

Total Sustainability Assessments for Manufacturing Operations Using the Lean Six Sigma Approach

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Abstract

This paper discusses research and education activities related to the application of lean six sigma principles in sustainability assessments for single facilities using a novel concept called Total Sustainability Assessments (TSA). Lean Six Sigma has not been used in the solid waste reduction or environmental protection fields to the extent that it has been applied in manufacturing and in other sectors. The goal of this research was to investigate the application and benefits of conducting TSAs versus standalone assessments for waste reduction, energy reduction, and productivity improvements. The hypothesis for this research involved investigating the financial, environmental, and time benefits of conducting TSAs over separate assessments. Traditionally, productivity aspects are not a high consideration when performing environmental assessments; this research is novel that it incorporates these issues into a single assessment framework. The results of the study indicated that the TSA methodology can be completed 23.4% fewer work hours versus standalone assessments and identified over \$120,000 in annual cost savings for the organization. The application of this case study and the TSA methods are discussed in this paper.

Keywords: solid waste audits; energy audits; productivity audits

1. Introduction

In recent years, greenhouse gas emissions, energy usage, and solid waste rates have been climbing (US EPA, 2013). In the United States alone the U.S. EPA estimates greenhouse gas emissions totaled 6, 821.8 million metric tons of carbon dioxide; this figure rose by 3.2% from 2009 to 2010 and 10.5% since 1990 (US EPA, 2013). From 1960 to 2005 municipal solid waste rates were continually climbing (US EPA, 2013). The United State Department estimates that the average person in 2009 used 308 million BTUs per person (US DOE, 2013). With greenhouse gas emissions, energy usage, and solid waste rates on the rise, a way to diminish these byproducts is needed in order to maintain a sustainable environment.

Performing these assessments simultaneously will result in the greatest benefits. These benefits vary between facilities; however, the main benefits of the total assessment process include economic, environmental, and corporate moral. Facilities conduct audits for any or all of these reasons. From a business perspective, improvements are easier to justify when economic in nature versus environmental. In a company or facility looking to reduce costs with waste disposal, energy consumption, or lack of productivity, these assessments are sometimes not completed. Often times, these assessments are not completed due to a lack of knowledge or the lack of understanding of the potential cost savings. The costs that can be reduced are sometimes hard to see and neglected by the average person that is not trained in looking for them hence it is important to provide a detailed breakdown. Having a detailed breakdown of overall costs of the upgrade to a new technology or process and a payback period for that specific item will make it more likely for that product to be upgraded due to the often daunting price of all improvements simultaneously.

Performing assessments of this nature simultaneously has the benefit of being a much lower cost process than performing assessments independently of one another. Each independent assessment requires its own transportation, group of auditors, and associated equipment to perform all individual audits. Combining auditing techniques and resources between the auditing methods allows for the combination of other parts of the assessment. Energy, productivity, and waste streams may be viewed at the same time for an area of a facility eliminating the need to come back and examine the area multiple times. In addition, the TSA process allows the consideration of other recommendations in the auditing results that otherwise could not be considered without the data support from the other audits. This can be seen in Figure 1. Having all assessments performed together will allow for a more optimal assessment and yield more accurate results.

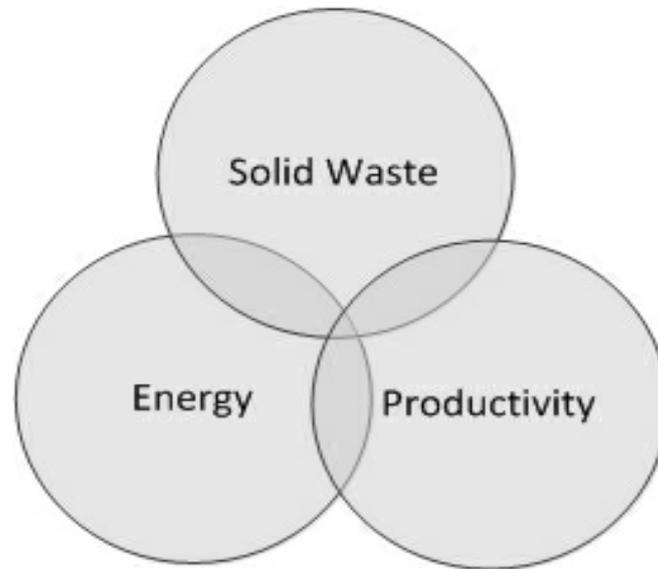


Figure 1: TSA Venn diagram

Corporations being assessed often do not have the time or a current working knowledge of new technology available to the public for waste, energy, or productivity improvements. A facility may benefit from simple improvements like light bulbs, computer monitors, or even a new way of walking through a plant or even disposing waste in a different manner. Making small changes like this will have a big impact long term in the carbon emissions generated by a corporation.

Carbon emissions of facilities in today's society have been of the upmost concern. Data and numerous published research articles have indicated that carbon emissions have a direct impact on climate change throughout the world. The United States EPA currently is putting through regulations against these emissions. These regulations put a cap on the emissions generated by facilities. An emissions cap of this magnitude could be a financial burden on companies exceeding it.

2. Background and Application of Lean Six Sigma

The Total Sustainability Assessment (TSA) concept has two roots: Lean Six Sigma (Laureani et al., 2008) and the TAA concept (Haman, 2000). The TSA concept uses the premise that through the waste elimination of Lean Six Sigma along with combining the various assessment types as done in Total Assessment Audits that better results will be yielded and a standardized process will be created in turn allowing manufacturing facilities to be evaluated more effectively.

Single focus environmental assessments are very common in literature; such as energy (Thollander, 2009), solid waste (Rugulo, 2008 and Abou-Elala et al., 2008), and greenhouse gas (Astrup, 2009). Very little literature is published regarding conducting multiple assessments simultaneously; the most notable example is from Haman (2000). This study examined the application of Total Assessment Audits (TAA) and found that scrap was reduced by 39%, energy usage was reduced by 29%, and productivity was increased by 12% for a metal company located in Iowa (Haman, 2000). The research work presented in this paper expands on this work by integrating lean six sigma concepts and additional sustainability measurements (Calia et al, 2009).

Six Sigma has been a popular manufacturing trend since the 1970's. In the 1970's, Six Sigma was credited to have been invented by Motorola (Pande and Holpp, 2002). During this time, a Japanese firm took control of a United States television set factory making radical changes to the factories operation resulting in 1/20th of the defect rate. Viewing this Motorola admitted to its quality issues. In the 1980's Motorola began implementing Six Sigma methodology under the CEO Bob Galvin. Motorola became a quality leader in industry (Pande and Holpp, 2002).

Six Sigma as a whole can function primarily in three different mannerisms: As a metric, management system, and methodology. As a metric, Six Sigma can be a scale of how good a company's quality is. To have "Six Sigma" quality standard, a company must only have 3.4 defects per one million opportunities (DPMO). As a management system Six Sigma pulls in the concepts of Six Sigma into a corporate business strategy. As a methodology, Six Sigma is represented by the DMAIC model (Goodman, 2012). DMAIC is the acronym for Define, Measure, Analyze, Improve, and Control. DMAIC is used to state what a problem is and in turn determine how to deal with that quality issue. Lean similarly is an approach for improvement in an organization focusing on waste elimination. This waste is of seven types: (1) Overproduction, (2) Waiting, time in queue, (3) Transportation, (4) Non-value-adding processes, (5) Inventory, (6) Motion, and (7) Costs of quality: scrap, rework, and inspection (Pande and Holpp, 2002). This concept started small and progressively became the lean methodology over time. Starting primitively back during the production of the Ford Model T. Ford used the concept of a production line and interchangeable parts proving to be highly effective during World War II for the Bomber production. Post World War II and the reconstruction of Japanese manufacturing, the Japanese were getting very effective at production due to the development of the Toyota Production System and mistake proofing (Pokayoke).

In the late 1990's, both Lean and Six sigma were becoming very prominent methodologies in manufacturing (Pande, 2002). This was seen by both Maytag and Allied Signal independently and began combining the frameworks of Six Sigma and Lean into what is seen today as Lean Six Sigma

[C]. Lean Six Sigma combines the principles of both the reduction of the seven types of wastes as well as the reduction of defects in manufacturing operations (Pyzdek and Keller, 2003). With manufacturing facilities picking up the premise of Lean Six Sigma, the idea of doing an assessment to capture these wastes together was the next step. The premise behind Total Assessment Auditing (TAA) was driven from the Energy Policy Act that was drafted in 1992 by the Northwest-Midwest Congressional Coalition. With a grant founded by the Kellogg Foundation to research integrated auditing, collaboration between the state government, electrical companies and other industrial centers were formed. This formation led to the need to test the TAA process. Variations in this methodology have been used across the nation in various capacities (Haman, 2000).

This methodology has seen a significant usage from the Department of Energy (DOE) sponsored Industrial Assessment Centers (IAC). Industrial Assessment Centers are located at universities and colleges across the United States. The industrial assessments provided by these centers provide savings opportunities in the energy, waste, and productivity fields. Currently there are 24 universities in the US participating in this program between the years of 2012 and 2016 (Beringer, 2006).

The assessment at a university based IAC takes one to two days and is conducted by engineering faculty with the assistance of upper classmen and graduate students over a one to two day span after which the IAC will analyze data collected at the facility and generate a report of recommendations based upon their findings within sixty days. This report will include cost estimates, performance analysis, and payback periods for recommended equipment (Haman, 2000). A need had been realized for this type of assessment at the University of Toledo in the Business Waste Reduction Assistance Program (BWRAP). BWRAP at the University of Toledo is a partnership between the University of Toledo and the Lucas County Solid Waste Management District. BWRAP was founded in 1996 (Franchetti, 2009).

This initiative was a partnership between University of Toledo's College of Engineering and the Lucas County Waste Management District with the goals of lowering costs for local manufacturing facilities within Lucas County (Ohio, USA) and promoting environmental sustainability within the county. With increasing costs of waste in corporations, a solid methodology for BWRAP to use on assessments was needed. Using the concepts of Lean Six Sigma and TAA the Total Sustainability Assessment was realized.

3. Research Approach and Methods

The methodology utilized for conducting TSAs is derived from Lean Six Sigma methods. The DMAIC cycle (Design, Measure, Analyze, Implement and Control) assists the researchers in reducing the various types of waste throughout the corporation being assessed along with the organization performing the assessment.

This methodology is broken into twelve steps. The twelve steps are then broken into the five phases of the DMAIC cycle. The "Define" phase is broken down into four steps:

- (1) Identification of a Candidate, the corporation being assessed must have a need for solid waste, energy waste, and productivity waste analysis.
- (2) Initial Survey, an initial survey will be sent to the corporation identifying the types of equipment being used, contact information, size, goals, etc.
- (3) Pre-Assessment Meeting, the Pre-Assessment meeting involves the discussion of what will take place during the assessment process, along with addressing any concerns that the corporation may have at that time.
- (4) Establish Evaluating Team, from the pre-assessment meeting, an idea about what specific tasks are needed to be done by the research associates for evaluation of the plant will be apparent along with the number and what kind of research associates need to be involved will be chosen.
- (5) Pre-Assessment Site Visit, the Pre-Assessment Site Visit allows for the researching staff to see the facility prior to assessment allowing for the assessment team to have an idea of how to accomplish the assessment effectively as well as inquiring from the corporation as to any specifics along with any safety concerns due to the industrial nature of the assessment process.

Phase two or the "Measure" phase is composed of two steps:

- (6) Baseline Current Performance establishes the current state of the manufacturing facility whether this is solid waste stream, energy consumption, or plant productivity level.
- (7) Additional Data Acquisition is used to collect other documents that may be needed in the future for completion of the assessment process. These documents can vary but are often found to be water, electricity, and natural gas bills.

Phase three or the "Analyze" phase is composed of one step:

- (8) Determine the annual usage establishes from the information collected during the measure phase how much waste is being disposed of, amount of energy being consumed, or feet of travel on an annual basis.

Phase four or the "Improve" phase is composed of three steps:

- (9) Identification of Alternative Products or processes finds alternative means that the company can use to alter or replace their existing processes in order to make their facility more efficient. This may be as simple as changing a light to a different type to moving machinery. These alternatives vary between projects.
- (10) The Economic Evaluation determines whether these options found in step seven are in fact viable long term solutions for the company. Typically with the methods mentioned above a two year payback period is sought unless other payback period lengths are discussed

with the corporation specifically. Upon completion of the economic evaluation, a report will be generated.

(11) The Report Generation is composed of the findings resulting from the TSA. This report outlines not only the findings but will also outline the background of the corporation, the steps taken to generate the results of the assessment, and also any additional material that may be necessary for the recommendations listed in the report itself.

In the final phase of the assessment process, the "Control" phase, is composed of a single step.

(12) Follow up Visit is the revisit of the plant to see if the results did in fact yield an effective reduction in cost or to see if other alternatives should be looked at. If this is indeed the case, this process can be repeated to determine the most effective methods for the corporation in the future. This cycle is displayed in Figure 2.

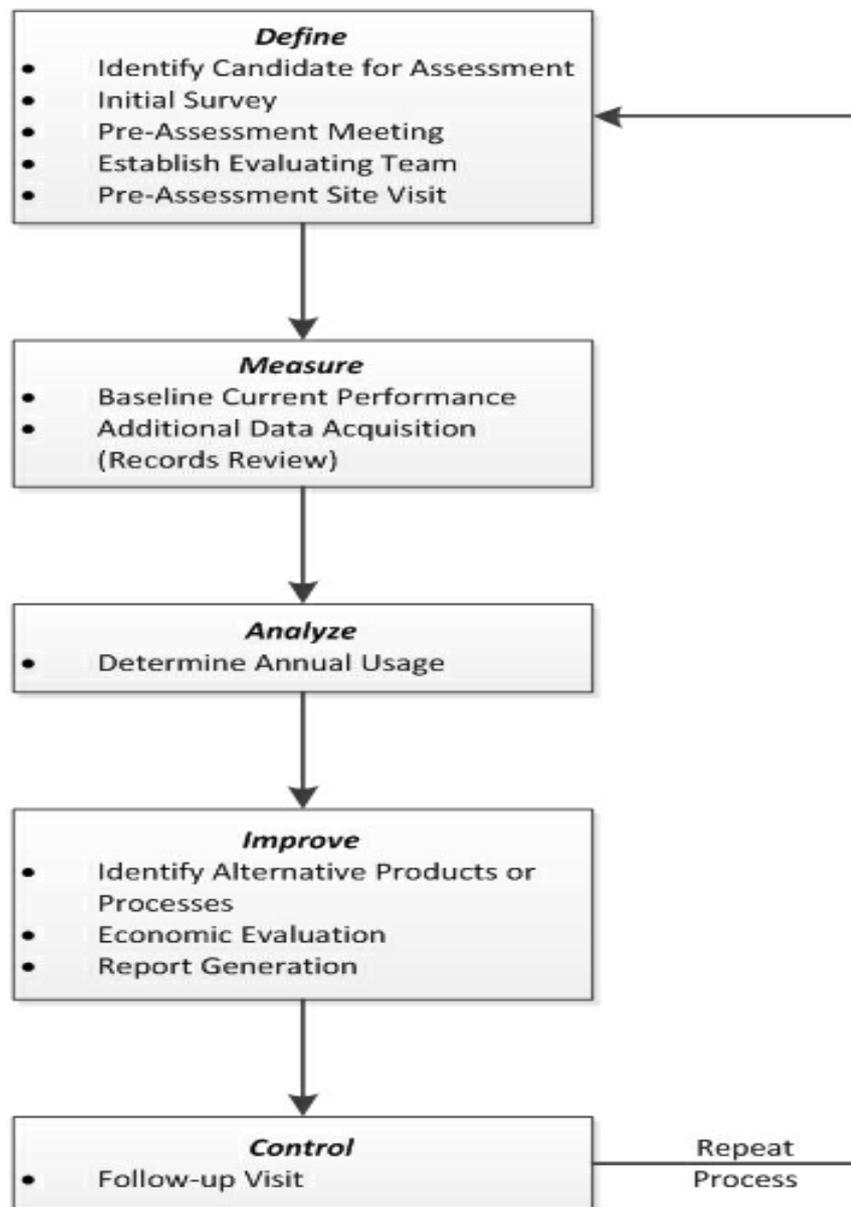


Figure 2: TSA Methodology

4. Case Study Overview

The manufacturing facility used as a case study in this research was a privately owned manufacturer located within Lucas County, Ohio, USA. The manufacturing corporation was founded in 1855 and has since grown to the second largest manufacturer in its industry. The current manufacturing facility was constructed in 1997 and has seventy-five employees. The manufacturing area is currently

running two shifts and is operated sixteen hours per day. The warehouse is currently only running a single shift.

For this case study, the offices, warehouse, and manufacturing area were the main focus of the study. This facility has peak waste generation, energy consumption, and productivity during regular business hours. The solid waste stream for the facility was primarily traditional waste receptacles throughout the facility. This waste stream does

not include that of the manufacturing processes. The waste from the manufacturing processes is recycled internally by the corporation to another one of their facilities to be melted down and reused for future products.

The energy usage for the facility other than machinery primarily is lighting and heat dissipation through the facility. In the warehouse, high bay 400w high pressure sodium fixtures were being used to light the area. For the manufacturing area, 400w high bay lighting was used. In the office space, T-8 and T-12 lighting was in use. For heating of the manufacturing and warehouse areas three heating units were in use and the facility was set to seventy degrees Fahrenheit during the weekdays and sixty-two degrees Fahrenheit during the weekends.

The productivity of the facility was looked at from a look at the plant layout specifically. The corporation is currently restructuring machining operations to this facility exclusively. Additional machinery was in the process of being brought from another facility to this facility. The corporation is hoping to not have to hire additional staff to run the increased amount of machinery. At the time of assessment, many operators were exclusively running only a single machine leaving room for potential improvement in staff utilization.

5. Results and Discussion

Upon completion of the baseline assessment, it was determined by the assessment team that throughout the facility there was potential rooms for improvement in process improvements, recycling opportunities, along with improvements in power consumption.

With regards to Solid Waste, a cost savings may be seen through the sale of recyclable materials. Sale of these materials in this situation was composed of Mixed Office Paper, Magazines, Cardboard, Aluminum Cans, PET (1), and Plastic Wrap. At the time of the calculation, the company was producing 19.6 Tons / Year of solid waste of which 15.1 Tons

could be recycled. This results in a savings of approximately one-thousand dollars per year. The price used for this calculation changes daily based on current market value of materials. This calculation also assumes that materials are bailed.

With regards to energy, a cost savings was seen though lighting improvements and heating changes. Both the lighting in the Warehouse and the Machining area, were using 400w fixtures. Switching these to high output 4 bulb T-5 fixtures saves approximately twenty-two thousand dollars per year. In the offices, switching the ballasts on the existing fixtures to accept T-8 bulbs, will result in cost savings of approximately four hundred dollars per year. The twenty exit signs throughout the facility were originally incandescent. By switching these to LED based fixtures, an almost three-hundred dollar cost savings per year will be seen. The disposal of the different lighting fixtures will only have a single impact on the waste stream. In terms of heating, by turning the programmable thermostats down throughout the facility from seventy degrees to sixty-five degrees Fahrenheit during the week and from sixty-two to sixty degrees Fahrenheit during the weekend results in an approximate twelve-hundred dollar cost savings per year.

With regards to productivity improvements, cellular operations for many machines throughout the facility were justifiable. Prior to the assessment, twenty-nine machining centers were in use at the facility. Of the existing machining centers, to run all simultaneously twenty-four operators were needed. Through implementation of cellular operations and a re-design of the machining center layout, of the existing machinery twenty-two operators will be needed to run all of the machining centers simultaneously. This is a cost reduction in man power of \$50,000 for each operator totaling a \$100,000 savings. This will cost around four-hundred and fifty dollars for each machine to be moved. Seven machines need to be moved. This more than justifies this movement in the facility. A complete look at the economic savings from the proposed changes can be seen in Table 1.

Table 1: TSA Case Study Results

Waste Item	Original	Proposed	Yearly Savings
Solid Waste Stream	\$3,761	\$2,200	\$976
		Subtotal	\$976
Energy			
	\$1,644	\$1,274	\$370
	\$31,920	\$12,504	\$19,415
	\$4,992	\$2,371	\$2,621
	\$311	\$37	\$274
	\$6,360	\$5,210	\$1,150
		Subtotal	\$23,832
Productivity			
	\$821,600	\$721,535	\$100,065
		Subtotal	\$100,065
TOTAL			\$124,873

This savings was not only economic but also good for the environment. With a conversion rate of 1.779 pounds of CO₂ per kWh produced, the environmental impact or carbon footprint reduction is estimated to be 449,940 pounds of CO₂.

6. Conclusion

For the first time, this research and case study applied lean six sigma methodologies to the field of simultaneous sustainability assessments related to solid waste, energy, and productivity. This research found that a comparison of the three independent assessments for solid waste, energy waste, and productivity waste versus the TSA process yields improvement on the integrity of the results as well as a decreased time required for assessment. With each individual assessment (solid waste, energy waste, and productivity waste) being performed separately, the TSA reduces the assessment time from 71.5 hours to 54.5 (23.8% reduction) though the removal of many redundant meetings and surveys, while simultaneously merging many of the other operations. This additional time will allow the research team to generate results faster and conduct more assessments. Additionally, the TSA method identified over \$120,000 in cost savings for the organization.

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