LEAN SIX SIGMA: METHODOLOGY AND PRACTICE IN OPERATIONS
MANAGEMENT CASE: BOTTLE WATER DISTRIBUTION IN SERBIA

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Abstract Six Sigma and Lean Manufacturing are the two most popular and successful programs espoused by the industries over the last few decades. Many companies such as Toyota, Danaher Corporation, General Electric, Motorola and many others have achieved impressive results by implementing either a Lean or Six Sigma methodology in their organisation. Six Sigma, originated in Motorola in mid 1980s, brought revolution in the industries worldwide and has become the long term business strategy to achieve competitive advantage and to excel in operations excellence. Six Sigma is widely recognized as a methodology that employs statistical and non-statistical tools and techniques to maximize an organization’s Return on Investment (ROI) through the elimination of defects in processes (Antony et al. 2011). Lean Manufacturing, on the other hand, was another quality initiative proposed by Americans in response to compete with Japanese manufacturers and its superior manufacturing techniques (following the concept of Toyota Production System (TPS) to resolve quality problems in their organization) as their import became serious concern to western producers.

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1 Introduction

Operations Management is the activity of managing the resources which produce and deliver goods and services (Slack et al., 2010). Operations can be seen as one of many functions (e.g. marketing, finance, personnel) within the organisation. The operations function can be described as that part of the organisation devoted to the production or delivery of goods and services. This means all organisations undertake operations activities because every organisation produces goods and/or services.

1.1 Operations priorities

Operations should focus on specific capabilities that give it a competitive edge which may be termed competitive priorities. Four operations priorities or measures of these capabilities can be termed cost, time, quality and flexibility (Porter, 2011).

1.1.1 Cost

If an organisation is competing on price, then it is essential that it keeps its cost base lower than the competition. Then it will either make more profit than rivals, if price is equal, or gain market share if price is lower. Cost is also important for a strategy of providing a product to a market niche, which competitors cannot provide. Thus cost proximity (i.e. to ensure costs are close to the market average) is important to maximise profits and deter competitors from entering the market. The major categories of cost are staff, facilities (including overheads) and material with the greatest scope for cost reduction lies with reduction of the cost of materials. A relatively small proportion of costs are usually assigned to direct labour.

1.1.2 Time

The time delay or speed of operation can be measured as the time between a customer request for a product/service and then receiving that product/service. Speed is an important factor to the customer in making a choice about which organisation to use.
The concept of P:D ratios (Shingo, 1989) compares the demand time D (from customer request to receipt of goods/services) to the total throughput time P of the purchase, make and delivery stages. Thus in a make-to-stock system D is basically the delivery time, but for a customer-to-order system the customer demand time is equal to the purchase, make and delivery stages (P). In this case the speed of the internal processes of purchase and make will directly effect the delivery time experienced by the customer. Thus the advantage of speed is that it can either be used to reduce the amount of speculative activity and keep the delivery time constant or for the same amount of speculative activity it can reduce overall delivery lead time. Thus in competitive terms speed can be used to both reduce costs (making to inaccurate forecasts) and reduce delivery time (better customer service).

1.1.3 Quality

Quality covers both the quality of the product/service itself and the quality of the process that delivers the product/service. Quality can be measured by the ‘cost of quality’ model were costs are categorised as either the cost of achieving good quality (the cost of quality assurance) or the cost of poor quality products (the costs of not conforming to specifications). The advantages of good quality on competitiveness include increased dependability, reduced costs and improved customer service.

1.1.4 Flexibility

There are a number of areas in which flexibility can be demonstrated. For example, it can mean the ability to offer a wide variety of products/services to the customer and to be able to change these products/services quickly. Flexibility is needed so the organisation can adapt to changing customer needs in terms of product range and varying demand and to cope with capacity shortfalls due to equipment breakdown or component shortage. Types of flexibility include product flexibility which is the ability to be able to quickly act in response to changing customer needs with new product/service designs and volume flexibility which is the ability to be able to decrease or increase output in response to changes in demand. Volume flexibility may be needed for seasonal changes in demand as services may have to react to demand changes minute by minute.
1.2 JIT and lean systems

Just-In-time (JIT) is a philosophy originating from the Japanese auto maker Toyota where Taiichi Ohno developed the Toyota Production system (Ohno, 1988). The basic idea behind JIT is to produce only what you need, when you need it. This may seem a simple idea but to deliver it requires a number of elements in place such as the elimination of wasteful activities and continuous improvements.

1.2.1 Eliminate waste

Waste is considered in the widest sense as any activity which does not add value to the operation. Seven types of waste identified by Toyota are as follows (Ohno, 1988):

- **Over-Production.** This is classified as the greatest source of waste and is an outcome of producing more than is needed by the next process.

- **Waiting Time.** This is the time spent by labour or equipment waiting to add value to a product. This maybe disguised by undertaking unnecessary operations (e.g. generating work in progress (WIP) on a machine) which are not immediately needed (i.e. the waste is converted from time to WIP).

- **Transport.** Unnecessary transportation of WIP is another source of waste. Layout changes can substantially reduce transportation time.

- **Process.** Some operations do not add value to the product but are simply there because of poor design or machine maintenance. Improved design or preventative maintenance should eliminate these processes.

- **Inventory.** Inventory of all types (e.g. pipeline, cycle) is considered as waste and should be eliminated.

- **Motion.** Simplification of work movement will reduce waste caused by unnecessary motion of labour and equipment.

- **Defective Goods.** The total costs of poor quality can be very high and will include scrap material, wasted labour time and time expediting orders and loss of goodwill through missed delivery dates.
1.2.2 Continuous improvement and JIT pull systems

Continuous Improvement or Kaizen, the Japanese term, is a philosophy which believes that it is possible to get to the ideals of JIT by a continuous stream of improvements over time.

The idea of a pull system comes from the need to reduce inventory within the production system. In a push system a schedule pushes work on to machines which is then passed through to the next work centre. A production system for an automobile will require the co-ordination of thousands of components, many of which will need to be grouped together to form an assembly. In order to ensure that there are no stoppages it is necessary to have inventory in the system because it is difficult to co-ordinate parts to arrive at a particular station simultaneously.

The pull system comes from the idea of a supermarket in which items are purchased by a customer only when needed and are replenished as they are removed. Thus inventory co-ordination is controlled by a customer pulling items from the system which are then replaced as needed (Ohno, 1988).

To implement a pull system a kanban (Japanese for ‘card’ or ‘sign’) is used to pass information through the production system. Each kanban provides information on the part identification, quantity per container that the part is transported in and the preceding and next work station. Kanbans in themselves do not provide the schedule for production but without them production cannot take place as they authorise the production and movement of material through the pull system. Kanbans need not be a card, but something that can be used as a signal for production such as a marked area of floorspace.

There are two types of kanban system, the single-card and two-card. The single-card system uses only one type of kanban card called the conveyance kanban which authorises the movement of parts. The number of containers at a work centre is limited by the number of kanbans. A signal to replace inventory at the work centre can only be sent when the container is emptied. Toyota use a dual card system which in addition to the conveyance kanban, utilises a production kanban to authorise the production of parts.
This system permits greater control over production as well as inventory. If the processes are tightly linked (i.e. one always follows the other) then a single kanban can be used. In order for a kanban system to be implemented it is important that the seven operational rules that govern the system are followed. These rules can be summarised as follows (Ohno, 1988):

- Move a kanban only when the lot it represents is consumed.
- No withdrawal of parts without a kanban is allowed.
- The number of parts issued to the subsequent process must be the exact number specified by the kanban.
- A kanban should always be attached to the physical product.
- The preceding process should always produce its parts in the quantities withdrawn by the subsequent process.
- Defective parts should never be conveyed to the subsequent process.
- A high level of quality must be maintained because of the lack of buffer inventory. A feedback mechanism which reports quality problems quickly to the preceding process must be implemented.
- Process the kanbans in every work centre strictly in order in which they arrive at the work centre.
- If several kanbans are waiting for production they must be served in the order that they have arrived. If the rule is not followed there will be a gap in the production rate of one or more of the subsequent processes. The system is implemented with a given number of cards in order to obtain a smooth flow. The number of cards is then decreased, decreasing inventory and any problems which surface are tackled. Cards are decreased, one at a time, to continue the continuous improvement process.

2 Total quality management (TQM) as a part of operations management

Total Quality Management (TQM) requires that the principles of quality management are applied in all aspects and at every level in an organisation (Hill, 2005). TQM has evolved over a number of years from ideas presented by a number of quality Gurus. Deming (1985) proposed an implementation plan consisting of 14 steps which emphasises continuous improvement of the production process to achieve conformance to specification and reduce variability. This is achieved by
eliminating common causes of quality problems such as poor design and insufficient training and special causes such as a specific machine or operator. He also places great emphasis on statistical quality control techniques and promotes extensive employee involvement in the quality improvement program. Juran (2001) put forward a 10 step plan in which he emphasises the elements of quality planning - designing the product quality level and ensuring the process can meet this, quality control - using statistical process control methods to ensure quality levels are kept during the production process and quality improvement - tackling quality problems through improvement projects. Crosby (1996) suggested a 14-step programme for the implementation of TQM. He is known for changing perceptions of the cost of quality when he pointed out that the costs of poor quality far outweigh the cost of preventing poor quality, a view not traditionally accepted at the time.

Six Sigma is one of the most important and popular developments in the quality field. It has saved huge amounts of money and improved the customer experience for a large number of organizations across the world, yet it is applied in an inconsistent and often reductive fashion in many companies.

2.1 The cost of quality

All areas in the production system will incur costs as part of their TQM program. For example, the marketing department will incur the cost of consumer research in trying to establish customer needs. Quality costs are categorised as either the cost of achieving good quality - the cost of quality assurance or the cost of poor-quality products - the cost of not conforming to specifications.

2.1.1 The cost of achieving good quality

The costs of maintaining an effective quality management program can be categorised into prevention costs and appraisal costs (Knowles, 2011). Prevention reflects the quality philosophy of “doing it right the first time” and includes those costs incurred in trying to prevent problems occurring in the first place. Examples of prevention costs include:

- The cost of designing products with quality control characteristics.
- The cost of designing processes which conform to quality specifications.
The cost of the implementation of staff training programmes.

Appraisal costs are the costs associated with controlling quality through the use of measuring and testing products and processes to ensure that quality specifications are conformed to. Examples of appraisal costs include:

- The cost of testing and inspecting products.
- The costs of maintaining testing equipment.
- The time spent in gathering data for testing.
- The time spent adjusting equipment to maintain quality.

### 2.1.2 The cost of poor quality

This can be seen as the difference between what it actually costs to provide a good or service and what it would cost if there was no poor quality or failures. This can account for 70% to 90% of total quality costs and can be categorised into *internal failure costs* and *external failure costs* (Knowles, 2011). Internal failure costs occur before the good is delivered to the customer. Examples of *internal failure costs* include:

- The scrap cost of poor quality parts that must be discarded.
- The rework cost of fixing defective products.
- The downtime cost of machine time lost due to fixing equipment or replacing defective product.

*External failure costs* occur after the customer has received the product and primarily relate to customer service. Examples of external failure costs include:

- The cost of responding to customer complaints,
- The cost of handling and replacing poor-quality products,
- The litigation cost resulting from product liability,
- The lost sales incurred because of customer goodwill affecting future business.
Although anyone who works in an organization will be familiar with many examples of these issues, business accounting systems are not set up to capture these costs. Traditional accounting approaches are designed to track the inflow and outflow of money in an organization (and, by extension, to product lines or departments). There is little emphasis on whether the money in the department is spent effectively.

Figure 1. shows Feigenbaum’s Prevention-Appraisal-Failure (P-A-F) model of costs of poor quality, although there are others.

| Cost Area            | Cost of Control (Cost of Conformance) | Cost of Failure of Control (Cost of Non-Conformance) |
|----------------------|---------------------------------------|------------------------------------------------------|
| Sub-Category         | Prevention Costs | Appraisal Costs | Internal Failure Costs | External Failure Costs |
| Description          | Arise from efforts  
to keep defects from  
occurring at all    | Arise from detecting  
defects via test, audit,  
inspection               | Arise from defects caught  
internally and dealt with by  
discarding or repairing the  
affected items            | Arise from defects that  
actually reach the final  
customer.                     |
| Examples             | Quality planning  
Statistical Process  
Control               | Test and inspection of  
purchased materials  
Inspection                 | Scrap                   | Warranty costs          |
|                      | Quality training  
and workforce  
development           | Testing                  | Rework costs            | Out of warranty  
complaints               |
|                      | Product design  
verification          | Quality audit             | Management of rework  
systems                 | Product recall           |
|                      | Market research     |                         | Rejection paperwork    | Product liability claims |

Figure 1: Cost of Quality types and examples  
(adapted from Feigenbaum, 1961)

The lack of clarity of the cost of poor quality in organizations led to a lack of focus on improvement for many years. It was only with the advent of the “Cost of Quality” approach in the 1950’s (Defoe and Juran, 2010) that organizations had a financial tool to assess the costs associated with quality failures and thus focus on the most important areas for improvement.
The basic logic is that a relatively small increase in spending on prevention activities will deliver a more than compensating reduction in appraisal and failure costs (see figure 2.)

The concept of waste is fairly generic in nature and has been around for a long time. Many organisations refer to ‘non-value added activities’ and ‘process waste’. However, these are rather broad terms and, whilst it is easy to agree that waste is bad and should be eradicated (or at least reduced) it does not much help in the process of improvement. The Seven Wastes were identified by Ohno as part of the Toyota Production System (Ohno, 1988) and have since been widely applied to process improvement, becoming particularly associated with the principles of lean manufacturing.
### Lean Six Sigma (LSS)

During late 1980s, two other business improvement strategies evolved (namely Lean and Six Sigma) that were cynosure for resolving quality or process related problems in manufacturing and service industries and having significant impact on the bottom-line of corporations globally. Six Sigma and Lean Manufacturing are the two most popular and successful programs espoused by the industries over the last few decades. Many companies such as Toyota, Danaher Corporation, General Electric, Motorola and many others have achieved impressive results by implementing either a Lean or Six Sigma methodology in their organisation (Knowles, 2011).

#### Figure 3: Types of waste and associated costs
(adopted from Ohno, 1988)

| Type of Waste | Potential Associated Costs |
|---------------|----------------------------|
| **Waiting**   | **Labour** cost associated with idle time. Value of lost production (if units are lost) or cost of overtime if this has to be worked to catch up. Cost of late delivery if overall process time affected. |
| **Correction**| Rework cost (direct and overhead if applicable). Cost of delays (as above). Inspection costs. Disposal costs if correction is not possible. Paperwork system costs. |
| **Over-Production** | Storage costs (inc. handling costs & capital tied up). Extra material costs if excess cannot be sold. Deterioration/depreciation costs (if appropriate). Cost of delays (as above). |
| **Processing** | Additional processing costs (direct and overhead if applicable). Transportation costs. |
| **Conveyance** | Additional cost of unnecessary conveyance system. Cost of late delivery if overall process time affected. Deterioration/damage costs. |
| **Inventory** | Storage costs (inc. handling costs & capital tied up). Deterioration/depreciation costs (if appropriate). Obsolescence costs (if appropriate). |
| **Motion**    | Additional labour costs (including absenteeism). |
Before we study the subject of Six Sigma in any depth, we need to define the term. Perhaps unusually, Six Sigma has 3 distinct elements to its definition (Knowles, 2011):

- A Measure: A statistical definition of how far a process deviates from perfection.
- A Target: 3.4 defects per million opportunities.
- A Philosophy: A long term business strategy focused on the reduction of cost through the reduction of variability in products and processes.

Accordingly, it is defined in a variety of ways by several authors, but for the purposes of these notes the definition from (Pande et al. 2000) focused on the more comprehensive philosophy of Six Sigma will be used: “A comprehensive and flexible system for achieving, sustaining and maximising business success. Six Sigma is uniquely driven by close understanding of customer needs, disciplined use of facts, data, and statistical analysis, and diligent attention to managing, improving, and reinventing business processes.”

The use of Lean Six Sigma (LSS) as a business improvement methodology has increased significantly over the last decade and its usage has broadened from the manufacturing sector to virtually every industry sector and developed country there is. Its ability to be applicable in this way is quite probably unique as it continues to spread out and grow in more diverse business sectors including pharmaceutical and banking (Wiesenfelder 2009).

LSS has evolved during a journey that can be traced back well over a century. This family tree, depicted in Figure 4., clearly demonstrates how LSS followed two completely different paths and only converged in recent years to become what is now the most accepted methodology namely Lean Six Sigma (Antony et al. 2011).
Lean and Six Sigma are both business improvement methodologies but they have some important fundamental differences. These differences are well documented in numerous academic research papers e.g. (Antony and Escamilla 2003), but can be summarised in Figure 5, below:

Figure 4: Evolution of Lean Six Sigma
(adopted from Antony et al. 2011)

Figure 5: Key differences between Lean and Six Sigma Approaches
(adopted from Antony and Escamilla 2003)
What is well known however, is that when implemented correctly the benefits of combining Lean and Six Sigma makes it a formidable business improvement methodology (Snyder and Peters 2004).

Lean is much more than just about reducing and eliminating process wastes, it is a philosophy than can be applied in a continuous form for years if not decades. Toyota was the leaders in this philosophy which is still highly relevant today. Six Sigma meanwhile concentrates on the reduction/elimination of problems, which could manifest themselves in the form of defects or variation. The Six Sigma approach tends to be much more finite than Lean and mostly last over a period of weeks to months.

4 Planning tools for lean and Six sigma: case study in water distribution – case Serbia

The performances are defined in the context of measuring company’s ability to determine/plan and accomplish goals, so that importance of objectives represents a key factor in the choice of performance indicators. According to Rameshwar (2011), it can be identified links between strategic planning and (measurable) performance indicator in distribution, in order to provide logistics processes involved in planned objectives achievement. Priority objectives in distribution management are:

1. Orders fulfillment,
2. Target Customer Service,
3. Flexibility and rate of response,
4. Customer service innovation, and
5. Costs.

Rameshwar (2011) proposed a group of performances that apply regardless of business strategy and logistics strategy in a company: time, cost and quality.

Leong et al. (1990) identified role of production function and key indicators of manufacturing performance defined in terms of performance: quality, delivery speed, delivery reliability, cost and flexibility. Johnston et al. (2003) identifies scope and speed of response as performance "flexibility", where range of responses represents number of various possibilities for changes in the production system,
while speed of reaction is the time required to change the production system. After selection of performances, it is important to define appropriate categories of indicators and/or concrete, measurable performance indicators, shown in Figure 6.

| Performances | Indicators |
|--------------|------------|
| Cost | Cost to satisfy customer requirements | Cost with continuous improvement activities | Cost of safety stocks | Cost of reverse logistics |
| Flexibility | Responsiveness to customer requirements | Logistics system responsiveness to special orders | Logistics system responsiveness to environmental changes |
| Quality | Stock data accuracy | Level of stock out | Percentage of orders fulfilment | Percentage of order without quality problems |
| Time | Delivery lead time | Order cycle time |

Figure 6: Performances and indicators in physical distribution systems (adopted from Rameshwar, 2011)

KPIs (Key Performance Indicators) represent selected indicators used for measuring and planning MQI (and increasing business performance). KPIs are quantifiable key performance attributes, those that directly affect quality of company management and achievement of goals. KPI are defined in accordance with the importance of business processes for different participants (stakeholders) in business. Each KPI is related to a single measurable attribute (indicator) of the observed performance, while complex KPI can represent successfulness of more business entities (functions, processes, products). Performance indicators are defined and used by applying business intelligence techniques and through monitoring of activities, called BAM (Business Activity Monitoring). KPIs represent the key "package" of measurable properties of a (business) system and, therefore, important planning tools. They are defined by the rules, indicators, targets and time dimensions. KPIs dynamics should illustrate planned and actual states of observed entities of business system, thus they constitute a model for quality management system measuring.
LSS model for monitoring distribution using key performance indicators, in water distribution company _La Fantana_, Serbia. This company, with about 160 employees, is a leader in the field of bottling and distribution of water and water coolers in Serbia. Today, company has more than 10,000 clients with 25,000 installed water cooler devices at companies and individuals. _La Fantana_ produces and distributes yearly over 16,000,000 liters of natural noncarbonated mineral water. Diversity of company offer is reflected in subscription packages adapted to various requests of our clients, as well as in the functionality of water cooler devices, enabling to enjoy cold, hot, carbonated or water heated to room temperature. _La Fantana_ carries out water production and bottling in its own modern factory located in Mitrovo Polje, near Aleksandrovac Zupski in Serbia. _La Fantana_ has 6 logistics distribution centers (LDC), positioned in different parts of a country. From these LDCs _La Fantana_ company is supplying customers with small truck fleet (about 30 vehicles). All deliveries are done in 24h, and company has 99,6 % rate of success deliveries in 24h. Full truck loads (FTL) are supplying LDC, from the plant and less than full trucks loads (LTL) shipments are supplying customers.

_La Fantana_ company’s KPIs system (as it is presented in this paper) is modelled and used in spreadsheets, in accordance with defined problems. The main method for data processing is simulation, "what-if" analyse that is significantly cheaper than with standard software packages. As shown in figures below, KPIs of logistics (distribution) model are developed in spreadsheet software and built from real data, collected in the Company in 2011 and 2012. KPI model was created in spreadsheet workbook, which contains eight different sheets with input data formats and forms for indicators calculation. Spreadsheet KPI model consists of the following sheets:
- Procedure sheet - which presents instructions for making KPI model and which verified steps of model development.

![Figure 7: Procedure sheet](image)

- Input LDR sheet - represents Logistic delivery report for daily base input of distribution data (about vehicles, delivery agent, number of bottles, new cooler installations, successful delivery etc.)

![Figure 8: Logistic delivery report (LDR)](image)
Fuel data sheet - refers to a report of fuel consumption in the distribution and consumed fuel values, per vehicle and each distribution center.

Data sheet - which includes a monthly based data about bottle sales and bottles delivery, vehicle capacity, vehicle capacity per active days, number of routes, number of kilometres, number of vehicles, number of undelivered orders, spent fuel, number of installed and withdrawn coolers, number of sanitizations and service.

Figure 9: Fuel consumption data sheet

Figure 10: Logistics Data Sheet
- Rolling sheet - which presents plan realization, or percentage of achieved in comparison with scheduled from a sheet Data.

![Figure 11: Rolling sheet](image1)

- Summary distribution sheet - is used to represent and calculate distribution indicators.

![Figure 12: Summary distribution sheet](image2)
Summary KPI sheet - which presents crucial KPI for understanding success of distribution. Observed report is one of the most important reports for distribution management. If we observe indicator km/bottle, we can see that this is one of the most important indicators for distribution management in the company. It shows how many kilometers are passed for one bottle delivery. As distribution of water is one of the most difficult types of distribution, it can be said that the expansion of the market for distribution is based on this indicator.

Figure 13: Summary KPI sheet

Diagram distribution sheet - refers to the graphical presentation of the most important KPIs in water distribution.

Figure 14: Diagram distribution sheet
The application is automated by procedures (macros), created in Visual Basic for Application, designed specifically to work in MS Office. Macros, made in this application, enable automation of data entry, linking tables (data) and formation of output reports. In order to prove superiority of spreadsheets for modelling, conclusion can be: this case is more convenient than standard software packages, at least in terms of development speed and user training for observed software. Finally, we can say that spreadsheets can be necessary LSS tool for simple, quick and easy processing and data analysis or in activities of planning, modelling and control of inventories.

5 Conclusion

LSS has developed and broadened its range of appeal both globally and by industry sector. Its ability to reduce costs, improve quality and reduce customer delivery time has sealed its place as a leading methodology for improvement of our businesses in the past, present and hopefully the future.

Also, according to the competition analysis, company is the only one in this kind of industry that has the organization for distribution operation described in this paper, and that has shortest time to customer in delivery.

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