Zimbabwe Journal of Science & Technology pp 68-79 Vol.15 [2020]
e-ISSN 2409-0360
Zimbabwej.sci.technol

Green manufacturing implementation in zimbabwe: an assessment of current issues

[a]Tinotenda Machingura, [b]Davison Zimwara
[a]Department of Fuels and Energy Engineering, Lupane State University. P.O. Box 170, Lupane, Zimbabwe.

[b]Department of Industrial and Manufacturing Engineering, National University of Science and Technology. P.O. Box AC939, Ascot, Bulawayo, Zimbabwe.
Email: tmctino@gmail.com

ABSTRACT

Green manufacturing (GM) is becoming very important as it will determine an organisation's sustainability in the long term. The protection of the environment is essential to avoid land, air and water pollution. Challenges of global warming, land degradation and ozone layer depletion are pushing companies to adopt GM. This paper aims to assess the implementation of GM in Zimbabwe and shed light on the current position. A GM framework that can be adopted by the mining and manufacturing companies in Zimbabwe was developed. 76 manufacturing and mining companies in Zimbabwe participated in this study. The data was analysed using SPSS v 23. Financial constraint was highlighted as one of the challenges faced in implementing GM. All the companies highlighted that they use power grid electricity and that their processes produce a lot of waste. Several companies indicated that they do not have pollution prevention equipment.

Keywords: green manufacturing, pollution; framework, challenges, critical success factors, environmental management

Received: 16.11.20 **Accepted**: 20.05.21

1. INTRODUCTION

To ensure customer loyalty and satisfaction, organisations must consider the consequence of their operations to the community, employees, and environment. The effects of the products during use and after use must be considered. Employees, shareholders, customers, and the community are interested in environmental issues (Lina et al., 2011). Thus, it is vital to create an image that increases customer satisfaction as it will lead to an increased market share (Rehman et al., 2013). Manufacturing and mining industries have a more significant role to play in developing economies. However, they bring in challenges like water, soil, and air pollution, fast depletion of natural resources and health hazards to humanity. Environmental pollution is encountered on the entire product life cycle, from the raw material, processing and disposal (Galeazzo et al., 2013). Mining industries are associated with heavy metals and acid mine drainage, contaminating ground and surface water, killing aquatic life, humans, and animals. One thousand cattle died due to the pollution of Odzi, Save and Singwizi rivers with waste from Marange mine (*The Zimbabwean*, 23 November 2014). More than 2.5 million tonnes of waste are produced annually in Zimbabwe and more than 70% of this waste is disposed in open dumpsites, of which 90% of the waste do not meet the stated environmental standards (*The Standard*, 4 May 2014). There is greater pollution in Zimbabwe, especially in water bodies leading to an increase in water treatment costs. As a result, the Harare city council needs about US$3 million for water treatment every month (*The Standard*, 7 April 2013).

Manufacturing and mining industries need to adopt strategies that will improve their organisational performance, decrease the consumption of materials, and pollution levels. Techniques such as GM can reduce costs, minimise health risks, meet environmental regulations and improve company image (Eshikumo and Odock, 2017). However, the developing countries have not considered the implementation of such improvement philosophies. An example is Zimbabwe, which is facing many challenges that hinder the implementation process. With the issues surrounding climate change and the quest to meet sustainable development goals, the operations of manufacturing and mining industries need to be fully analysed. Thus, this study aims at examining the implementation of GM in Zimbabwe to understand the level of adoption of GM, the current situation, and improvements to be made. As a result, a GM framework was developed that will guide the manufacturing and mining organisations on GM implementation.

2. INTRODUCTION

2.1 Green manufacturing

Green manufacturing (GM) is a concept focusing on reducing the damage to the environment by manufacturing processes and products (Rehman et al., 2016). Its emphasis is on minimising resource usage by using techniques Life Cycle Assessment (LCA), green design, green purchasing, green packaging and 6R (recycling, recover, redesigning, reduce, remanufacturing and reusing. It considers both the resource consumption and environmental impact during the product entire life cycle (Qureshi et al., 2015). GM advocates for the use of environmentally friendly energy such as solar energy and biofuels.

Implementation of GM starts with the identification of the waste produced by the companies. These include gas emissions, solid waste, water waste amongst other things. This waste can be controlled and monitored by different equipment and methods. Pollution control can be achieved by using membrane filters, thickeners, biodegradation, natural degradation, effluent treatment plant, chemical precipitators amongst others (Driussi and Jansz, 2006). Pollution monitoring can be done through the use of gas sensors, gas analysers and particulate matter sensors.

The implementation of GM is hindered by a lot of challenges which include financial challenges (Famiyeh et al., 2014) and lack of government support (Barve and Muduli, 2013). The critical success factors for the successful implementation of GM are top management commitment (Mangla and Kumar, 2014), government incentives (Luthra et al., 2015) amongst others. Organisations should be able to measure their performance to create room for improvement. The performance measures include wastewater discharge, solid waste, energy consumption rate Mutingi et al., (2013).

2.2 Green manufacturing in developing Countries

Green manufacturing implementation in developing countries is still in its infancy (Rehman et al., 2016). The study in Brazil concluded that the adoption of green operation practices has a positive relationship with green performance (Soubihia et al., 2015). The reduction in emissions, resource consumption, waste, consumption of hazardous materials, environmental accidents was realised. Mafini and Loury-Okoumba, (2018) study in South Africa outline that green purchasing, environmental collaboration with suppliers and reverse logistics has a positive impact on operational performance. Li, Lim and Wang, (2019) research in China pointed out that the stakeholders (government, suppliers, customers and society) have a significant impact on GM. It was also highlighted that GM is positively related to firm performance. In Kenya, a study was conducted in the cement industry and it was concluded that the implementation of GM improves operational performance through cost and emission reduction (Mukonzo and Odock, 2017).

In Zimbabwe, evidence of GM implementation has been reported. (Mbohwa et al., 2010) find out that there is a positive relationship between participation in cluster environmental activities and the achievement of GM. A study in the tobacco process industry concluded that the implementation of GM can reduce energy use and minimise waste (Nyoni et al., 2011). Madanhire and Mugwindiri, (2012) highlighted that the implementation of GM is cost-effective compared to end-of-pipe solutions. Mutubuki and Chirinda, (2021) proposed solutions such as recycling, reusing, reducing, recover in minimizing waste produced by the Zimbabwe food industry. Masike and Chimbadzwa, (2013) also proposed solutions to minimize the waste produced in the foundry industries. Other studies that have reported the adoption of GM in Zimbabwe include (Mbohwa, 2002; Ciccozzi et al., 2003; Gumbo et al., 2003; Tagwireyi, 2017; Muchaendepi, 2019).

Although the implementation of GM has been reported in Zimbabwe, there is a lack of a standard GM implementation framework that can be adopted by the Zimbabwean industry. It seems organisation are implementing different GM practices as they are not sure what practice exactly suit their needs. This leads to haphazard implementations. Thus, the purpose of this research is to develop a GM framework that can be adopted by the Zimbabwe manufacturing and mining industries. The framework can also be extended to other developing countries.

3. MATERIALS AND METHODS

A general survey was conducted in this research, which focused on mining and manufacturing companies in Zimbabwe. Questionnaires were used as the data collection tool. The email and traditional paper and pencil self-administration interview methods were also used to gather data from appropriate respondents. The snowball method was used to identifying the respondents. The target group was production engineers, production managers and safety, health and environments (SHE) personnel. 201 questionnaires were distributed to the manufacturing and mining companies in Zimbabwe. 76 valid responses were obtained giving a response rate of 38 %. The data was analysed using SPSS v 23.

4. RESULTS

4.1 Profile of respondents

A total of 76 valid responses were used in the study. Of these responses, 87% were from the manufacturing sector and 13% from the mining industry. The participants were higher for the manufacturing industry than the mining industry. This is because the manufacturing companies are less geographically spaced making it easier for the researcher to cover more companies in a short space of time.

4.2 Reliability and validity analysis

The Cronbach's alpha was very high for all the factors and the data was considered highly reliable. The Cronbach's alpha value was 0.867 and 0.903 for the critical success factors and the challenges, respectively.

4.3 Type of waste produced

Figure 1 shows that the most produced waste is solid waste while the least produced waste is tailings.

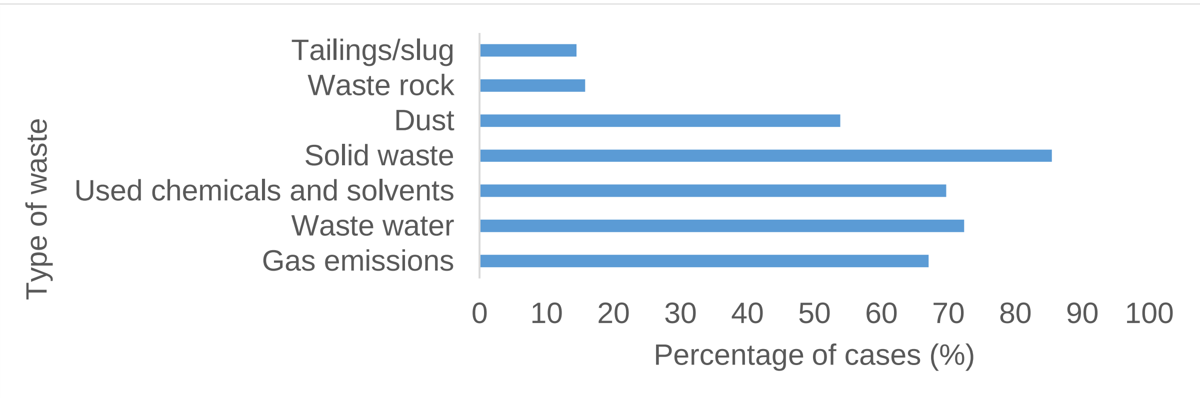

Figure 1. Types of waste

This shows that most companies are associated with solid waste in both the manufacturing and mining industries. Tailings were the least produced waste as it is common in the mining industry and not the manufacturing companies.

4.4 Significance of waste on pollution

Table 1. Significance of waste

Waste	Mean	Std. Deviation
Gases on air pollution	4.23	1.257
Wastewater	3.78	1.301
Used chemicals and solvents	4.09	1.405
Solid waste	3.78	1.256
Tailings	2.56	1.548
Waste rock	2.50	1.505
Dust on air pollution	4.23	1.257

4.5 Pollution prevention equipment and methods

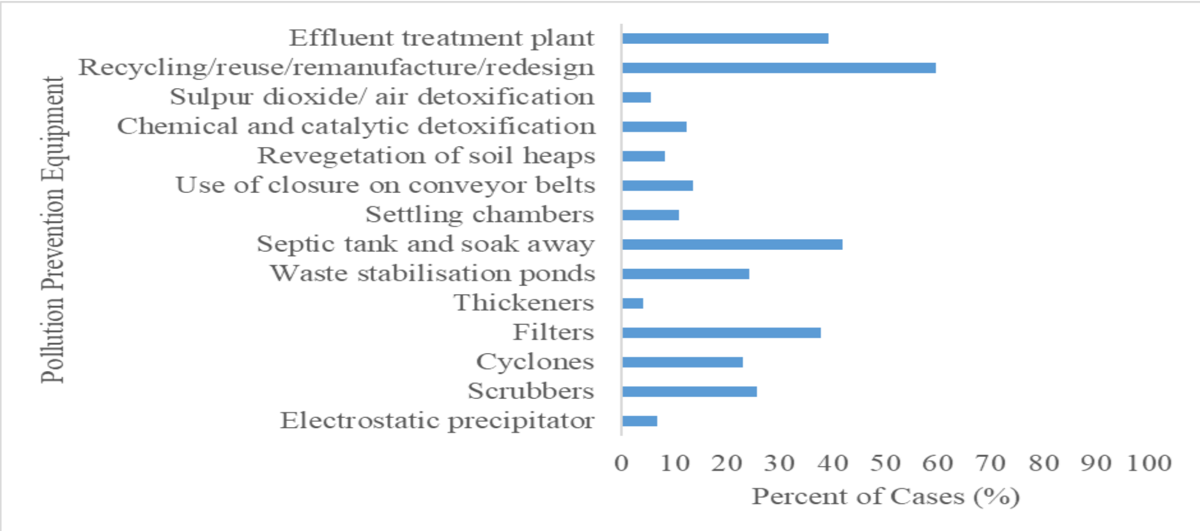

Figure 2: Pollution prevention equipment and methods

Companies need to invest more in pollution prevention equipment. Figure 2 shows the pollution prevention equipment and methods used by different companies. Thickeners are the least used equipment while recycling is the most common method.

4.6 Effectiveness of pollution prevention methods and equipment

Table 2 shows the effectiveness of waste reduction methods whilst Fig 3 shows pollution momitoring cases. A lot of companies highlighted that they do not have any pollution monitoring equipment. The effluent monitoring system is the most common, while the particulate matter sensor was the least common

Table 2: Effectiveness of waste reduction methods

Method	Mean	Std. Deviation
Solid waste reduction/ prevention	3.07	0.977
Gas and dust reduction/ prevention	3.25	1.064
Water treatment methods	3.40	1.030
Solvent/ chemical use reduction	4.49	1.451
Water use reduction	3.43	1.190
Noise pollution reduction/ prevention	3.25	1.181
Recycling of products or waste	3.74	1.195
Reuse of substance	3.44	1.141

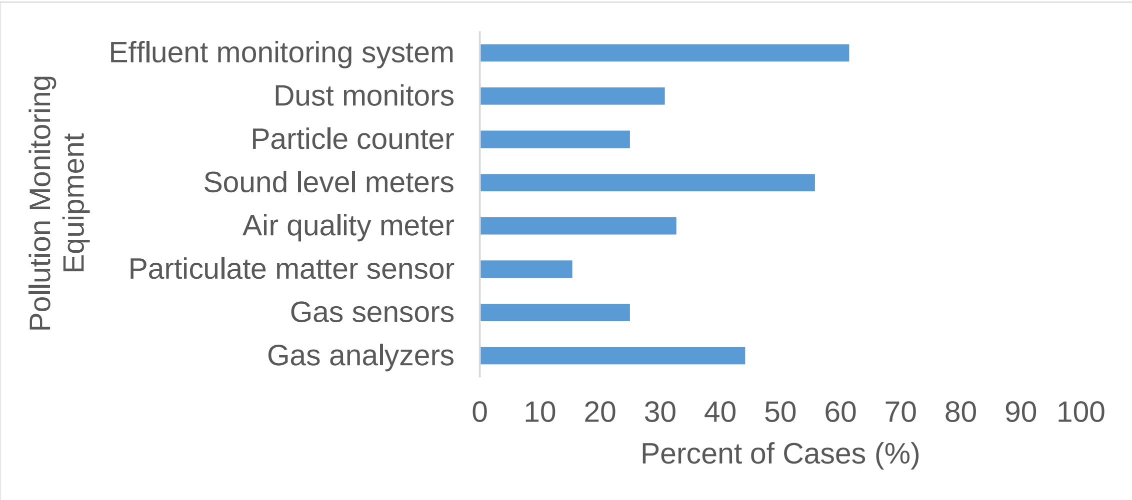

Figure 3: Pollution monitoring equipment cases

4.8 Energy sources

It can be seen from Figure 4 that the most used energy source is power grid electricity, followed by petrol and diesel and then coal. GM is supported by using energy sources that are friendly to the environment. Coal, petrol and diesel need to be substituted as they are the main sources of greenhouse gas emissions. Power grid electricity is greatly affected by load shedding; hence companies are losing production time.

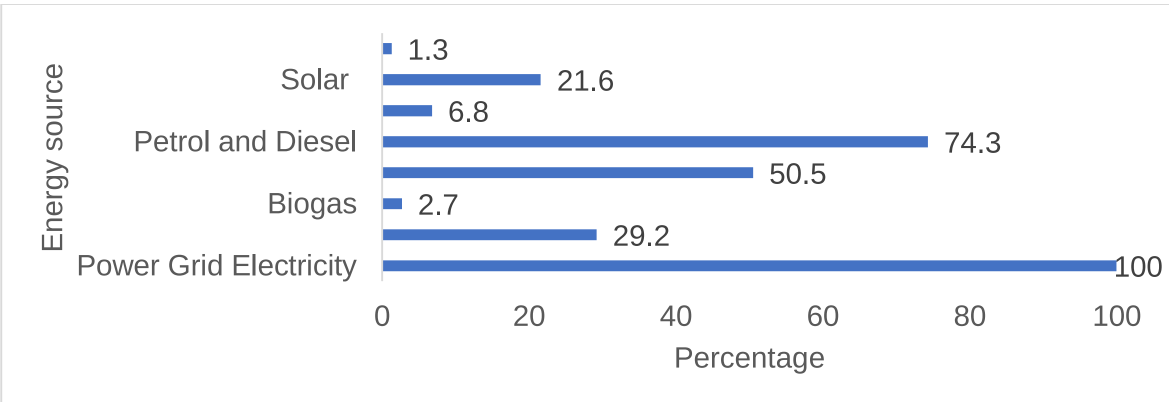

Figure 4: Energy sources used by companies

4.9 Challenges on Green manufacturing implementation

Financial constrain, changes in technology, lack of government support and lack of education and training were noted as significant. However, lack of employee commitment was found to be less significant as shown in Table 3.

4.10 Critical success factors

Table 4 shows that top management's support and understanding of the value of GM implementation is crucial for the success of the GM programs and this agrees with (Hair et al., 2009).

Table 3: Ranking of challenges to GM implementation

Challenges	Mean	Std. Deviation	Rank
Financial constraint	4.21	1.219	1
Changes in technology	4.05	1.236	3
Lack of education and training	4.01	1.295	4
Lack of government support	4.11	1.427	2
Lack of top management support	3.07	1.428	7
Lack of employee commitment	2.72	1.244	9
Lack of awareness	3.14	1.214	6
Organisational culture	3.15	1.305	5
Poor communication	2.94	1.271	8

Table 4: Ranking of the critical success factors

Critical Success Factors	Mean	Std. Deviation	Rank
Top management commitment	4.73	0.580	1
Legislation	4.30	1.023	2
Societal issues	3.72	1.092	11
Scarcity of natural resources	3.60	1.171	13
Economic benefits	4.11	.959	5
Pressure from customers	3.69	1.260	12
Involvement of people	4.00	1.007	7
Effective communication	4.20	.860	3
Competitiveness	3.76	1.108	10
Training of employees	4.19	.855	4
Financial incentives	4.11	1.021	5
High cost for the disposal of hazardous material	3.84	1.190	9
Effectiveness	3.96	1.020	8

The scarcity of natural resources is less important. The top management are responsible for setting the goals and targets for the company. They are responsible for providing resources for the implementation of GM, training of employees, providing incentives. They also construct polices to make sure that there involvement of peopleand effective communication in the organisation. Generally, companies indicated that they do measure productivity. The results indicated that all the productivity performance measures are well utilized by the companies as illustrated by Figure 5.

Energy consumption rate, water consumption rate, environmental fines, and solid waste generated were the most used while carbon footprint is the least common environmental performance measure. Figure 6 illustrates more.

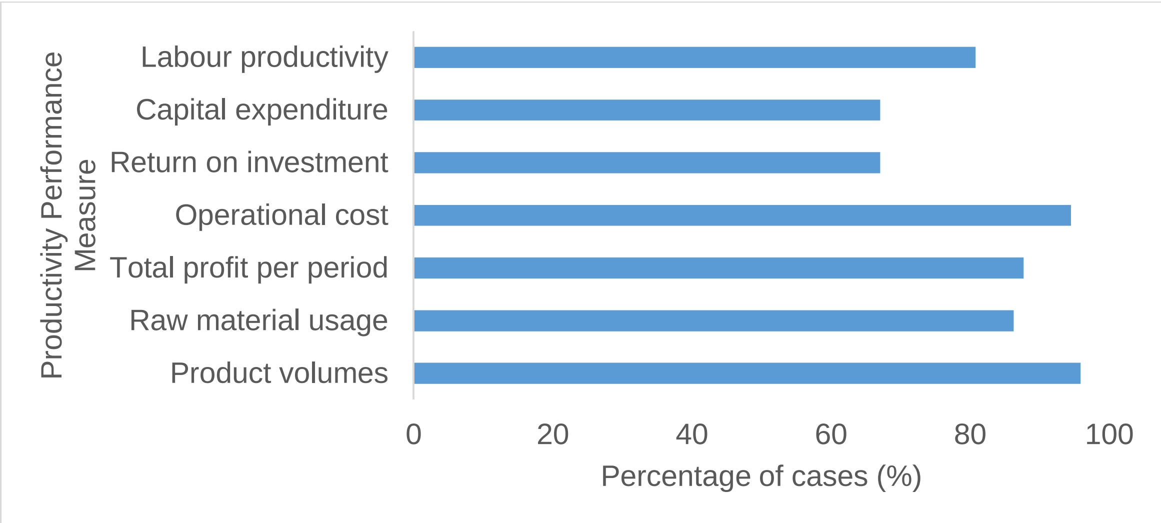

Figure 5: productivity performance measures cases

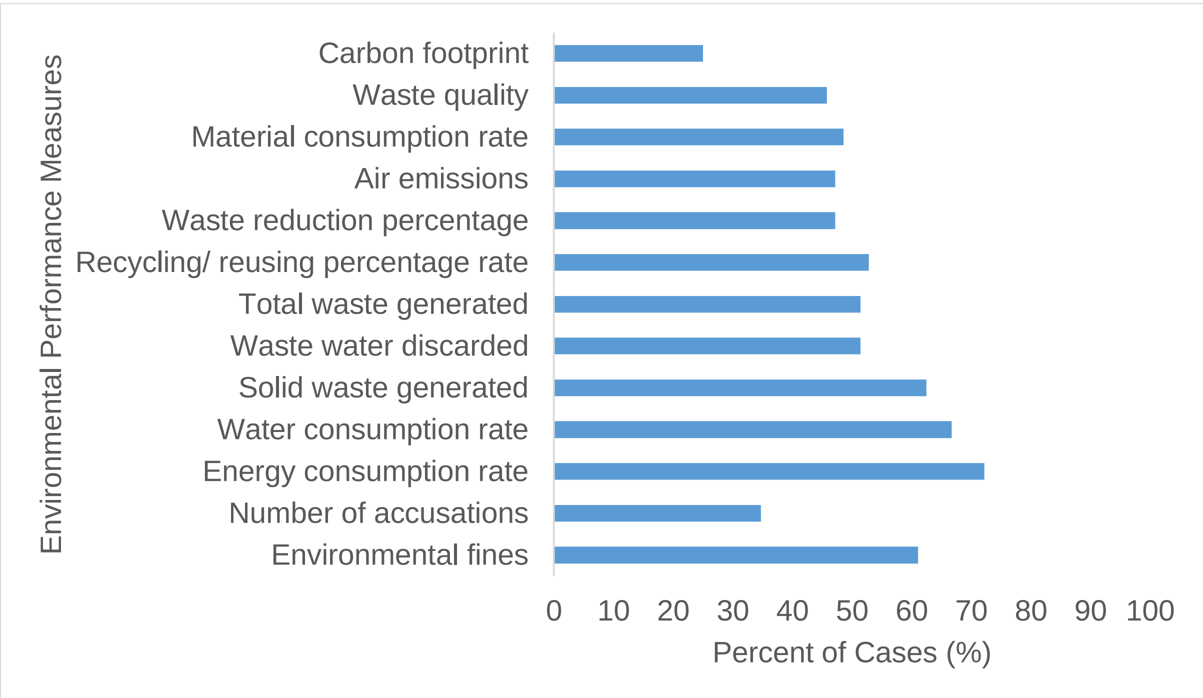

Figure 6: environmental performance measures cases

5. DISCUSSION

5.1 Green manufacturing implementation framework

The frameworks published by other scholars were reviewed and the common attributes were extracted from these frameworks. These common attributes were combined with the attributes obtained from the survey to yield the final framework.Table 5 shows the attributes obtained through the literature review. Based on the results, it can be concluded that the elements of the framework are technical training, Total Quality Management (TQM), Performance Measurement (PM), Life Cycle Assessment (LCA), Design For Environment (DFE), Effective Energy Management through the use of Renewable Sources of Energy (RSE), need for Pollution Monitoring Equipment (PME), Pollution Prevention Equipment (PPE) and waste management. These were used to construct a GM framework shown in Figure 7. Table 6 shows the attributes obtained from the survey.

Table 5: Common attributes from the literature

Common attributes	Authors who proposed the attribute	Research outcome
Effective energy management	• Jasti et al., (2011) • Lawrence et al., (1998) • Borri and Boccaletti, (1995)	The survey showed the use of non-renewable and very polluting energy sources such as coal, petrol and diesel. In addition, it indicated the use of power grid electricity leading to shortages and load shedding. Therefore, it is a strong candidate for the framework.
Waste management	• Jasti et al., (2011) • Lawrence et al., (1998) • Borri and Boccaletti (1995)	Results from the survey indicate that a lot of waste is produced by manufacturing and mining companies. This makes waste management a vital part of the framework.
Design for Environment	• Lawrence et al., (1998) • Borri and Boccaletti (1995) • Chen (2013)	The survey noted the need for methods like the design for recycling, design for reuse, design for pollution prevention, design for energy minimisation. Thus, design for environment is a crucial part of the framework.
Life Cycle Assessment (LCA)	• Jasti et al., (2011) • Chen (2013)	The survey showed the need for product life cycle management making LCA a strong candidate for the framework.

Table 6: Attributes from the survey

Attributes	Research outcome
Total Quality Management (TQM)	The survey showed a lack of financial incentives, need for effective communication, and involvement of people. Therefore, it is a strong candidate for the framework.
Technical training	Results from the survey indicate that workers lack education and training. Hence, it must be included in the framework.
Pollution Prevention Equipment (PPE)	The survey noted the need for pollution prevention equipment as a result it makes part of the framework.
Pollution Monitoring Equipment (PME)	The survey highlighted the need for pollution monitoring equipment thus, it is an important part of the framework.
Performance Measurement (PM)	The results from the study outlined the need for measuring productivity and environmental performance, therefore, it must be included in the framework.
Effective energy management	The survey showed the need for effective energy management through the use of renewable sources of energy (RSE). Therefore, it is a strong candidate for the framework.
Waste management	The result from the study indicates that waste management is required to deal with the waste produced by the manufacturing and mining companies. Therefore, it plays an important role in the framework.

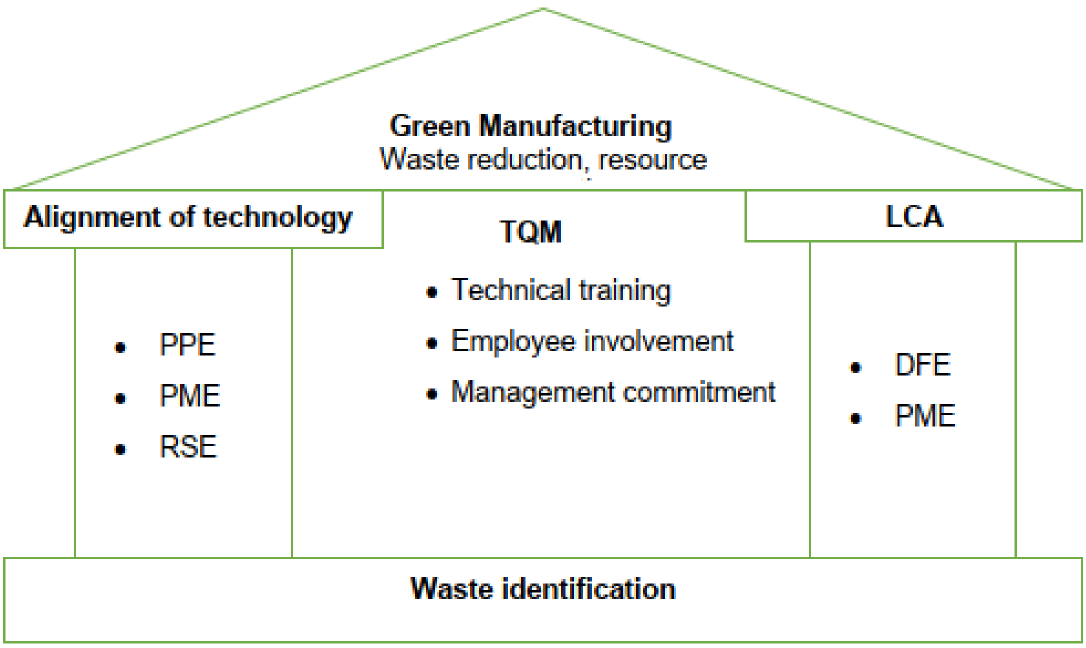

Figure 4:Green manufacturing framework

At the base of the framework, there is waste identification. This is the starting point, and it supports the whole framework. For successful GM implementation, there is a need to identify the waste that is produced by the products and processes. This enables the organisations to determine the correct and most appropriate GM practices to use. A haphazard implementation may occur if there is no proper waste identification process that can make the implementation process fail.

One of the pillars of the framework is the alignment of technology. Alignment of

technology address issues that deal with technical requirements for waste reduction and resource conservation. The pillar is made up of PPE, PME and RSE. The other pillar is LCA which deals with monitoring the product through its entire life cycle. To reduce environmental pollution and the consumption of raw material, processes and products must be designed accordingly. During the LCA process, organizations need to measure their performance to make sure that they are operating within acceptable and set standards.
Inside the framework, there is TQM which encourages the involvement of everyone, from the management to shop floor workers. Employees are the key to successful GM implementation as they take part in every process. They assess whether correct procedures are being followed or not. Management has to play a bigger role by making sure that the employees are motivated, they are incentivised, they have proper education and training, and their suggestions are considered. They should also provide financial support and other resources required for the implementation process. The roof summarises the objective of GM which is to reduce pollution levels and resource consumption. If companies can identify the waste, perform life cycle analysis, acquire the appropriate technology, and involve everyone, the GM goals would be easily achieved.

6. CONCLUSION AND RECOMMENDATIONS

The research indicated that manufacturing and mining organisations produce many waste, and most of these companies do not have PME and PPE. They should invest more in PPE and PME and buy equipment such as cyclones, gas analyzers and bag filters to minimize pollution levels. Monitoring is essential as it indicates the pollution levels and companies can act accordingly if the levels exceed the acceptable limits. At the same time, some available equipment needs regular servicing so that they remain effective while others need replacement as they are very old. Government should play a bigger role in assisting companies financially as most of the companies are having financial challenges. Most equipment and gadgets require huge sums of money and most companies may not afford them. The number of companies that measure productivity performance is higher than those which measure environmental performance. Companies should focus on productivity output and consider how harmful their processes are to the environment and take appropriate action.
Power grid electricity, coal, petrol, and diesel were the most used energy sources. Coal, petrol and diesel are the main sources of greenhouse emissions, therefore, need to be replaced by renewable sources that are friendly to the environment. This will ease the demand for power grid electricity, thus reducing cases of load shedding leading to an increase in the production time.

The successful implementation of GM requires top management to set clear objectives and play a leading role. They should make sure there is effective communication by involving everyone from the top, middle and bottom. The leadership should provide enough resources for the training of workers and reward workers with incentives so that they are motivated to do well. Finally, the government should make sure the legislation drives companies in the implementation of GM.

5.1 Research limitations and study gap

This study focused on the implementation of GM by the mining and manufacturing companies in Zimbabwe. Therefore, it is generic as it does not narrow down to a specific company. Organisations need to assess their level of GM implementation and act accordingly. Further studies assessing GM implementation by other industries like service, construction and agriculture can be carried out as GM is not limited to mining and manufacturing industries only. There is a need for research that examines the impact of GM on organizational performance in Zimbabwe industries. If the companies understand the benefits of GM implementation, the level of adoption will increase.

ACKNOWLEDGEMENTS

The authors would like to thank the Lecturers at the National University of Science and Technology, particularly at the Department of Industrial and Manufacturing Engineering for their useful suggestions and contributions. We also wish to thank all the respondents who participated in the survey for their time and knowledge. We also want to thank Carlos Meki and Carradine Garan'anga for assisting in identifying potential respondents for the survey.

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