

The business objectives for the organisation need to be identified first because business objectives are the reason why the organisation exists. For SMEs, business objectives are the highest level objectives in the organisation, they have direct influence on manufacturing strategy.

The business objectives set the targets of the manufacturing facility based on its capabilities, potentials and future directions. A lean survey carried out by The Manufacturer in 2002, showed that the most important business objective sought by lean manufacturers are: increasing profitability, increasing customer satisfaction and winning competitive edge.

The empirical study conducted by the first author in 2008 – 2009 has revealed similar results presented in Table1.

Reasons for using	Percentage of Cases
Reduce operation cost	82.6%
Increase total annual sales	30.4%
Improve Return On Investment	56.5%
Increase gross annual profit	69.6%
Reduce inventory turns	91.3%
Reduce Defective Parts Per	56.5%
Improve process capability	69.6%
Increase productivity	95.7%
Reduce cost of poor quality	69.6%
Improve delivery	65.2%

Table 1: Why companies use lean manufacturing

The above list contains business and manufacturing strategy objectives. The business objectives can be classified into 4 common categories that SMEs manufacturers try to achieve:

- High profit margin
- High Return On Investment
- Bigger market share
- High customer satisfaction

These are the business objective the lean six sigma framework is based on.

8.2. Manufacturing strategy:

For manufacturing strategy to support business objectives, strategy planners need to be aware of strengths and weaknesses of competition, different market forces, gaps & opportunities and customer requirements.

Formation of manufacturing strategy is critical for manufacturing companies because it is the link between business objectives and operation. It links company functions together, enhance communication

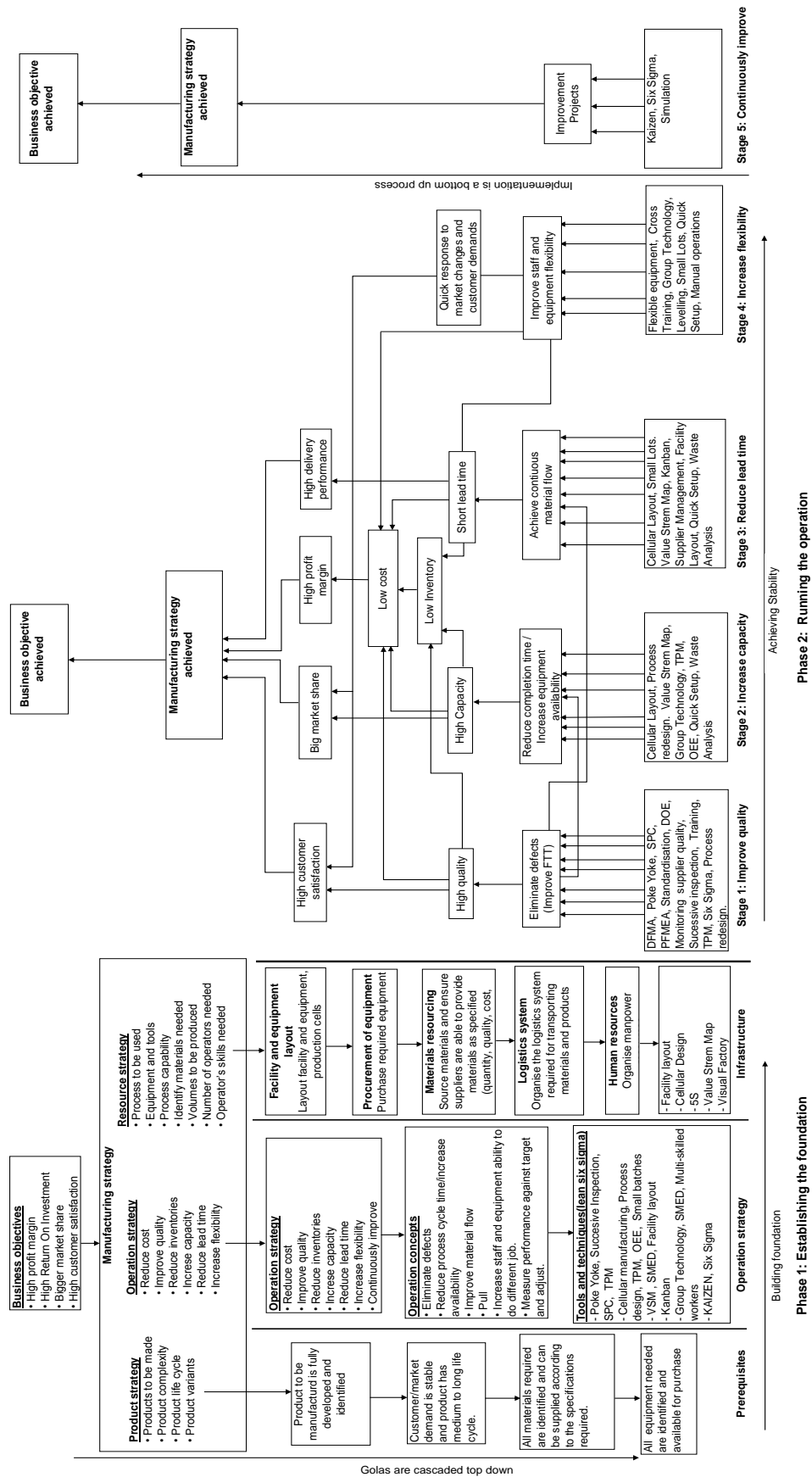


Fig.1. The lean six sigma framework

between functions and different management levels; it can also prevent decision conflicts (Miltenburg, 1995). Furthermore, manufacturing strategy enable the organisation to use their capabilities wisely to compete, ensure capabilities are fully utilised, identify any needs to strengthen the operation capabilities and sets priorities for improvement projects.

The manufacturing strategy generates three types of data outputs:

1- Product development strategy:

These are the data required by research and development department to design the product to be manufactured such as Products type, complexity, life cycle, Product variants.

The product development stages should be completed before considering developing the manufacturing system. These data will be used as inputs for the prerequisites section of phase1.

2- Resource strategy:

These are the data needed in the infrastructure section to plan all the resources needed to physically produce the product, such as Process, Equipment and tools, Process capability, Volumes to be produced, Number of operators needed and Operator's skills needed.

These data will be used in the infrastructure section of phase 1.

3- Operation strategy:

These are the manufacturing strategy objective that will be needed to develop the operation.

The most common operation strategy objectives for lean manufacturers are: reduce cost, improve quality and improve delivery (Womack and Jones, 2000; George, 2002; Ahrens 2006). Increasing flexibility has been identified an additional key

objective. The same lean survey conducted by The Manufacturer in 2002, showed that the most important operation objective sought by lean companies are: cost reduction improving delivery, improving productivity, improving quality, and reducing inventories.

Comparing these data to Table 1 and sorting in categories we end up with the following five groups of common operation strategy objectives:

- Reduce cost
- Improve quality
- Reduce inventories
- Increase capacity
- Reduce lead time
- Increase flexibility

These strategy objectives are then used to identify operation concepts and tools & techniques in the operation strategy section of phase1.

9. Phase1: Establishing the foundation:

Phase1 of the framework is about establishing the foundation for the manufacturing system, this phase is broken down into three sections: prerequisites, operation strategy and infrastructure, they should be completed in their numbering order.

The three sections of this phase are explained below:

1- System Prerequisites:

These are the elements that should be in place before thinking about creating or restructuring a manufacturing system. The key element in this section is the product to be manufactured, it must be fully identified and developed, also the amount of products to be made must justify the investment cost,

therefore customer demand and duration must be understood. The product life cycle must be long enough to justify capital investment in equipment and other resources. All materials required to make the product must also be fully specified and found to be available in the market with the specifications identified during product development stage such as quality, volumes, cost, and frequency of delivery. Process technology and equipment required to make the product also must be specified and found to be available in the market.

2- Operation strategy:

Operation strategy needs to be established before installing the infrastructure.

The main objective of the framework is to set up an efficient manufacturing system that enables the organisation to run a profitable operation and stay competitive (Vaughn et al, 2002), and the manufacturing operation is the backbone of this system.

The framework promotes a process oriented operation strategy that integrates organisation functions and departments and sets operation performance targets. It also provides the guidelines, objectives and targets at operation level.

The details needed here are: operation type, cost, capacity, quality and flexibility targets. Now using the manufacturing strategy elements for SMEs identified above and by utilising the Quality Function Deployment tool (QFD) the operation strategy elements that support them are identified as:

- Improve quality
- Increase capacity
- Reduce lead time
- Increase flexibility
- Continuously improve

To achieve the operation strategy, the elements are broken down further to identify

the operation concepts and policies that support them which are:

- Eliminate defects
- Reduce process cycle time
- Improve material flow
- Pull
- Increase staff and equipment ability to do different job.
- Measure performance against target and adjust

3- Infrastructure:

The operation strategy section must be completed before starting this stage; this is because operation strategy dictates activities in this section. Before the organisation commit themselves to purchasing or hiring site, new equipments, sourcing materials and hiring human resources, they need to study their operation strategy and understand process, quality, flexibility and setup time requirements, as these requirements determines the type of equipments they need to purchase. The need for reducing cost, eliminating waste and continuity of material flow influence facility layout and agreements with suppliers.

There are five key elements in this section to be executed in the numbering order:

- 1- Facility and equipment layout
- 2- Procurement of equipment
- 3- Materials sourcing
- 4- Logistics system
- 5- Human resources

10. Phase 2: Running operation:

10.1. Stage 1: Improve quality:

This is the first stage in the phase 2. Once the manufacturing operation started, the first task is to ensure that the processes can produce the required quality consistently.

The performance measure is the first time through (FTT) which can be defined as percentage of items processed right first time. The target set for this is 99.5%, as per the benchmarking data produced by the DTI which are shown in Table 2.

Household & General Products Sector (2000–2002 data)		
Supply Chain Management	Average*	Top 25%
Delivery reliability	(%) 98.0 +	99
Ex-stock availability (%)	99.0 +	99.8
Total stock turns	20	28
People Management		
Training on job (days):		
Existing employees	9	10
New employees	22	25
Annual absenteeism (%)	4.1	3.0
Process Repeatability		
Scrap rate (%)	2.7 +	1.0
OEE (for the best line)	72.0	85.0
Right first time at final test (%)	96.0	99.5
Flexibility		
Average component set-up time (mins)	30 +	15
Average assembly set-up time (mins)	15 +	10

* This column contains the mean performance level; however where the + symbol appears the median figure has been given as the best indicator of the central tendency. © Copyright Dr Marek Szejczewski.

Table.2: Benchmarking data for the household and general product sector (DTI Manufacturing Report, 2000 – 2002)

10.2. Stage 2: Increase capacity:

In stage 2, the company need to ensure that they have enough capacity to achieve maximum expected customer demand plus 15% reserve capacity, i.e. maximum expected customer demand should be 85% of full equipment capacity (Black, 1991), if that is not the case, the company need to follow steps described in stage 2 until the target is achieved. The techniques and tools that could be utilised to achieve this target are shown in Fig.1 Stage 2.

10.3. Stage 3: Reduce lead time

Reducing lead time means the manufacturer is able to repeat their value adding process

more frequently and hence generate more profit. The target for this is that the ratio of value adding time to overall lead time should be 25% or higher (George, 2000). To achieve this, stage 1 and 2 must be completed successfully. The techniques and tools that could be utilised to achieve this target are shown in Fig.1 Stage 3.

10.4. Stage 4: Improve flexibility

To increase flexibility companies need to make sure their equipment are easy to set up to produce different product variant as and when the customer need them. The time needed to perform the set up should be as minimum as possible such that it does not cause equipment availability issues, the target for this is a single digit figure (Shingo, 1988), the benchmarking data from DTI shown in table 2 has set the target for this as 10 minutes.

The same goes for human resources; operators must be multi skilled and able to make/process all different types of product variants.

The lean six sigma framework has introduced the two concepts of equipment flexibility index and operator flexibility index to measure equipment and operator flexibility respectively.

The Equipment Flexibility Index (EFI) is given by the following equation:

$$EFI = \frac{PPT}{N * AST} \dots\dots\dots(1)$$

Where:

- PPT is Planned Production Time
- N is the number of equipment setups
- AST is Average Setup Time

The lean six sigma objective is to increase EFI, and that is by following two approaches:

- 1- Reduce the average setup time.
- 2- Reduce the need for frequent equipment setup.

The lean six sigma target for EFI is 25.

The Operator Flexibility Index (OFI) is given by the following equation:

$$OFI = \frac{A}{M} \dots\dots\dots(2)$$

Where:

A is the average no of training elements completed by operator

M is the total no of training elements.

OFI represents flexibility of operators to do different jobs which they have learned through training that split into different training elements.

The lean six sigma objective is to increase OFI to a target value of 1.

10.5. Stage 5: Continuously improve

This stage represents the correction and fine tuning of all the work completed in the previous phases and stages. The high competition in today’s manufacturing industry makes continuous improvement imperative for manufacturer to survive (Shamou and Arunachalam, 2008). Continuous improvement is required for any manufacturing system as long as it is active (Vaughn et al, 2002), it simply never ends (Womack and Johns, 2000). Lean six sigma has introduced use of simulation as a continuous improvement aid because it is expected to help achieving results faster and first time, this in turn saves the user from following traditional trial and error approaches which can take longer and consume considerable resources.

Simulation should be carried out early before the physical implementation work begins. Once the process design or change is adjusted based on simulation result, a trial run can be carried out to validate the new process or change, final corrections and adjustments may be required depending on

trial runs results before the new process or change is finally implemented (Barber et al, 2003). Once the new process is implemented, future changes may be required as part of the continuous improvement culture of the lean six sigma methodology (Fig.3).

For continuous improvement initiatives to succeed they need top management champions support (Morgan, 2006).

The major tools used at this stage are Kaizen six sigma and simulation.

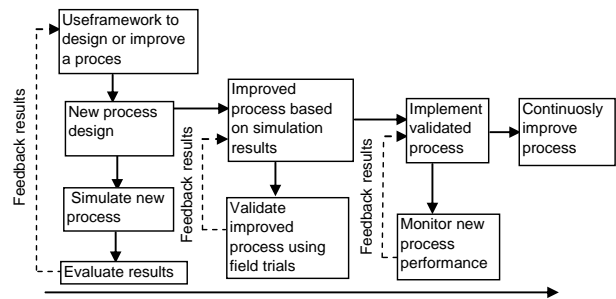


Fig.3. The lean six sigma continuous improvement journey

11. Conclusion

The lean six sigma framework provides an implementation plan for lean six sigma methodology.

The framework showed that factory floor activities are prerequisites for achieving high level goals and top business objectives. Unlike manufacturing systems based on unstable market trends, the lean six sigma framework is based on best manufacturing practices which enable companies to compete effectively. Furthermore, as the framework used typical top level business objectives for SMEs, it can be said that the framework suits most SME manufacturers. Because the lean six sigma framework use business and manufacturing strategies that take into account the product to be made,

there is no risk involved in using the framework to design a manufacturing facility for any product.

Because the framework process outcome is based on business and manufacturing objectives, if these objectives are significantly changed, the whole manufacturing system has to be reviewed.

The tools and practices noted in the framework are the major ones that are proved and verified in practice and hence recommended. However they are not the only ways to achieve top-level objectives.

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