Sustainability for the Manufacturing and Service Industries in Zimbabwe

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Abstract

The Zimbabwean manufacturing and service industries are struggling to survive in the current country's economic state. Industrial Engineering (IE) is a branch of Engineering that pursues organisational efficiency through methods improvement and resource-saving. The world as a whole is now anxious about the environment, this suggests that the next evolution of Industrial Engineering will include subjects on greener manufacturing. The paper examines how Industrial Engineering (IE) and Environmental Sustenance ideas may be applied to the Zimbabwean industry and the benefits that can be drawn from this application in order to improve the operations in Zimbabwean Industries.

Keywords
Industrial Engineering, Environmental Sustenance, Zimbabwe Industry, Productivity

1. Introduction

Even though developing countries in the Sub-Saharian Africa have a higher Gross Domestic Product (GDP) than the rest of the word, Africa remains the poorest continent in the world. Its per capita GDP declined from 18% of the world average in 1960 to 11% of the world average in 2011. (Yifu Lin, 2012) Africa is the only region in the world whose development status has been a crucial topic in the summits of G8 since 2000. Access to modern energy and technology and its proper management is the one solution to lead to sustainable development faced in this continent (Angeliki N. et al, 2016). Despite the factors that lower commodity prices and a less-supportive global environment the economic activity in sub-Saharan Africa has slowed severely. The region's output is only expected to expand by 1.4 percent in 2016, the worst growth performance in more than 20 years, and the loss in momentum over the last two years has been on par with the deep slowdowns of previous decades. In figure 1 the GDP growth rates are averaged across corresponding years of the previous episodes of rapid slowdown centered around 1977, 1983, 1992, and 2009. The current slowdown is centered on 2016. (IMF, 2016).

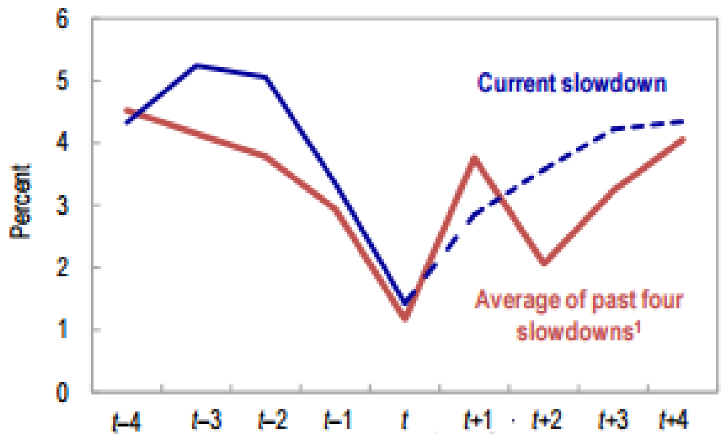

Figure 1: Source: IMF, World Economic Outlook database.

Climate change has the worst effects of Africa. The risks associated with climate change in Africa are well established. High levels of background poverty, dependence on rainfall, weak infrastructure and limited provision of safety nets combine to make climate risk a major source of vulnerability, even without global warming. However Africa has abundant reserves of fossil fuels and an even greater abundance of renewable energy assets (Africa Progress Panel, 2015). So less developed countries strive to find solutions for the severe problems that are obstructing the growth and development of its industrial sectors. In Egypt problems like high scrap, losing market shares, high levels of inventory, poor quality in products and labor, long lead times and the existence of many sources of waste in production processes need to be resolved (Salaheldin, 2006). The Zimbabwe Manufacturing and Service industries are facing the same difficulties as most less developed countries and this is made worse by seriously lagging behind in technology. Following a decade of economic decline and hyperinflation during the years 2007 and 2008 Zimbabwe's economy had started to grow. The then emerging economic recovery has been supported by a significant improvement in economic policies. In February 2009, authorities established a multicurrency system. Under this system, transactions in hard foreign currencies were authorized, payments of taxes are mandatory in foreign exchange, and the exchange system largely was liberalized. (Kramarenko, et al, 2010). Most companies in Zimbabwe, however, are still facing viability problems. The economy quickly took a turn for the worse from the growth that was characterized with the introduction of the foreign currencies into the economy. This is well illustrated in Table 1 that is reflecting the IMF Revised Global Growth Projections. The economic growth of Zimbabwe started to decrease in 2012 and dismally from 2013 up to 2015. The forecast of 2016 and 2017 has a marginal increase.

Table1: The IMF Revised Global Growth Projections [13]

	2011	**2012**	**2013**	**2014**	**2015E**	**2016F**	**2017F**
World	4.20%	3.40%	3.30%	3.40%	3.10%	3.40%	3.60%
Advanced Economies	1.70%	1.20%	1.10%	1.80%	2.00%	2.10%	2.10%
Emerging Economies	6.30%	5.20%	5.00%	4.60%	4.00%	4.30%	4.70%
SSA	5.00%	4.30%	5.20%	5.00%	3.80%	4.00%	4.70%
Zimbabwe	11.90%	10.60%	4.50%	3.30%	1.40%	2.40%	2.70%

The GDP grew from 5.4% in 2009 to about 11.9% in 2011 then declined to 1.5% in 2015, the lowest growth since the adoption of the multicurrency regime in 2009. Projected GDP to register 2.7% in 2016 against an average target of 7% between 2013 and 2018. This is indicated in the graph in Figure 2. (ZEPARU, 2016)

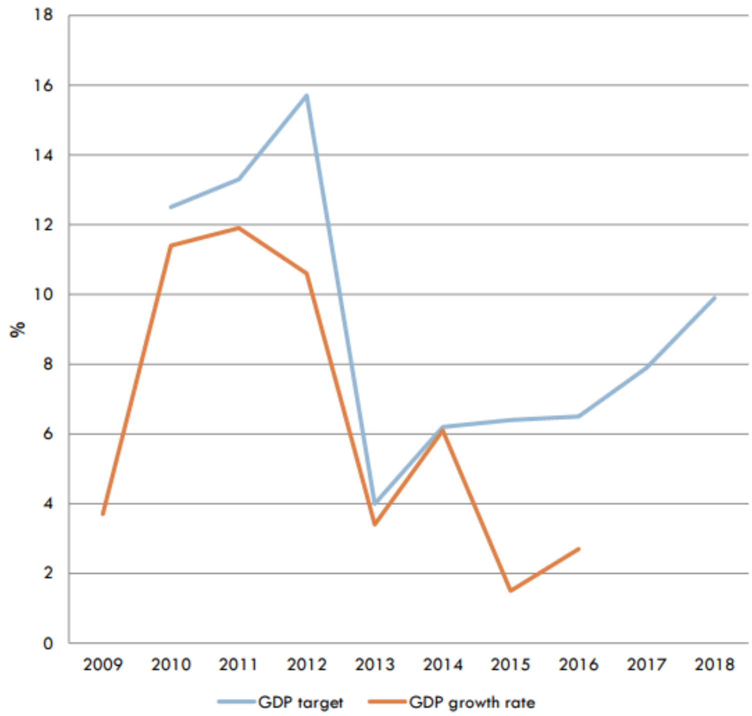

Figure 2: GDP Growth Rates and Targets, 2009 -2018 [14]

Major drivers of GDP in 2015 were: construction, finance and insurance, distribution, hotel and restaurants, transport and communication. Structural change of growth drivers as Agriculture, Manufacturing and Mining are underperforming relative to their potential. Table 2 shows that there is great need for the Manufacturing industry and some sectors of the service industry to better their current performance. (ZEPARU, 2016). All these have been the drivers for this research on how the Manufacturing and Service industries may be sustained.

Table 2: Sectoral Growth Rates and Projections, 2009 –2016 [14]

	2009	2010	2011	2012	2013	2014	2015	2016
	Act.	Act.	Act.	Act.	Act.	Est.	Est.	Proj.
Agriculture, hunting and fishing	31.1	7.2	1.4	7.6	-2.6	23	-3.6	1.8
Mining and quarrying	18.9	37.4	24.4	8	11.7	-3.4	-2.5	1.6
Manufacturing	17	2	13.8	5.3	-0.6	-5.1	1.6	2.1
Electricity and water	1.9	19.5	6.4	0.3	5	5.4	-10.8	3.6
Construction	2.1	14.1	65.1	23.5	3.9	6.9	7	4.5
Finance and insurance	4.5	8.3	8.3	28	11.3	7.7	6	5

Real estate	2	4.9	48.9	5.9	0.7	4.7	3.9	2.5
Distribution, hotels and restaurants	6.5	8.8	4.3	4.3	3.9	2.5	4.7	4
Transport and communication	2.2	4.7	0	6.7	7	1.1	4.2	2.8
Public administration	2	30.3	19.6	19.1	3.4	6.3	1.5	1.3
Education	2.8	37	63.9	38.1	2.9	3.9	2.1	1.3
Health	3.2	15.7	7.7	7.7	0.5	1.8	2.1	2.1
Domestic services	2.2	10	1	-3.5	6	2.2	2	1.8
Other services	2.3	14.7	11.3	-10.7	-4.7	-3.3	3	2.5
Less imputed bank service charges	4.5	32.9	38.7	9.8	11.3	4.7	3.7	5
GDP at market prices	5.4	11.4	11.9	10.6	3.4	6.1	1.5	2.7

2. RESEARCH AIM

The objective of this research is to postulate the benefits of industrial & manufacturing engineering and environmental sustenance in improving productivity in Zimbabwe Manufacturing and Service Industries.

3. RESEARCH METHOD

A wide range of published works, which contain the recent thoughts and debates of the globalization to developing nations are reviewed, analysed and critiqued. The authors take some case study examples and evidence from developing worlds, most notably in Zimbabwe.

4. INTERACTION BETWEEN INDUSTRIAL ENGINEERING AND ENVIRONMENTAL SUSTENANCE

One of the most widely accepted definitions of industrial engineering is the one used by the American Institute of Industrial Engineers: Industrial Engineering is concerned with the development, improvement, implementation and evaluation of integrated systems of people, money, knowledge, information, equipment, energy, material and process (Lo and Sculli, 1995). In lean manufacturing systems, Industrial engineering works to eliminate waste of time, money, materials, energy, and other resources. Industrial engineering has over the years grown from methods engineering and work measurement, to a profession that now covers a wide range of skills that are useful in national and multinational organisations both large and small across all sectors of business. This wider range of skills include, plant layout, computer simulation, production planning, MRP systems, project management, motivation and psychology, industrial relations, engineering mathematics, quality management and resource planning. Lean manufacturing is also one of the main pillars of environmental sustenance and its application is crucial as the world is going “green”. People in all sectors of life are anxious about the environment, this suggests that the next evolution of Industrial Engineering will include subjects on greener manufacturing. The abilities required will include energy management, waste management, water and effluent treatment, sustainability and environmental management. (Mbohwa et al, 2013) These skills will provide a wider scope for the employment of industrial engineers as the industry sectors in which they can work in broaden and in Zimbabwe this will bring in the much needed improvement in the Manufacturing and Service industries. In the current challenging economic climate the role of the industrial engineering and environmental sustenance is the catalyst for the urgent need for improvement in production of goods and services.

5. INDUSTRIAL ENGINEERING

Industrial engineering has been around for many years and has stood the test of time [5]. It has principally been concerned with:

1. The pursuit of organisational efficiency through methods improvement and resource-saving;
2. Organizational reform through business, market and technology development (Mohanty, 1998).

Industrial engineering may also be referred to as Operations management, Production Engineering, Manufacturing Engineering or Manufacturing Systems engineering. These terms vary depending on how the user intends to apply the profession. Companies or Institutions of higher learning use these names to distinguish themselves from the others. (Mbohwa et al, 2013)

Applications of Industrial Engineering principles vary widely. The Toyota Production System (TPS), based on industrial engineering principles and operational innovations, is used to achieve waste reduction and efficiency while increasing product quality. (Jimmerson et al, 2005)

Masin et al (2001) stated that very few managers in the Czech Republic, at the turn of the twentieth century, knew about the field of ``industrial engineering''(IE) an approach with a strong tradition of, and a significant effect on productivity measurement and improvement. They go on to say that the realisation that ``catch up'' must be strong and quick is forcing the adoption of a number of the tools and techniques, and especially the basic approaches of IE. Companies are realising that they must exploit the most-up-to-date industrial engineering systems; and information on the use of such methods is more and more available with the advancement in information dispersion techniques. Departments of industrial engineering have been created in two universities in Zimbabwe which alludes to the recognition by the government and industry that IE methods are the answer to improving productivity. (Mbohwa et al, 2013)

Hospital operations benefit from adapting to several key industrial engineering tools and principles. In healthcare Industrial Engineers are referred to as Clinical Engineers. The majority of clinical engineers serve as part of the healthcare team along with physicians, nurses, technologists, and other hospital staff. The clinical engineer's role is to ensure that other team members have adequate and effective technology for the time delivery of quality healthcare. In essence, clinical engineers must act as the "stewards" of healthcare technology. As effective stewards, clinical engineers need to understand the practitioners' intent, they need to possess knowledge with respect to both existing and developing healthcare technology, and they must also understand the various implications of applying the technology. Only when forearmed in this manner can clinical engineers hope to serve as successful stewards and help insure healthcare technology is applied for the greatest benefit. The implications of technology adoption and integration between diagnostic, information processing, and therapeutic systems are discussed. (Grimes, 2004).

Whereas most engineering disciplines apply skills to very specific areas, industrial engineering is applicable in virtually every industry. Examples of where industrial engineering might be used include shortening lines (or queues) in a bank, streamlining an operating room, distributing products worldwide, and manufacturing of cheaper and more reliable industrial and household goods. The term "industrial engineer" initially applied to manufacturing, it has grown to encompass services and other industries as well. Similar fields include operations research, systems engineering, ergonomics and quality engineering.

6. ENVIRONMENTAL SUSTENANCE

Closer to the end of the twentieth century there has been increasing scrutiny and toughening of regulation towards the environmental impact of industrial processes. The history of pollution legislation was led by an 'only what we can see, feel or smell' philosophy. When the industrial revolution was manifested in Western Europe there was drastic atmospheric pollution, most visibly from particulate emissions, and physiological effects from poisoning by lead, arsenic, mercury and phosphorous laden dusts. All this resulted in legislation that led to the Factories Acts in the UK as early as 1878. Fogs, resulting in unacceptable levels of mortality, caused by particulate emissions from coal fires culminated in Clean Air Acts in the 1950s in most industrialised societies. The harmful gases we cannot see were added to the lists of pollutants in the 1960s, only after their effects became apparent. For example nitrogen dioxide became a known significant pollutant after smog in large conurbations replicated the respiratory problems of fog, or after the combined effects of Sulphur and Nitrogen oxides created sterile areas of land and water and eroded the exterior of buildings, through the action of acid rain (Mullinger, et al 2008).

The latest manifestation of pollution is that of climate change. This has been brought about to a certain degree by human activity contributing to an increase of greenhouse gases in the atmosphere, principal among these being Methane (CH_4) and CO_2. As such there is considerable pressure on industries which rely on combustion to minimise their emissions of CO_2. An in-depth understanding of these processes is relevant for the reduction of CO_2 emission. Proposals included capturing the CO_2 in the combustion gases, and then release it separately in a concentrated stream, which is able to be fixed more efficiently and economically than the dilute combustion gas (Freund, 1997). CO_2 capture and storage (CCS) is gradually becoming an important concept in reducing greenhouse gas emissions, next to other options, such as, the use of renewable energy, the use of nuclear energy, energy efficiency improvements and switching from coal to gas firing (Feron, et al 2005). This option is now much better understood and can be compared with these more established measures, such as fuel switching, energy efficiency improvements and use of renewable energy (Freund, 1997).

7. DISCUSSIONS

There are a number of things that Industrial Engineering and Environmental Sustenance methods do in their work to make processes more efficient, to make products more manufacturable and consistent in their quality, and to increase productivity. The expertise required by Industrial Engineering allows for:

- Investigation of problems relating to component quality or difficulties in meeting design and method constraints
- Investigation of problems with the performance of processes or machines and
- Implementation of design changes at the appropriate times.

The expertise in Environmental Sustainability alerts the fact that the need for environmentally conscious manufacturing is becoming increasingly important due to the fact that:

- there is an environmental impact for all manufacturing processes
- the designer must think about potential environmental impacts at all design stages.

To achieve these, the following elements are applied. Companies with less investment resources may at least specialize in only a few of these:

7.1 Specifically per Product (short term)

1. Scrutiny of the complete product design to determine the way the whole process could be split into steps, or operations, and whether to produce sub-assemblies at certain points in the whole process. The individual operations or processes may then be made “greener”. This requires knowledge of the facilities available in-house or at sub-contractors.

2. Specification of the method to be used to manufacture or assemble the product(s) at each operation. This includes the machines, tooling, jigs and fixtures and safety equipment, which may have to be designed and built. Notice may need to be taken of any quality procedures and constraints, such as ISO9000. This requires knowledge of Health and Safety responsibilities and Quality policies. This may also involve the creation of programs for any automated machinery. If a specific operation emits any greenhouse gases then measures must be put in place to clean the emissions of the harmful components before they are released into the air.

3. Measurement or calculation of the time required to perform the specified method, taking account of the skills of the operator. This is used to cost the operation performed, to allow balancing of assembly or machining flow lines or the assessment of the manufacturing capacity required. This technique is known as Work Study. These times are also used in Value Analysis.

4. Specification of the storage, handling and transportation methods and equipment required for components and finished product, and at any intermediate stages throughout the whole process. This should eliminate the possibility for damage and minimize the space required.

5. Storage, handling and transportation of any greenhouse gases that may have been collected needs to be cared for too.

7.2 Specifically per Process (medium term)

1. Determine the maintenance plan for that process to avoid cost of time lost during corrective maintenance.

2. Assess the range of Products passing through the process, then investigate the opportunities for process improvement through a reconfiguration of the existing facilities or through the purchase of more efficient equipment. More efficient machinery will improve utilisation of raw materials and ideally reduce the release of unwanted gases. This may also include the out-sourcing of that process. This requires knowledge of design techniques and of investment analysis.

3. Review the individual Products passing through the Process to identify improvements that can be made by redesign of the Product, to reduce (or eliminate) the cost that process adds, or to standardize the components, tooling or methods used.

7.3 Generically (long term)

1. Analyse the flow of Products through the facilities of the factory to assess the overall efficiency, and whether the most important Products have priority for the most efficient process or machine. This means maximizing throughput for the most profitable products. This requires knowledge of statistical analysis and queuing theory, and of facilities positional layout.

2. Training of new workers in the techniques required to operate the machines or assembly processes.

3. Conscientising the employees of the need to “save” the environment

4. Project planning to achieve timely introduction of new products and processes or changes to them.

5. Generally, a good understanding of the structure and operation of the wider elements of the Company, such as sales, purchasing, planning, design and finance; including good communication skills. Modern practice also requires good skills in participation in multi-disciplinary teams.

7.4 Value engineering

Value engineering is based on the proposition that in any complex product, 80% of the customers need 20% of the features. By focusing on product development, one can produce a superior product at a lower cost for the major part of a market. When a customer needs more features, sell them as options. This approach is valuable in complex electromechanical products such as computer printers, in which the engineering is a major product cost. To reduce a project's engineering and design costs, it is frequently factored into subassemblies that are designed and developed once and reused in many slightly different products. For example, a typical tape-player has a precision injection-molded tape-deck produced, assembled and tested by a small factory, and sold to numerous larger companies as a subassembly. The tooling and design expense for the tape deck is shared over many products that can look quite different. All that the other products need are the necessary mounting holes and electrical interface.

7.5 Quality assurance/quality control

1. Quality control is a set of measures taken to ensure that defective products or services are not produced, and that the design meets performance requirements. Quality Assurance covers all activities from design, development, production, installation, servicing and documentation. This field introduced the rules “fit for purpose” and “do it right the first time”.

2. It is a truism that "quality is free." Very often, it costs no more to produce a product that always works, every time it comes off the assembly line. While this requires a conscious effort during engineering, it can considerably reduce the cost of waste and rework.

3. Commercial quality efforts have two foci. First, to reduce the mechanical precision needed to obtain good performance. The second is to control all manufacturing operations to ensure that every part and assembly are within a specified tolerance.

4. Statistical process control in manufacturing usually proceeds by randomly sampling and testing a fraction of the output. Testing every output is generally avoided due to time or cost constraints, or because it may destroy the object being tested (such as lighting matches). The variances of critical tolerances are continuously tracked, and manufacturing processes are corrected before bad parts can be produced.

5. A valuable process to perform on a whole consumer product is called the "shake and bake." Every so often, a whole product is mounted on a shake table in an environmental oven, and operated under increasing vibration, temperatures and humidity until it fails. This finds many unanticipated weaknesses in a product. Another related technique is to operate samples of products until they fail. Generally the data is used to drive engineering and manufacturing process improvements. Often quite simple changes can dramatically improve product service, such as changing to mold-resistant paint, or adding lock-washed placement to the training for new assembly personnel.

6. Many organizations use statistical process control to bring the organization to Six Sigma levels of quality. In a six sigma organization, every item that creates customer value or dissatisfaction is controlled to assure that the total numbers of failures are beyond the sixth sigma of likelihood in a normal distribution of customers setting a standard for failure of fewer than four parts in one million. Items controlled often include clerical tasks such as order-entry, as well as conventional manufacturing processes

7.6 Produceability

1. Quite frequently, manufactured products have unnecessary precision, production operations or parts. Simple redesign can eliminate these, lowering costs and increasing manufacturability, reliability and

profits.For example, Russian liquid-fuel rocket motors are intentionally designed to permit ugly (though leak-free) welding, to eliminate grinding and finishing operations that do not help the motor function better.Some Japanese disc brakes have parts toleranced to three millimeters, an easy-to-meet precision. When combined with crude statistical process controls, this assures that less than one in a million parts will fail to fit.Many vehicle manufacturers have active programs to reduce the numbers and types of fasteners in their product, to reduce inventory, tooling and assembly costs.

2. Another produceability technique is near net shape forming. Often a premium forming process can eliminate hundreds of low-precision machining or drilling steps. Precision transfer stamping can quickly produce hundreds of high quality parts from generic rolls of steel and aluminum. Die casting is used to produce metal parts from aluminum or sturdy tin alloys (they are often about as strong as mild steels). Plastic injection molding is a powerful technique, especially if the special properties of the part are supplemented with inserts of brass or steel.

3. Faster, digital signal processing software is beginning to replace many analog electronic circuits for audio and sometimes radio frequency processing

4. On some printed circuit boards (itself a producibility technique), the conductors are intentionally sized to act as delay lines, resistors and inductors to reduce the parts count. An important recent innovation was to eliminate the leads of "surface mounted" components. At one stroke, this eliminated the need to drill most holes in a printed circuit board, as well as clip off the leads after soldering.In Japan, it is a standard process to design printed circuit boards of inexpensive phenolic resin and paper, and reduce the number of copper layers to one or two to lower costs without harming specifications.

5. It is becoming increasingly common to consider produceability in the initial stages of product design, a process referred to as design for manufacturability. It is much cheaper to consider these changes during the initial stages of design rather than redesign products after their initial design is complete.

6. Produceability involves consideration of the environmental harm. Heavy fines are being implemented in developed countries as a measure of insisting on “greener” manufacturing. This technique is encouraged to be implemented even on already functional systems.

7.7 Motion economy

1. Industrial engineering studies how workers perform their jobs, such as how workers or operators pick up electronic components to be placed in a circuit board or in which order the components are placed on the board. The goal is to reduce the time it takes to perform a certain job and redistribute work so as to require fewer workers for a given task.

2. Industrial engineering frequently conducts time studies or work sampling to understand the typical role of a worker. Systems such as *MOST* have also been developed to understand the work content of a job.

8 RECOMMENDATIONS

8.1 Industrial Engineering Tools

In industrial engineering, the research tools and techniques aim at improving the productivity of organizations by optimum utilization of organization’s resources that are men, materials and methods. The various tools and techniques of industrial engineering which manufacturing and service industries in Zimbabwe should use are as follows:

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i. Method study: to establish a standard method of performing a job or an operation or thorough analysis of the jobs and to establish the layout of production facilities to have uniform flow of material without tracking

ii. Time study (work measurement): this is a technique used to establish a standard for a job or for an operation.

iii. Financial and non-financial incentives: these help to evolve a rational compensation for the efforts of the workers

iv. Production, planning and control: this includes the planning for the resources (men, materials and machines), proper scheduling and controlling production activities to ensure the right quantity, quality of product at predetermined time and pre-established.

v. Inventory control: to find the economic lot size and reorder level for the items should be made available to the production at the right time and quantity to avoid stock out situation and with minimum capital lockup

vi. Job evaluation: this is used to determine the relative worth of the organization to aid in matching jobs and personnel and to arrive at sound policy

vii. Materials handling analysis: to scientifically analyse the movement of materials through various departments to eliminate unnecessary movement and to enhance the efficiency of material handling

viii. Ergonomics (human engineering): it is concerned with the study of relationship between man and his working conditions to minimize mental and physical stress. It is concerned with man-machine system

ix. System analysis: the study of various sub-systems and elements that make a system, their interdependencies (connections) in order to design, modify and improve them to achieve greater efficiency and effectiveness

8.2 Six goals of green engineering

The following should be the target of all the industries in Zimbabwe:

i. Selection of low environmental impact materials

ii. Avoiding toxic or hazardous materials.

iii. Choosing cleaner production processes.

iv. Maximising energy and water efficiencies.

v. Designing for waste minimization.

vi. Designing for recyclability and reuse of material.

8.3 Operations research techniques

These techniques assist in arriving at the optimum solutions to the difficulties based on the set objective and constraints imposed on the challenges. The techniques of operations research that are frequently used are:

i. Linear programming problems

ii. Simulation models

iii. Queuing models

iv. Network analysis (CPM and PERT)

v. Assignment, sequencing and transportation models

vi. Dynamic and integer programming

vii. Games theory

9 CONCLUSION

The discussion is not on whether to implement or not to but to bring industrial engineering and environmental sustenance as a must to companies in Zimbabwe. The industrial engineering personnel can act as catalysts in this endeavor. But the guiding spirit should come from top management. Training in Industrial Engineering and Environmental Sustenance techniques should be the motivator for all manufacturing and service companies in order to improve on their performance. Training should also be instituted with the same passion given to making of profits.

REFERENCES

Africa Progress Panel. 2015. Power People Planet Seizing Africa's energy and climate opportunities

Angeliki N. et al, (2016). Rethinking the energy-growth nexus: Proposing an index of, sustainable economic welfare for Sub-Saharan Africa. Energy Research & Social Science Vol 17 pages 147–159

Feron P.H.M., et al CO2 Capture Process Principles and Costs [Journal] // Oil & Gas Science and Technology – Rev. IFP. - 2005. - 3 : Vol. 60. - pp. 451-459.

Freund P International collaboration on capture, storage and utilisation of greenhouse gases [Journal] // Waste Manage. - 1997. - Vol. 17. - pp. 281–287

Grimes S L, 2004. Clinical engineers: stewards of healthcare technologies Published in: Engineering in Medicine and Biology Magazine, (Volume:23 , Issue: 3)

Gudukeya L., Mbohwa C., Success Factors For Manufacturing and Service Industries in Zimbabwe , International Conference on Management Engineering, Cape Town, South Africa, 20-21 November, 2013, pp. 1017-1046

IMF, 2016. World Economic and Financial Surveys Regional Economic Outlook. Sub-Saharan Africa Multispeed Growth

Intellego, 2016. Zimbabwe Economic Outlook. Presentation to the Business Herald-CZI Symposium

Jimmerson C, Weber D, Sobek D K. Reducing Waste and Errors: Piloting Lean Principles at Intermountain Healthcare. Joint Commission Journal on Quality and Patient Safety, Volume 31, Number 5, 2005, pp. 249-257(9)

Kramarenko V, et al, 2010. Zimbabwe: challenges and policy options after hyperinflation. Washington, D.C. International Monetary Fund, 2010.

Lo V H Y, and Sculli D, 1995. Industrial Engineering and TQM, Training Quality, Volume 3, Number 3, pp 4-7, MCB University Press.

Masin I,. and Vytlacil M, (2001), Industrial Engineering in the Czech Republic, Work Study, Volume 50, Number 5, pp 194-196, MCB University Press.

Mohanty R P, 1998. BPR-Beyond Industrial Engineering?, Work Study, Volume 47, Number 3, pp 90-96, MCB University Press.

Mullinger P., et al Industrial and Process Furnaces - Principles, Design and Operation [Book]. - Amsterdam, Boston, Heidelberg, London, New York, Oxford : Butterworth-Heinemann, an imprint of Elsevier, 2008

Salaheldin, S. I., (2006), JIT Implementation in Egyptian Manufacturing Firms: Some Empirical Evidence, International Journal of Operations and Production Management, Volume 25, Number 4, pp 354-370, Emerald Group Publishing Limited.

Yifu Lin J, 2012 Industrial Policy and African Development National School of Development. Peking University

ZEPARU, 2016. Zimbabwe Economic Review

Biography

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