Industrial Area Into Eco –Industrial Park (EIP) Case Study of Harare

Ignatio Madanhire and Taurai Mupaso
University of Zimbabwe, Department of Mechanical Engineering,
P.O Box MP167, Mt Pleasant, Harare,Zimbabwe
imadanhire@eng.uz.ac.zw

Charles Mbohwa
University of Johannesburg, Department of Quality Management and Operations Management, P. O. Box 524, Auckland Park 2006, South Africa.
cmbohwa@uj.ac.za

Abstract

The research study was done to an analyze and assess Harare industrial sites setup and practices, with the view to develop possible industrial symbiosis connections. This was achieved by carrying out a case study and developing a simple EIP framework prototype model. The approach that was used included developing a methodology for identifying and quantifying potential environmental and economic impacts of the EIP, collected data from existing industries on current eco-related activities and developed a prototype using the information gathered. A virtual eco industrial park model was developed with Msasa as the central part of the park having cement, chemical and coal power station acting as the anchors of the park. The overall estimated environmental impact of the final industrial park model was 15-25% decrease of waste deposited in landfills on implementation.

1.Introduction

Harare as city is facing challenges with waste disposed in landfills with its main dumpsite Pomona already filled up. It is already in the process of acquiring some land for another dumpsite. The environment is characterized by disturbing smells due to uncontrolled waste disposal. Failure to collect waste on regular basis is proving to be a problem for the council. Harare produces millions of tons of waste per annum, and most of this being industrial waste from the processing of natural resources into industrial products. A large percentage of this waste is either discharged into water bodies (e.g. rivers) or dumped in landfills. In this regard the municipality and industries are thus challenged to collaboratively find alternative waste management practices. Eco Industrial park (EIP) initiative could be recommendable leap towards sustainable development where industrial cooperate with each other to reduce pollution and waste. As well as efficiently share with the intention of increasing economic gains and improving environmental quality(Wikipedia 2015). EIP concept can also take the form of shared logistics, wastewater cascading and receiving facilities, green technology purchasing blocks, multi-partner green building retrofit and energy systems. This study seeks to come out with an EIP model to improve competitiveness material efficiency, energy efficiency and collaboration among firms.

2. Justification

Many industrial operations in Harare are shutting down due to high cost of raw materials, high costs of the unsustainable processing and manufacturing methods and poor waste and environmental management strategies which lead to country losing millions of dollars, in form of wastes, pollution fees and local products not performing well on local market. Continuous pollution remains a cause of limited level of technological implemented during processes as well as waste treatment procedure. Thus there is need for sustainable and eco-friendly as well as cost effective processes to revive the once vibrant industry (Ndoro, 2014). “Our methods are not sustainable thus consumers prefer imported cheap products than local expensive products” (Michael Bimha, 2015). To counter act the problems Eco Industrial parks could be initiated to kick start viability in the industry. Analysis and assessment of Harare industrial sites setup and practices could enhance possible development of industrial symbiosis connections.

3. Literature review

3.1 EIP mandate

EIP was popularized by Frosch and Gallopoulos (1989) when they proposed that waste from one industrial process could serve as the raw materials for another, thereby reducing the impact of industry on the environment as a strategy of manufacturing. The argued for recycling of resources rather than their extraction and eventually discarding after use. EIPs were proposed to be an approach towards green industry, thus there were the pillars supporting green industry. Cooperation among firms would be facilitated by a coordination mechanism and information sharing. The interaction amongst businesses, and between businesses and the natural environment being the feature of essence.

EIPs operate based on the concept of industrial ecology, collaborative strategies not only include by-product synergy ("waste-to-feed" exchanges), but can also take the form of wastewater cascading, shared logistics and receiving facilities, green technology purchasing blocks, multi-partner green building retrofit, district energy systems, and local education and resource centers. Thus industrial symbiosis is present as a sub-field of industrial ecology that is primarily concerned with the cyclical flow of resources through networks of industrial units as a means of cooperatively approaching environmentally sustainable industrial activity.

In summary the basic concept behind EIPs operation is the concept of Cleaner Production applied to a group of participating firms, and this implies that no operation can work for all situations but rather how it operates is best determined by the situation where it is to be applied.

3.2 Benefits of eco-industrial parks

Eco-industrial park implementation results in a higher business and environmental performance as a way of achieving cost competitiveness and business advantages. The intended networking provides companies with competitive advantages by giving them access to critical resources and allowing cost savings and inter-organizational learning (Starlander 2003). In Eco-industrial parks there is effective use of resources and tend to be flexible actors in the market. Networks are organized to use information and resources optimally thus tend to adapt flexibly to strain and change. There is reduction in virgin raw materials and energy use this is because they are replaced by wastes and by-products produced in the area. The biodiversity of the area is cherished and emissions are reduced. Attention is paid to the total well-being of the community.

EIP offers the opportunity to realize decreased production costs through increased energy and material efficiency, reduction of regulatory burden and new revenue streams from former wastes. In addition, some costs which could have been carried by one individual firm can be shared. This cost sharing could include the cost of infrastructure, the expense of designing and maintaining sophisticated information systems, training, research and development. Such collaboration could help EIP members achieve greater economic efficiency than their stand-alone counterparts and companies may use their EIP membership as a solid foundation for green marketing campaigns.

For the wider community Eco Industrial Parks could yield a significant reduction in many sources of pollution and decreased demand for natural resources and improved sustainability. The EIP evolution generates the demand for more innovative approaches to pollution prevention, product disassembly, resource recovery, energy efficiency, and other advanced environmental management technologies. This demand in turn will increase demand for research and development in these areas.

3.3 Development of eco-industrial parks

The development of EIP can either be planned or spontaneous that is it can evolve on its own without any planning. Still with the same mandate of achieving Cleaner Production through good housekeeping, reduction and substitution of toxic materials, strict control of emissions, separation of by-product or residual materials, etc. In some cases to use of renewable energy and materials to replace fossil fuel sources and finite material supplies; and to enhance quality of life and economic development in neighboring communities through projects between industry and community government and community-based organizations. It also promotes the establishment of environmental management systems such as ISO 14000 with objectives and indicators informed by eco-industrial development, not only compliance with regulations.(Leslie W. Ayres and Robert U. Ayres)

In planned EIP, the planning of the systems involves a stakeholder group of diverse actors in order to guide the process. Governmental agencies are often represented in the group in order to facilitate land planning and long term financing. New development can serve as a basis for trust building and a higher focus on sustainable development. On the contrary, Chertow (2007) suggests that attempts to plan industrial symbiosis in the form of eco-industrial parks, particularly from scratch, are rarely successful. Instead, the self-organized systems, often

developed from a single successful exchange, have been more fruitful. Which is another name for this kind of development self-organized park, and the formation is usually spontaneous. They evolved spontaneously without any policy management or administrative plans to develop cooperation and these systems have become eco-industrial parks by accident, because of independent linkages between its actors.

According to Chertow and Ehrenfeld, 2012 one of the reasons why unplanned are deemed to have successful results than that of planned, might be that by-product exchanges in planned developments are often given higher priority than economically motivated and that the focus on technical aspects, matching flows, makes the system rigid and less adaptable. They further explore the success of self-organized symbioses and suggest a three-stage model for the level of maturity of said symbioses:
Sprouting: A single or a few exchanges are formed on a random basis and their feasibility tested. Limited networks of exchanges are formed.
Uncovering: The networks are recognized for creating environmental value. Both goals andrange of membership are broadened.
Embeddedness and institutionalization: Further expansion of the network becomes intentionally driven by an institutional actor.

In the development of an EIP there are basically three stages which are planning, design and implementation, and each stage may follow a certain procedure:

Stage One – *Planning:* It is a necessity to ensure that the eco industrial development(EID) concepts are aligned with the community's priorities on economic growth, environmental quality and social goals. Traditional research must done to get data specific to community where the EID would be located, to establish what is consistent with community priorities. The research conducted in this phase represents the initial "set-up" information. This may entail the evaluation of infrastructural capacity - sewer, water, transportation, electric, storm water. Also analysis of access to markets and capital could be done. A determination of economic and environmental performance standards could be reviewed to evaluate economics of environmental benefits and analyze proposed industrial value-chain.

Stage Two - *Design:* The process of creating design concepts will be fluid, organic, and iterative; no formula exists with which to create an EID. Conceptual ideas will be developed and discussed, resulting in questions that will require further research and analysis. This may involve development of site master plans and schematic engineering plans. Model codes, site and building guidelines, covenants, conditions and restrictions that set the parameters for the EID may be developed to guide design, operations, and shared amenities and to promote continuous high performance.

Stage Three - *Implementation:* An anchor company or operation has to be identified, followed by the linking up of various firm operations.

3.4Eco industrial park activities
The base activities are waste management and recycling. Recycling plays a vital role in EIPs as suggested by Kumar "the goal is cradle to reincarnation, since if one is practicing industrial ecology correctly there is no grave." "It is essential for industrial ecosystems to have at least one industrial decomposer such as a recycling entity or network, and to create a symbiotic web among entities in the system"(Liwarska-Bizukojc, Bizukojc, Marcinkowski & Doniec, 2009). When planning for product end of life, two complementary types of recycling should be considered. The other key role eco industrial parks act as a waste management strategic units. It is given as solution to waste problems thus the basic operation within an EIP is based on waste management strategies. The three R's are commonly used terms in waste management; they stand for "reduce, reuse, and recycle" It must be seen that all resources going through an EIP can be checked if the three Rs can be applied.The rising of waste generation rates led to , increased processing costs, and available landfill space decreased, the three R`s have become a central tenet in sustainable waste management efforts (ElHaggar, 2007; Seadon, 2006; Suttibak & Nitivattananon, 2008; Tudor et al., 2011).

3.5 Eco industrial parks in Southern Africa

The concept of eco industrial parks is still in its early development with a few countries still trying to take the initiative. It is difficult to bring forward general guidelines on how to transfer the concept of Eco-Industrial Parks from industrialized countries to developing and newly industrialized countries (DC/NIC) this is because the framework conditions vary considerably from site to site even within a single country. Therefore, it is crucial to conduct site specific exploration and adapt the EIP vision to the ecological, economic, cultural and social

characteristics of the respective community and region(Lowe, Moran, & Holmes, 1996).On the other hand the pollution control agencies of other countries use drastic measures like heavy fines, closure or jail terms for heavy polluters (Fleig, 2000).Developing countries' economies are usually characterized by a greater percentage of "informal sector" with many small and individual enterprises in place of the large factories that are seen in developed countries. "The collective consumption of materials (and the resultant problems of waste and pollution) in these informal sectors is often larger than in the formal sector (Erkman & Ramaswamy, 2000). Thus, there is raising need for adapting measures to EIP concepts, when trying to implementing it to a region characterized by these factors. The most known are the Limpopo and Sasol Chemcity both based in South Africa:

Limpopo Eco Industrial Park (LEIP)-The LEIP mainly gassing coal waste in combination with municipal waste to produce syngas suppling to Gas-to-Liquids, Ammonia and a Power plant. The area is regarded as low environmental sensitivity occurring within a transition zone of the Vhembe Biosphere Reserve Declaration. The LEIP site is situated strategically at the northern-most tip of South Africa, adjoining Zimbabwe, ideally positioning it for easy access into Southern Africa Developing Countries (SADC) markets.

Sasol Chemcity -Sasolberg the industrial hub of the free state South Africa Phase one of the Chemcity Eco Industrial park was initiated. Industrial shells were sold with modern infrastructure with support services. (Bridgitte Backman). This aimed to provide sustainable solution through passionate innovation to stimulate economic growth. The park is designed to operate with a reduced carbon footprint through long term carbon reduction projects.(Charles Wyeth). The Park will be mainly solar powered and low voltage lighting with water collection and recycling. “The main challenge is changing mindset and perception as developing green is considered expensive which is not always the case” Jacques Stoltz.

EIP innovation is site specific as communities, resources, tradition, cultures and priorities vary from place to place.

4. Case study

Industrial base in Harare is geographically made up of four main industrial sites namely Msasa, Graniteside, Southerton and Workington as given by Table 1.All the industries are found in Harare and are within a radius of estimated 50km, Graniteside neighbors Msasa and Southerton being closer to Graniteside and Workington neighboring Southerton. Major industries in all four sites were identified which could contribute to the feasibility of the study. Harare industrial sites are dominated by manufacturing industries and warehouses. Most of the industries found range from small to medium industries with very few heavy industries. Banks, shops and other commercial services are found in all the areas. Most industrial sites are being underutilized with most of the industrial shells have been abandoned due to closure of companies resulting from the economic hardships with the railway networks linking the industries is clogged with grass.

Table 1.Major Industrial Sites in Harare

MSASA	GRANITE SITE	SOUTHERTON	WORKINGTON
Lafarge Cement,	Delta-Coca cola	Delta-Beer brew	Windmill
Feedmix,	Art Corporation	Schewpess	ZFC
GMB,	National Tyre Service	Hunyani Papers	Turnall
Zimphos	PG industries	ZLT	CAFCA
Multimanufacuring	Pro- Plastics	Cairns	National Foods
Firtst Plastics		Savanna	Verspak
Prime Sole		BAT	Dairiboard
Gyproc		Craster International	Zimbabwe sugar refinery
		Cochraine	Unilever
		Brown Enginnering	Cottco
			Colcom
			Zesa thermal power plant

Details of the questionnaires and interviews administered to respondents in the various industrial sites are as shown in Table2 below. It will be worth mentioning that a few industries are doing well despite the economic challenges. The questionnaire issued intended to point out the average composition of the site and also in it

intended to deduce also information about the environment, energy, water, traces of industrial symbiosis and recycling.

Table 2.EIP questionnaire response rate

Questionnaire distribution and response rate				
Site	**Questionnaires issued**	**Questionnaires returned**	**Percentage Response**	**Percentage with Quanitfied Data**
Msasa	35	8	23%	37%
Southerton	12	4	33%	50%
Granite site	12	2	17%	50%
Workington	12	6	50%	33%

On the other hand interviews yielded a very good response and gathered satisfactory data as about 50% of the data that was presented in the project was gathered through interviews. Interviews also meant questions could be altered to suit the specific company and situation at hand.

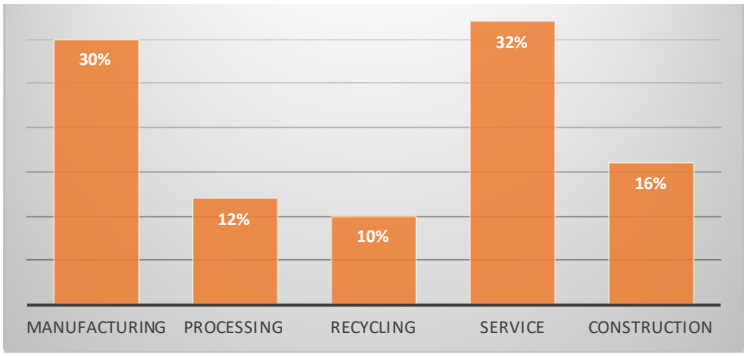

Figure 1.Current state of operations

Most of the companies of the in Harare not operate under any environmental policy that is according to the questionnaire response. Only a mere 20% operate with an environmental policy and are ISO certified leaving a bulky 80% operating without any environmental concern and are not ISO certified more over of the remaining 80%, only a small percentage (estimate 15%) operate with some other standard for example SAZ.

Every industry in Harare use Electricity supplied by ZESA as their primary source of energy with some having generators as backup power source. No industries were identified which used a form of renewable energy as their primary source of power for operation. A few solar water heaters were noticed during survey.

There is a major problem in Harare concerning water as most of the industries rely on water supplied by City of Harare, the water is not always available. Most companies have resorted to supplement the shortage by buying tanks 5000litre or 10000lt and constantly buy water at $40 for 10cubic compared with a mere 50cents that is charged by City of Harare. Water recycling is not a common practice in Harare with table below showing recycling of water.

4. Findings

The findings indicate that not much on the symbiosis was taking place at the moment as to lack of collaboration amongst the industry operators among the park. Figure 2 below shows a graphical representation of the current situation on symbiosis of Companies according to the response of the questionnaire. It was also noted that a significant amount of virgin material consumption could be decreased given the level and relations in by-product exchange is increased. Suggestions were given for facilitation of the by-product exchange to be initiated as it has benefits for the company and the environment.

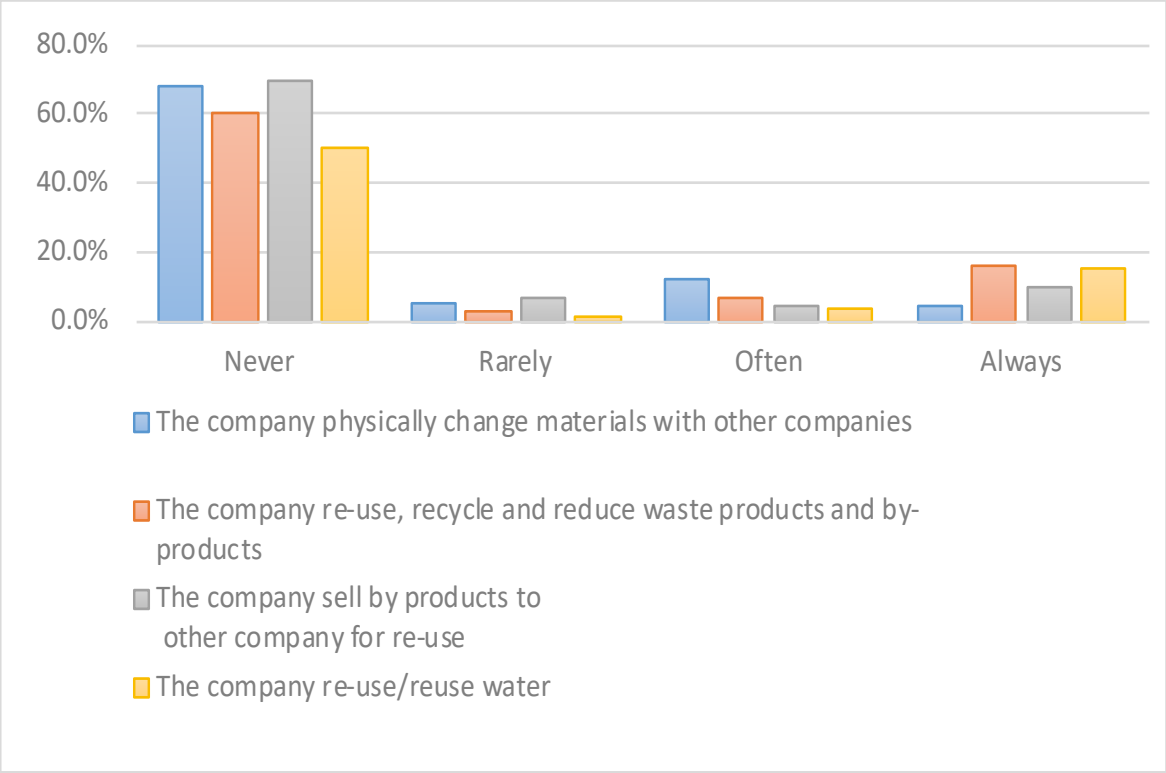

Figure 2.The graphical representation of current symbiotic practices

The graph shows clearly that few of the companies practise eco related activities that is by product exchange and recycling as we can see a greater percentage never share or recycles most of the industries are once of users. From the survey it was found out that the consumption of water could be reduced significantly given that proper measures are taken. 80% of the existing companies suggested that given proper training and capital they could reduce their water consumption by at least 30-50% that is through recycling and reuse of water. Most of the companies could not quantify the usage of water and how the water was disposed thus anapproximation of the general day to day running of the companies was taken to come up with estimates of the water consumed was as shown in Figure 3.

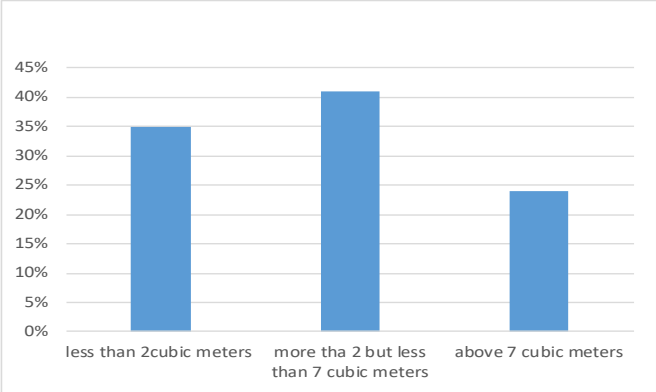

Figure 3.Estimated usage of water per day

It shows the use of water by different industries with different categories the small scale companies using an average of 1.5m^3 of water per day while medium scale averages 7m^3 and for larger industries the consumption has an average of 18m^3. The amount dispatched most did not know how much they dispatched and with 28% of the waste water being dispatched in batches and the remaining 29% being continuous discharge.The questionnaire also required the companies to identify their major waste and by-products and the products.
The most experienced waste in the industries was solid waste this was because waste generated was disposed in a single bin and was not segregated, as a result it was mostly considered as solid waste. 17% of the waste was considered fluid effluents with other waste like gas emissions contributing 20% of the total waste this is clearly.

This was due to ignorance among companies as they did not know where to take their waste and how it could be useful to other industries as well as their own industries. Most of the waste produced ended up in landfills. A few of the companies pointed out that they were recycling their waste 100%, with those recycling were recycling about 50% of their waste and a huge chunk of the industries were once of users.

5.Development of EIP framework for Harare

The prototype model is made up of companies that are existing, the detail of the model depend on the operation of current existing relationship and setup of the companies. A description of how the site was chosen for the prototype and how the potential symbiotic relationships where identified.Considering the traditional and additional baseline analysis points stated in chapter 2.6.3. The best site came out as Msasa. The processes of selection Table 3 shown below was used to pick the central site for the virtual industrial park. The site will act as the central controller of all activities within the park and gives room for expansion if members are to be co-located.

Table 3.Selection criteria for central site

BaseLine Point	Possible Mark	Msasa	Granite	Workingtor	Southerton
Land Availability	30	25	18	16	15
Anchor Members	15	10	8	12	11
Possible symbiosis Relationships	15	9	9.5	12	12
Infrastructure capacity	10	7	7	8	8.5
Access to Market	10	7.5	8	7.5	8
Natural Resource availability	10	7	7	7	7
Labour force	5	3	2	4	5
Industrial resource flow	5	3	3	3	4
Total	**100**	**71.5**	**62.5**	**69.5**	**70.5**

The choosing of the site was based on the principles explained in Fieldbook for the Development of Eco-Industrial Parks (Lowe, Moran, & Holmes, 1996). Section 2.6.3 explains part of the process adopted and the detailed selection is from mentioned source.

Choice on members of the EIP prototype depended on the ability of the company to provide opportunities for symbiotic linkages with other companies and an assumption was made that the companies chosen were willing to participate in the exercise. The criteria included size of the establishment since larger industries tend to be more conscious of their opportunities for economic enhancement through environmental improvement and are more likely to employ a process engineer who will be able to realize the environmental and economic benefits of potential symbiotic relationships. Potential and sufficient tenants for symbiosis to take place were considered an important fact since for the economic realization of the engagement is realized if there is a ready market for the waste or by products and the inverse is true that is the waste/ by product must be readily available. A description of potential participants is given

Lafarge Cement–Currently are using limestone quarry. Process fly ash for the coal power plant can be used in the cement production. The effect is on inputs and the percentage decrease is depended upon the fly ash available.

Chemical and Fertiliser Industry (Zimphosphate)–Currently they are importing chemicals for processing phosphate rock into fertilizer. The possible raw materials can be gas extracted from sewage ponds and waste from beer making processes and tobacco processing industries can work as inputs which might be of benefit as these can effect lower the cost of inputs. The same firm can work as an anchor industry as it can supply wide range of chemicals as different inputs for many processes within the EIP. This can earn a significant amount of income for the company.

ZPC Harare Power Station – This is a coal based power plant. The de-sulphurisation plant removes sulphur dioxide (SO_2) from the flue gas and forms gypsum as a by-product which can be fed to the chemical and fertilizer firm (Zimphosphate). Harare Power Station has reduced its use of water by recycling part of its own wastewater. Waste products of the process are fly ash and bottom ash which can used by the cement plant(Lafarge).

Craster International – This foundry produces slag as its main waste products are slag and access heat from furnace. The heat could be used by the tobacco curing organization in the area like Zimbabwe Leaf Tobacco(ZLT) and British American Tobacco(BAT) in its neighborhood.

Stage One: After choosing the participating members, the possible symbiotic relationships can now be developed based on baseline activities. The stage considers the selected members to identify the anchor that is the industries consuming most of the waste and those producing more waste and their outlines their baseline activities. Cement , chemical and coal power industries were singled out as the major anchors in their respective sites for the EIP framework.

Stage Two: The next stage identifies production practices and recycling opportunities that can provide economic and environmental benefits if implemented independently by each member. For each major player identified

possible methods of limiting the pollution impacts of their production methods are proposed. Since an Eco Industrial Park is a combination of both by product exchange and more eco-friendly production methods it is important to minimize the waste before it can be used by someone else.

Stage Three: The anchor members develop symbiotic relationships with each other. At this stage of development the major players participate though the symbiosis is not intensive, it has not yet spread. The industrial symbiosis between the three anchor industries – cement, chemical and power industries would constitute the major links.

Stage Four: The stage involves addition of new members that are potential players in the already established system. The new members in the model presented are companies that were identified within the four industrial sites and could be potential players of the proposed EIP. In this stage some possible industries may be proposed or arise to deal with abundant available waste/ by-product, the evolved company will come as a consumer to a ready prepared product. The operation of the evolved industry will entirely depend upon the symbiotic relationships. Such companies could be paper, stock-feeds and rubber industries.

Stage Five: It is the final stage in which combined symbiotic and pollution prevention relationships are intensified. The EIP will owe its existence to the anchor industries from which tenants image as a result of the benefits that are realized for being part of the EIP. The participation in the in the symbiosis will present an opportunity to improve economic and environmental efficiency. Figure 4 shows a possible solution for the Eco Industrial Park.

Summary of proposed EIP

Lafarge receives gypsum from Zimphos and fly ash from Harare power station and part of municipal waste for incineration in the kiln, the overall effect is a decrease in percentage of waste disposed in Pomona. Gyproc also use the Gypsum from the Zimphos dumps in manufacturing their plaster boards and this reduces mainly the ground water pollution in Msasa that come as an effect of the gypsum dams. The road construction industry also use the remaining fly ash from Harare Power Station to improve of the road quality as fly ash contributes to the properties of the hardened concrete through hydraulic or pozzolanic activity, or both. Fly ash is used in concrete at levels ranging from 15%-25% by mass of the cementitious material component. The bottom ash from Harare power station maybe utilized by PG industries for the production of bricks, thus all the dominating waste at Harare power station will be dealt with which is estimated at 63tonnes per day. The waste from PG industries brick production department which is brick rubble can be used by Lafarge cement for cement production. Currently the production at Lafarge utilize 9.6% brick rubble for producing and the percentage can be increased to PPC 4%, TFC 4%and MCC 12.5% giving a total of 20.5% which is 348.5tonnes considering a production rate of 1700 tons per day. Lafarge can also get calcium carbonate which is one by product at Star Sugars Africa which is a sugar refinery company. Gold star sugars which recently upgraded their production capacity to 600tonnes per day Calcium carbonate is a waste product from the refinery process. Gold Star Sugars uses 10-20kg of hydrated lime to produce a tonne of sugar and 200- 250kg of hydrated lime to produce a ton of sugar beets.

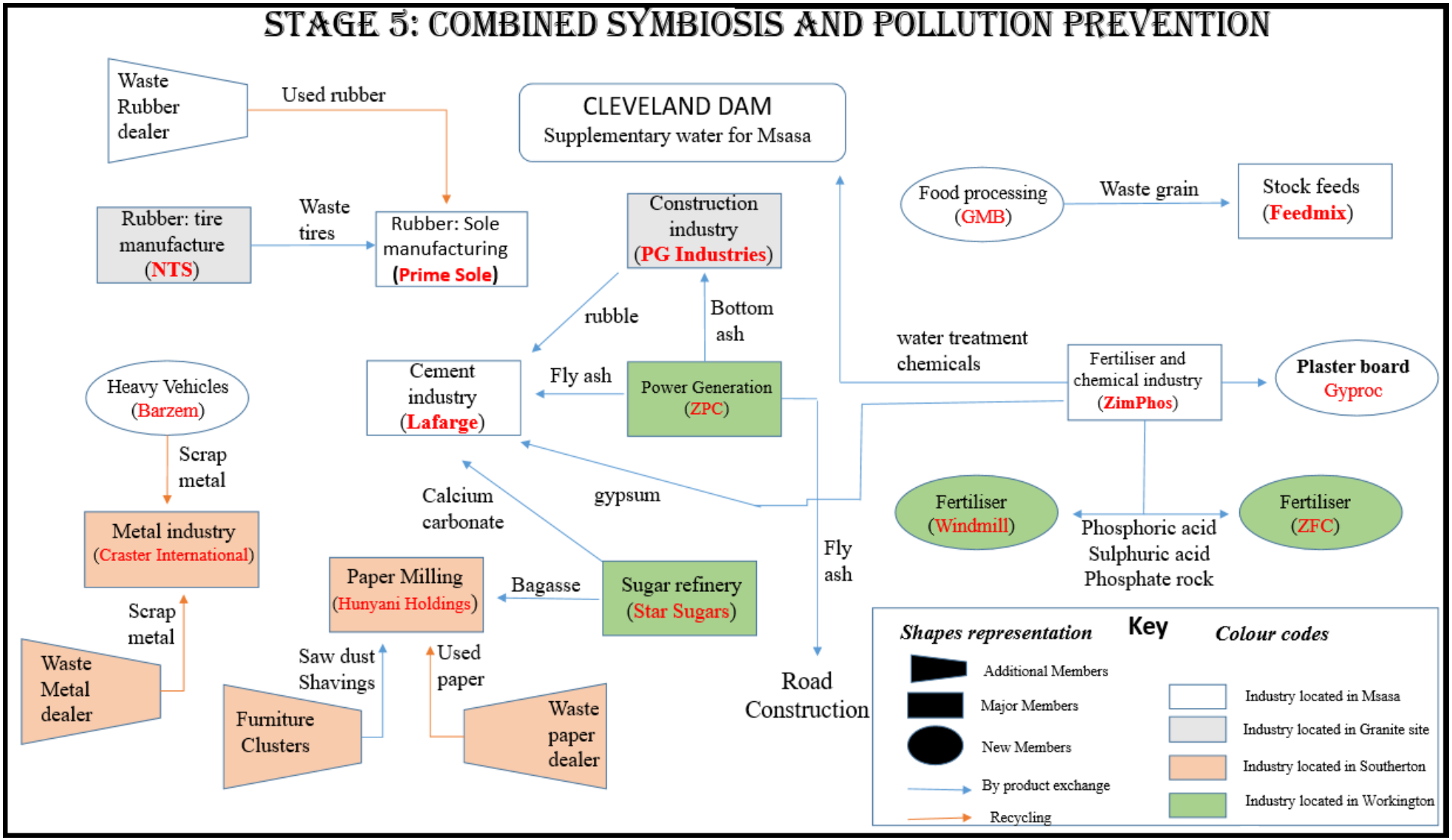

Figure 4. Stage five of the development

6. Recommendations

For successful implementation of the project the government should contribute significantly to the initiation of the project. This can be achieved by introducing laws which govern operations of industry so as to encourage symbiosis among firms. The environmental requirements must be improved and enforced when industrial parks evaluate existing and recruit new companies. This is achievable through review of the environmental management act with respect to industrial operations and with the Environmental Management agency (EMA) acting as the watchdog for the compliancy. Since the initiative of the plan can be capital intensive it is best that the government assist with funding of the program for quick realization of benefits both economically and environmentally. The funding would be directed to infrastructure development and technological improvements that is procurement of new machinery to suit specifically for the EIP.

The Zimbabwe chamber of commerce can spear head the project as it is the government body responsible for industrial development thus by conducting trainings specifically to raise awareness of the benefit of participating in the Eco Industrial Park the importance of building up relationships among firms. The basis of an EIP is by product exchange and since the proposed model for initiation is a virtual park it is recommended that the transportation modes should cheap, smooth and efficient as there is movement of material over a significant distance. The main focus could be put on National Railways of Zimbabwe (NRZ) as the current state has mainly railway lines linking quite a number of firms and industrial sites and provides the cheapest mode of transport.
It is important that the participating members develop the proper technologies specifically to suit the network formulated. The implementation of EIP results in modifications in many operating processes and machinery required, thus necessary adjustments should be made to the technologies used for production in order to realize the benefits of participating in the eco industrial park. Industrial sites should develop administration centers which are mainly responsible for recording and keeping statistical data for operations within the industrial site. Members from companies and interest groups can formulate and finance the centre so as to facilitate any research intended to benefit operations within the site. The centre can also be responsible for contribution to forming and consultation of new symbiosis projects. Harare as a city should improve on its waste segregation techniques. The municipal and industrial waste must be segregated in order for easy implementation of the waste exchange. Companies within the Harare industries should start implementing the use of renewable energy to minimize the consumption of the electricity from non-renewable resources.

7. Conclusion

The research study made an analysis and assessment of Harare industrial sites setup and practices, with the view to develop possible industrial symbiosis connections. This was achieved by carrying out a case study and developing a simple EIP framework prototype model. The approach that was used included developing a methodology for identifying and quantifying potential environmental and economic impacts of the EIP, collected data from existing industries and developed a prototype using the information gathered. The final model presented was a virtual eco industrial park model with Msasa as the central part of the park having Lafarge, Zimphos and Harare power stations acting as the anchors of the park. The overall estimated environmental impact of the final industrial park model was 15-25% decrease of waste deposited in landfills on implementation.

Further work could be done to identify the overall percentage waste decrease of the system. In addition life cycle analysis and material flow assessment can be conducted to give better information and more accurate figures concerning the impact as per product and process respectively.

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Biography

Ignatio Madanhire graduated with a PhD in Engineering Management at the University of Johannesburg, South Africa, he is also a Senior Research Associate. He is also a lecturer with the Department of Mechanical Engineering at the University of Zimbabwe. He has research interests in engineering management and has published works on cleaner production in renowned journals.

Charles Mbohwa is a Professor of Sustainability Engineering and currently Vice Dean Postgraduate Studies, Research and Innovation with the University of Johannesburg, SA. He is a keen researcher with interest in logistics, supply chain management, life cycle assessment and sustainability, operations management, project management and engineering/manufacturing systems management. He is a professional member of Zimbabwe Institution of Engineers(ZIE) and a fellow of American Society of Mechanical Engineers(ASME).