The Application of Lean Six Sigma in Alleviating Water Shortage in Limpopo Rural Area to Avoid Societal Disaster

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Abstract--**This paper aims to illustrate the implementation of lean six sigma principles in a water management system. It draws on process information and primary data from real water shortage situations which affect the lives of rural people. Lean Six Sigma are business management strategies commonly used in production industries to improve process efficiency and quality. During the past decade, these process improvement techniques have increasingly been applied outside of the manufacturing sector, for example, in water management systems. This article presents a description of the main principles, practices, and methodologies used in Lean Six Sigma. It is based on a case study conducted in the province of Limpopo in South Africa to illustrate the application of Lean Six Sigma tools. Furthermore, literature is reviewed involving applications of Lean and Six Sigma to manufacturing together with other production related environment research. As a result, specific issues concerning the use of these techniques in different phases are identified. Assessments of the monitoring program were identified which indicated that significant savings could be achieved in water shortages whilst still meeting all operational, regulatory and other requirements to supply water to rural areas.**

I. INTRODUCTION

Water access in South Africa is problematic. South Africa is facing water stress, with chronic water shortages in the rural municipalities. Until 2012, only 21 million people benefitted from an improved water source [6]. In Limpopo some people resort to using individual boreholes and walking a long distance to draw water from a river or spring. In some instances water is delivered very irregularly by trucks to some households.

Water management has been decentralized, and many structures and services have been implemented for the purpose of securing fresh supplies of water. According to Ulrike *et al.* [11] water management in some rural communities and in rural municipalities of Limpopo has not caught up with the national guidelines. The low compliance rate is generally explained using reasons such as under resourcing, skill shortage, lack of understanding of the required standards, lack of intervention to address problem areas and inadequate management, finance limitations [11]. After 22 years of democracy, the people of the Limpopo area don't have access to safe drinking water due to limited water supply capacity. It is therefore necessary to look carefully at the water management system and introduce new management technology and processes in order to solve this problem.

Some process improvements have been introduced in the manufacturing sectors and have proved to be successful. These processes have facilitated better management systems and have contributed immensely in quality and productivity. One such process is Lean Six Sigma.

Before applying any process improvement a needs analysis has to be done. It is important to look at challenges or problems in any operations or activities in order to identify the root causes of the problem.

Application of Lean Six Sigma is a unique way of solving problems. It does not just look at the effect of the problem and try to cover it with a Band-Aid. Rather, the root cause of the problem is identified and this, as well as all contributing factors, is eliminated from the system, process or infrastructure in order to permanently solve the problem. What is the difference in these two approaches? This is simple, when you find and rectify the root causes, the problem will be solved forever. Even other problems occurring due to these root causes will be eliminated in this effort.

It is very clear now that we must find out the root causes of the problems before we think about rectifying them in lean manufacturing environments. So, how should we do this? What are the tools available to perform these tasks? Let's look at what problem solving is about. We'll begin by asking the question: "What is a problem?" A good definition of a problem is a variation from a recognized standard. In other words, you need to know how things should be before you can recognize a possible cause for them not being that way. After a problem has been recognized, a formal problem-solving process should be applied.

II. LEAN SIX SIGMA

Across the world in many famous manufacturing and service industries, Lean and Six Sigma has been successfully used as a business improvement methodology. Its main purpose is to maximize shareholder value through improving customer satisfaction, speed, cost and quality. To complete that aim, we use the combined tools and principles of the Lean Sigma method.

In 1913s the Michigan plants of Fort recorded the first application of Lean, but the Toyota production system revolutionized this. The implementation of this methodology in the process was to deliver products and services faster, better, and at a lower cost [12]. The role of lean sigma was to drive process improvement methodology.

Motorola was one of the first companies to implement the six sigma approach coupled with lean. In the 2000s, both methods were used together as a business strategy methodology [8]. The integration of both tools and

techniques of Lean Six Sigma is easy to use, and their applications are effective in the problem solving process.

III. SIX SIGMA

De Mast, J. and. Does, RJMM [5], De Feo and Barnard [4] established five phases of the Six Sigma problem-solving method with DMAIC, refers to a data-driven improvement cycle used for improving, optimizing and stabilizing business processes and designs.

- *Define (D).* Define the problem, the system, the project goals, the customer requirements, assessed and selected on a cost/benefit analysis.
- *Measure (M).* The problem transforms into a measurable form by a way of Critical-To-Quality (CTQ) characteristics.
- *Analyze (A).* The data from the problem are analyzed to seek causes and effects and to determine which factors should be considered.
- Improve (I). In this step the solutions are designed and implemented to optimize the process and set up models to perform and establish process capability.
- Control (C). As a final point a control phase ensures that the process developed must continue to increase and be monitored.

Six Sigma is a flexible method which can be associated with another method like Lean, hence Lean Six Sigma.

IV. LEAN SIX SIGMA IN WATER MANAGEMENT

Application of Lean Six Sigma is not widely adopted in the water supply management sector. However, Lean application has been applied on water reduction or wastewater reduction in industries and manufacturing [10]. IBM, GE and DTE Energy have used the Lean approach to manage water use which produced satisfying results [10]:

- *IBM used Six Sigma tools to reduce water consumption and operating costs in wafer fabrication processes, saving $3 million annually, reducing water usage by 27%, and increasing production by over 30 %.*
- *GE combined high-tech water metering and other water efficiency practices with Lean Six Sigma improvement methodology, resulting in a 30% drop in water use since 2006.*
- *DTE Energy saved 20 million cubic feet of water (79%) and $700,000 annually in a Lean Six Sigma project examining electric substation water use* [10].

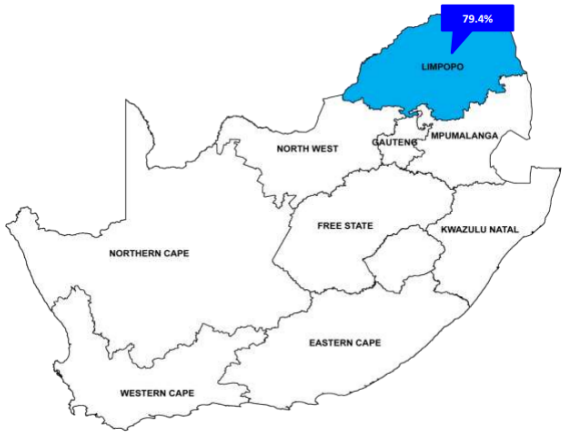
Lean Six Sigma was applied in other areas and it became become more and more integrated in social development to solve various problems. This study investigates the contribution of Lean Six Sigma following this question:

> "*Which could be the contribution of Lean Six Sigma to solve the water supply issue?"*

To answer this question, a case study on lean sigma in rural Limpopo was conducted focusing on waste water.

V. LIMPOPO CASE STUDY

Limpopo province is situated in the northern portion of South Africa. It stretches over 125 755 square kilometres with a population estimated at 5 405 868 according to the 2011 census. Limpopo is a major rural area with high levels of poverty. There is a frequent shortage of water; therefore water is delivered to communities using water tankers. There is a sparse number of boreholes in some localities to supply water. The water delivered by trucks is limited, because these do not supply the community at large. The number of boreholes also is not sufficient.



Map of South Africa: Limpopo Province in South Africa
Source: Blue Drop report 2012

VI. RESEARCH AND METHODOLOGY

The study was designed to investigate the application of Lean Six Sigma in water supply management in the Limpopo rural area. Qualitative data was collected using descriptive statistics. Closed ended questionnaires were designed and administered to staff of organisations in charge of supplying drinking water. Questionnaires were distributed to a sample of 150 people, and a 74 per cent response rate was achieved. The variables measured were the problems facing effective management as advocated by Lean Sigma.

VII. LEAN SIX SIGMA IN WATER SUPPLY MANAGEMENT

This section discusses the implications of Lean Six Sigma in the water management system by use of the DMAIC approach.

A majority of respondents highlighted the issues of operations, maintenance and management of infrastructure using DMAIC as explained below:

Define (D)

Water shortage was identified as a problem. This included different aspects including operations, maintenance, management and water capacity.

Measure (M)

Data was collected on parts of the aspect of operations, maintenance, management and the capacity of water. The list was gathered and tabulated. A close look at detailed descriptive analysis revealed that major parts of maintenance, operations and management were failures, and a shortage of infrastructure and equipment was observed.

Analyse (A)

This phase analyses the frequency of each component and the relation between different components. From the different frequency of each component and the histograms, the true sources of variations and potential defects that led to water shortages were identified by revealing the level of implication of each component.

Improve (I)

It was evident from the Pareto chart and the different values of measure that it is essential to continually improve efforts to take control of operations and maintenance.

The aim was used to identify the defect, analyse, prioritize and facilitate decision making, and improve the process. Cervone [3] concludes that Pareto Analysis is a useful tool to focus attention on problems in an organization.

The findings suggest that the capacity of water needs to be upgraded and new resources of water found. In addition the management approach helps to identify the root cause of any issues, to gather information and improve the water infrastructure, and improves monitoring and the control all aspect of the process. With these data as evidence, corrective action has to be taken in order to reduce the problems and issues and improve the most critical inputs in link to the operations, maintenance and management.

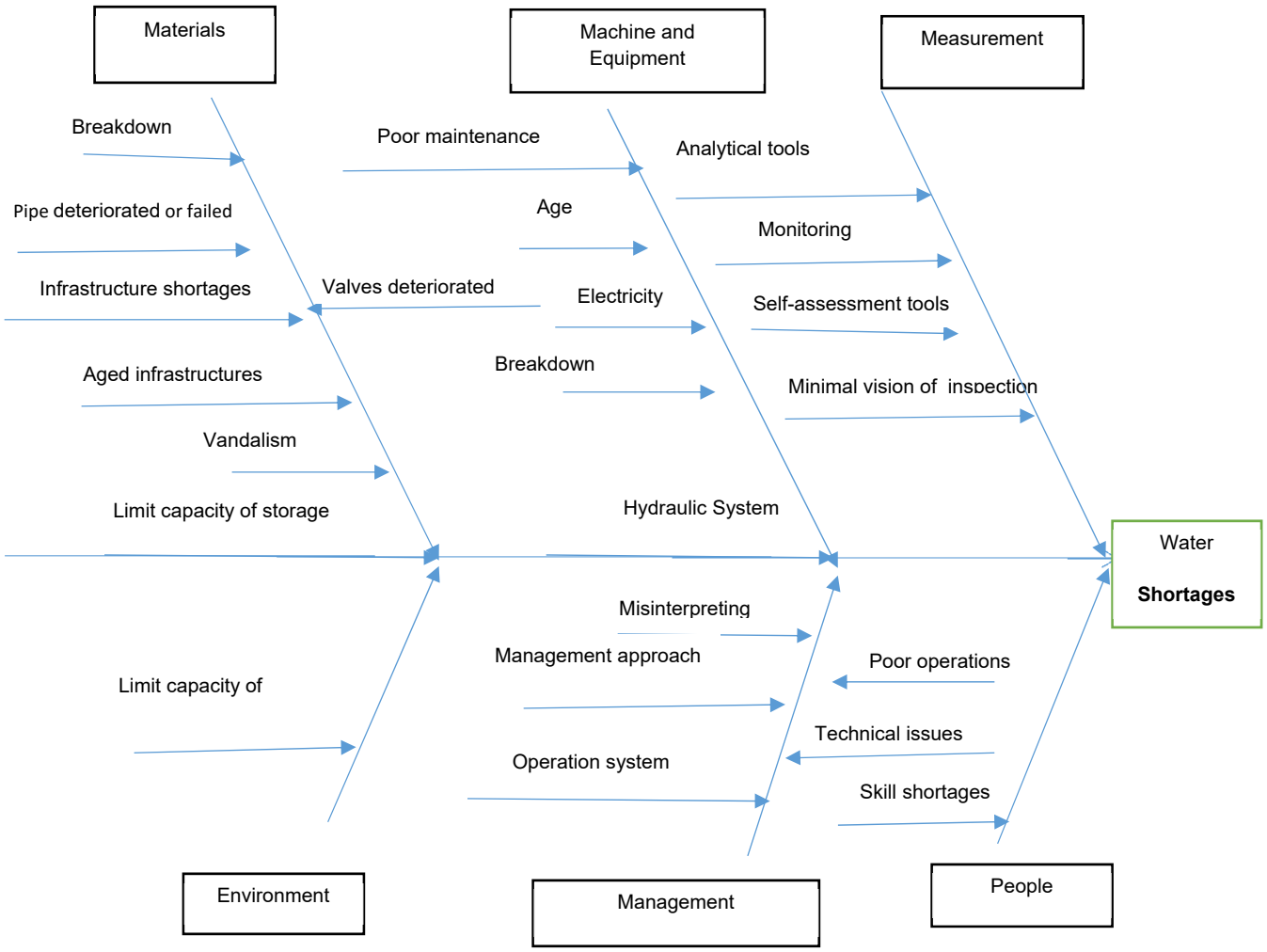


Figure 2: Fishbone diagram

Control (C)

This stage requires an anticipation of the quality and quantity of service by ensuring a long term run through creation of a plan which meets the continuous performance expectations.

Besides this, Value Stream maps can show the steps in a process where action needs to take place. Therefore drawing flow charts can help significantly in analysing a process and providing many ideas for improvement, after identifying the factors that are causing undesirable effects, or identify the factors that can bring about desirable results.

The application of the fishbone diagram (Fig. 2) emphasises the main categories that led to water shortages. This includes materials, machinery and equipment, measurement, environment, management people, among many reasons for the water crisis.

The fishbone, or cause-and effect diagram, or Ishikawa diagram is a quality tool normally used to identify the various causes of an effect or problem [7]. Therefore it helps to understand and to visually display the potential or the main sources and sub-sources leading to a specific problem. It is one way to capture the diverse concepts and stimulate the team's brainstorming on the root cause [7].

- Materials
  Overall the material is lacking and is old and unreliable. Deterioration of infrastructures are the potential threats and key concerns of water shortage. Like a physical leakage, poor maintenance, aging of infrastructure and breakdowns are contributing seriously to the water crisis.
- Environment:
  The geographical position of South Africa combined with climate change, could explain the scarcity of rains and therefore the limited capacity of water resources. In this case there is a need to work with nature rather than against it. Even the pollution from different sources also limits the use of available water.
- People
  It is true to say that people do use water efficiency to secure the water supply. However concerning the process of water supply, a skill shortage was identified as the cause of the problem, since machines and equipment could not be maintained.
- Management.
  Management failure or unsuitable management approaches are among those key concerns about water shortages that need to be sustained because the water resource is not infinite; therefore it requires good management to take control of the water supply crisis.
- Machine and equipment
  The following defects: poor operation, poor maintenance, miss-inspection, lack of repairs, lack of service and cleaning of existing machinery or replacement are undesirable issues which lead to water shortages.
- Measurement
  From downstream to upstream the failure of applying strict measures in water supply management gradually led to a critical water crisis. There is a saying which says "you cannot control that which you cannot measure".

VIII. RESULTS AND OBSERVATION

Based on the questionnaires, a large majority of respondents support an integration of the Lean Six Sigma method into the water management system to support effective management. The effectiveness of this integrated approach of Lean Six Sigma has been tested in many occasions. Success in most cases is obvious from the mentioned literature and case studies [1] [9].

The findings have established that there is a correlation between increasing capacities (dams, reservoirs, pumps, new water resources), an increasing of monitoring and control, and the management approach as indicated by respondents. All these factors lead to an alleviation of water supply shortages.

Lack of adequate and proper operations and maintenance, and management structures can lead to the need for an upgrading of the system. Moreover population growth puts pressure on the resources, and in order to support the increased population, considerable infrastructure upgrades and maintenance need to take place.

The following figure (Fig. 3) demonstrates the successful model used by the department of water affairs (DWA) in South Africa to alleviate water shortages.

It is evident from the figure above that there are many funding sources to improve water infrastructures, although the most important funding sources come from the government entities. National Treasury supplies the National Department which receives funds from other entities. The national department is the main entity responsible of investment on water infrastructure, funding of national research and operations. Brineco-Garmendia *et al.* [2] and the World Bank [14] conclude that one third of the capital expenditure goes to operation and maintenance requirements.

Dorsch, *et al. (*1997) illustrated an integrated framework for an effective service delivery as shown in Fig. 4.

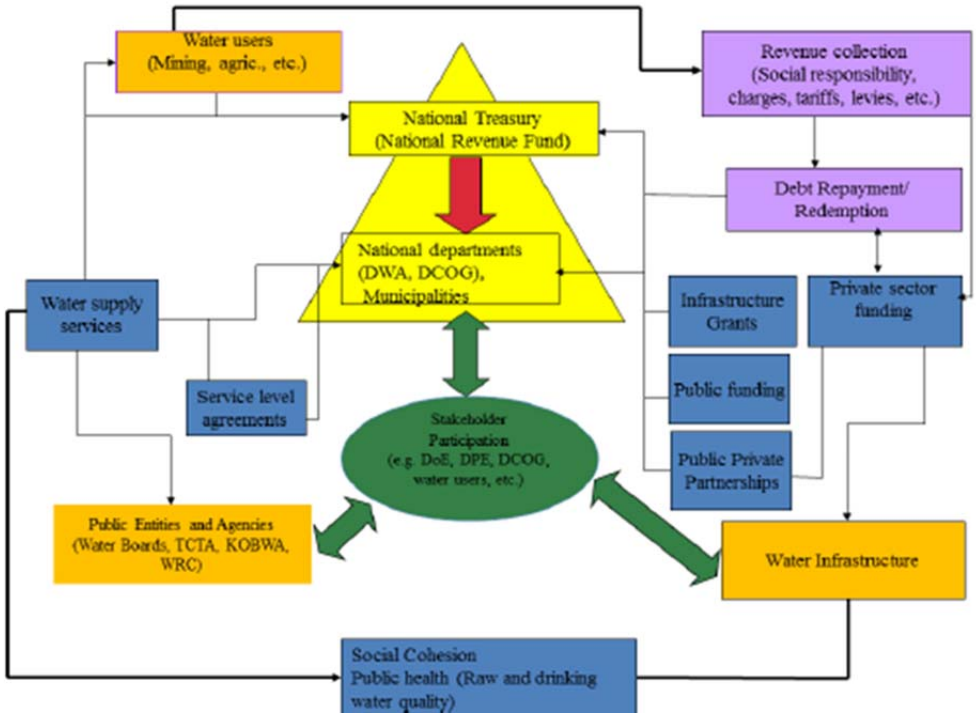


Figure 3: Anew water infrastructure funding model.
Source: Reuters Institute for the Study of Journalism Department of Politics and International Relations (2013)

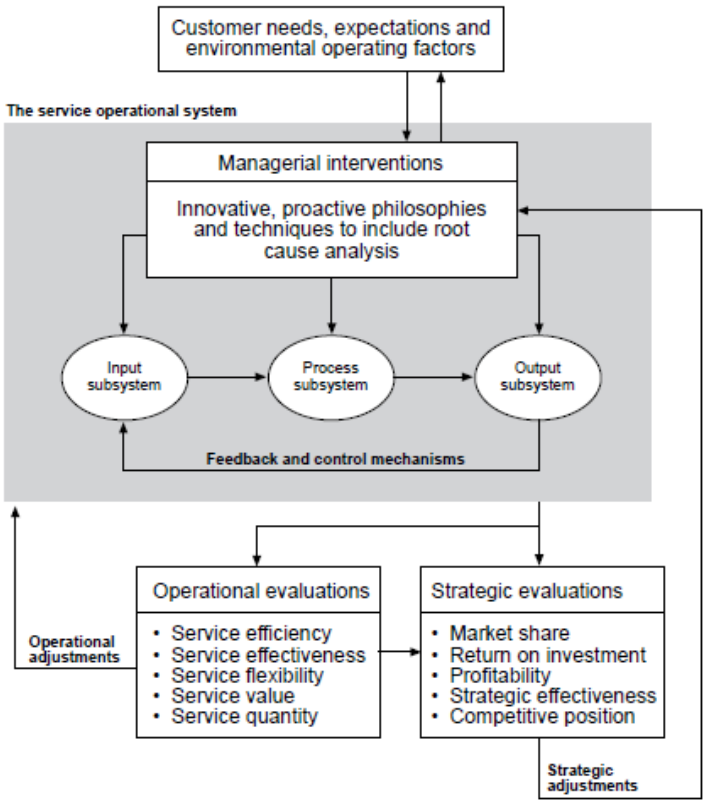


Figure 4: Integrated conceptual frame work for effective service delivery
Source: Dorsch, *et al.* (1997).

In summary the results show that the water supply is affected by many problems which could be due to long neglect of existing facilities, lack vision or backlog. The results indicated that 80% of the main causes of water shortages include;

- Aged infrastructure
- Work maintenance
- Pipe shortage and failure
- Pipes and pump failure
- Misinterpreting and checking records
- Vandalism
- Infrastructure and equipment shortage
- Electrical and mechanical operations systems
- Poor maintenance of reservoir and water towers
- Limited capacity of storage
- Low capacity to extend the reach of water distribution
- Equipment breakdown and shortage.

This reveals over and above that there is a poor operational, maintenance and management system. Operation, maintenance and management systems are the backbone of water management supply. This means it is a critical issue in addition to the challenges of the supply chain, skill shortage and poor co-operation and communication amongst the stakeholders.

IX. CONCLUSION

This paper is set out to understand the implementation of Lean Six Sigma in the Limpopo area in order to alleviate the water shortage. Ishikawa's diagram was used to identify the root causes of the problem. The Lean six sigma approach was used to identify and to solve the problem. Even though Lean is widely used in the manufacturing sectors, it has proved successful in identifying the root cause of the problems. The use of the Lean Six Sigma process provided a solution to the problem. These processes facilitated a better management system and have contributed immensely in provision of water in Limpopo.

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