Automated Waste Characterisation and Sorting for Large Institutions through Conceptualisation, Design and Simulation

Sudhir S. Zhuwawu
Department of Mechanical Engineering, University of Zimbabwe, P O Box MP 167, Mount Pleasant, Harare, Zimbabwe
sudhirzhuwawu@gmail.com

Wilson R. Nyemba
Department of Mechanical Engineering, University of Zimbabwe, P O Box MP 167, Mount Pleasant, Harare, Zimbabwe *and*
Department of Quality and Operations Management, University of Johannesburg, Auckland Park Bunting Road Campus, South Africa
nyemba@yahoo.com

Simon Chinguwa
Department of Mechanical Engineering, University of Zimbabwe, P O Box MP 167, Mount Pleasant, Harare, Zimbabwe *and*
Department of Quality and Operations Management, University of Johannesburg, Auckland Park 2006, Auckland Park Campus, South Africa
chinguwa@gmail.com

Abstract

A perennial crisis of growing waste accumulations and natural resource depletion are major challenges for most parts of the world today, of which many have explored recycling as a solution. However, recycling is impeded by the need to sort waste by material types before processing. Additionally, the composition of municipal solid waste is so random such that the processes cost more than the value of recyclables. This research aimed at increasing the quantum of waste recycled, by using waste sorting machines at large institutions such as universities and hospitals. Unlike municipal solid waste, the composition of the waste from such institutions was less random and could be analysed through waste characterisation and sorting. Waste characterisation was conducted for a university and the data directly integrated into the design and subsequent calibration of a customized and automated waste sorting machine. The modular and calibratable machine capable of sorting 200kg of waste per hour was designed, with an estimated cost of USD 5,966.72. The automated design was sound and sustainable, based on the simulation and stress analysis carried out, capable of achieving 12m travel distance per item and at least 85% accuracy in sorting, with Von Misses stresses not exceeding 0.168 MPa.

Keywords
Automation, Custom and Calibratable, Waste Characterisation, Waste Sorting.

1. Introduction

The world generates at least 3.5 million tonnes of plastic and other solid waste a day, 10 times the amount a century ago (Stephen , 2018). With the development of the world and global population growth, waste accumulations have become more prominent and the effects more pronounced. It is anticipated that by 2050, solid waste related emissions will increase to 2.6 billion tonnes of Carbon Dioxide from 1.6 billion tonnes in 2016 (Kaza, et al., 2018). Additionally, the consumption of natural resources is increasing due to the growing global population and increased demand from industries (Subramanian, 2018). As a result, the health of the environment has been deteriorating as observed through climate change and global warming. This trend is expected to continue unless action is taken to prevent, reduce and/or correct these effects. One of the key solutions for dealing with waste accumulations and growing demands for raw materials is to recycle waste. Recycling is emerging as a major tool to tackle climate change and promote sustainable economic growth due to the fact that: less energy is required in the manufacturing of products from recyclable raw materials, fewer materials are incinerated, thus saving further carbon emissions and less waste is sent to landfills meaning a decrease in greenhouse gases released into the atmosphere (Baxi, 2019).

Solid waste contains valuable recyclable materials which can help feed our growing need for raw materials. However, to produce usable material from waste (i.e. recycle), the waste needs to be sorted or separated by material type to capture the required recyclable materials for example, a plastic recycling plant will only require the plastic while an aluminium recycling plant will only require the aluminium cans. If the waste is segregated at collection for example using waste segregation bins, this assists the recycling process. However, in most cases the waste is not segregated at collection meaning that the different materials are mixed, making recycling expensive since it includes "the costs of collecting the waste in tiny, mixed amounts, transporting the waste to a handling facility, sorting, cleaning, repackaging, and then transporting it again, often for great distances" (Leblac , 2018).

Additionally, the municipal composition of solid waste is so random which requires highly complicated waste sorting machines and/or plants which are capital intensive and as a result, only a small amount of waste is recycled. However, large institutions such as universities, hospitals and business parks generate waste that is less random and can be analysed and predicted using waste characterisations. This research was aimed at utilizing the data available from conducting a waste characterisation on one such institution and then use the data to develop a custom and calibratable waste sorting machine. With the large populations at these institutions, the waste being produced is substantial and with the use of a waste sorting machine, the waste can be recycled more readily thereby reducing the amount of waste ending up in dumps, landfills and the environment, in addition to sustainably supplying raw materials made from recyclables to industry.

2. Literature Review

2.1 Mixed Waste vs Segregated Waste

Collected solid waste can be separated or mixed depending on the local regulations. It could be required that the waste be separated at the source for example using waste segregation bins as shown in Figure 1. However, in most cases the waste is collected from the source in a mixed state and then transported to sorting facilities or disposed as is. The degree of source separation impacts the total amount of material recycled and the quality of secondary materials that can be supplied (Kaza, et al., 2018). Recyclables recovered from mixed waste are usually of low quality, for example due to contamination by other materials, reducing marketing possibilities. Ideally, source separation is preferable but it is more complex to implement and results in higher costs which act as a major deterrent.

Figure 1. Waste Segregation Bins in Singapore (Cyrus Tata)

2.2 Waste Characterisation

Waste characterisation means finding out how much paper, glass, organics, etc. are discarded in a waste stream, hence it is synonymous with waste stream analysis. Waste stream analysis can be defined as any programme which involves a logical and systematic approach to obtaining and analyzing data on one or more waste streams or sub streams (Enivornmenta Protection Agency, 1996). This analysis provided an estimate of the solid waste quantity and composition referred to as waste characterisation.

Waste characterisation information helps in planning how to reduce waste, set up recycling programs and conserve money and resources (CalRecycle , 2019). The information from waste characterisation allows for waste management teams to access the effectiveness of their programs and also helps to identify how much recyclable waste is present and in what quantities. Additionally, where custom waste sorting machines are being designed as in the case of this project, waste characterisation allowed for: the selection of necessary components (for example magnetic and eddy current separators where metal content was high), the selection of waste sorting techniques and technologies to use and the sizing of specific sections (for example the size of drums and sieves required to remove small particles).

2.3 Existing Technologies Used in Waste Sorting

There are various methods and technologies employed in the sorting of waste and some of these are (McKinnon, et al, 2017):

1. Trommel – used to sort waste by size through rotating screens.
2. Shredders – used to shred the waste into uniformly sized particles for sorting.
3. Magnetic Separators – used to lift ferrous metals from a stream of waste.
4. Eddy Current Separator – used to remove nonferrous metals by ejecting them off the waste stream.
5. Balers and Compacters – are used to compress sorted waste ready for transport and packaging.
6. Air Separators – used to separate particles with relatively high weight differences. Mainly used in food processing to remove small particles from food items such as sticks and leaves from fruits.

2.4 Emerging Technologies for Waste Sorting

With the advent of the Fourth Industrial Revolution, all areas of society are impacted including waste management. As such, the emerging technologies find their roots in the fourth industrial revolution. The two most prominent technologies are robotics and recognition technology (McKinnon, et al., 2017).

Robotic technology promises to significantly increase the sorting efficiency of some waste streams, and could be particularly valuable in waste streams containing hazardous materials, as it could enable fine sorting without human intervention (McKinnon, et al., 2017). In Japan, at Shitara Kousan plant, they have a fully functioning robotics sorting plant in which a conveyor belt feeds the waste, past a package of sensors including visible spectrum cameras, Near Infrared (NIR) spectroscopic cameras, 3D laser scanners and metal sensors, while robotic arms operate above the conveyor belt, removing materials as the waste moves past underneath (McKinnon, et al., 2017).

Sorting techniques that do not rely on the physical properties of a material for separation require some form of material identification. For example, the use of Radio Frequency Identification (RFID) tags in packaging has been proposed to allow identification and classification of individual packaging items. The concept involves embedding RFID tags in individual packaging items, which could then be read either at collection or at the sorting plant to enable precise sorting of different plastic types (McKinnon, et al., 2017).

Advanced learning algorithms are being developed so that Artificial Intelligence (AI) controlled robotic arms can identify any material despite their appearance. For example, cans can be identified whether they are intact, crushed, shredded, mangled and so on. One such robot equipped with AI is being developed at MIT and is called ROCycle (Colman, 2019).

2.5 Value in Waste

It has been shown that using recycled materials as raw materials results in substantial energy savings which translate to reduced production costs. For example, the amount of energy that can be saved by recycling a tonne of aluminium cans is about 14 000 kilowatts (Environmental Protection Agency, 2017). Recyclable materials can be processed using reduced energy and with minimal damage to the environment. Industries can alter manufacturing processes to reduce the amount of material needed and use recycled materials as inputs (Kaza, et al., 2018). Waste actually contains a number of materials which can be processed (recycled) into new products meaning that the recyclable portion of waste should be and is considered as raw material input. Figure 2 shows the composition of global waste:

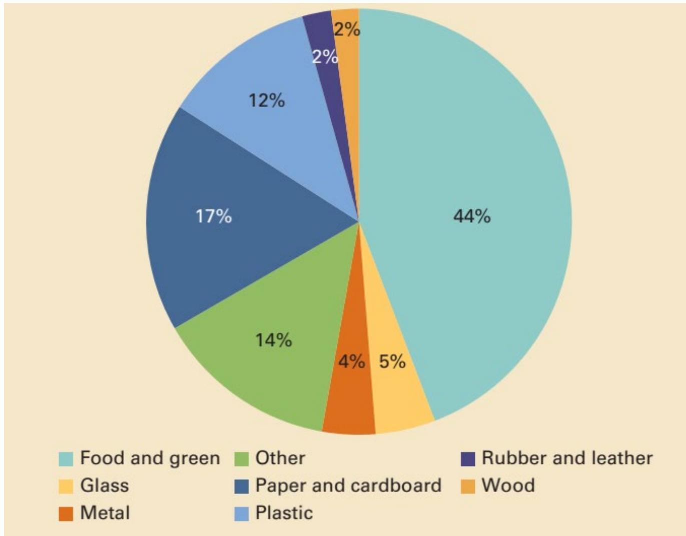


Figure 2. Global Waste Composition (Kaza, et al., 2018)

3. Research Methodology and Case Study

Research was carried out on existing and emerging waste sorting techniques and technologies that are in use, to understand the limitations and applications in specific waste sorting applications. Additionally, the effectiveness and cost to implement these techniques and technologies were analysed. Most of the research was presented in the form of a literature review. In addition to the research carried out, a case study on a case university was conducted. The case university had a population in excess of 18 000 students and an established waste collection system. The waste was collected per Faculty using bins and trailers with the collected waste being deposited at a designated dump on the university campus. At the dump, some recyclables from the waste (mainly plastic bottles of a particular brand) were removed and the rest of the waste (still full of recyclables) was transported to landfills. The dining hall waste was excluded in the analysis as it contained very high percentages of organics. Over a 6-month period, with the university operating normally, a waste characterisation was conducted.

3.1 Waste Characterisation

A waste characterisation was carried out for the case study university over a six-month period with cafeteria and dining hall waste being excluded as it contained very few recyclables. As much information as possible was included in the waste characterisation. This included studying the weight and volume distribution of the different materials in waste streams; the average particle size distribution across the different waste types; the colour and condition of the different types of materials in the waste (for example condition of plastic bottles was rated as intact, moderate damage, substantial damage; empty or not; with cap or not etc.). The data was then averaged on a monthly basis, recorded and presented in a waste characterisation report for the University. Once the machine is implemented, it will be able to automatically generate real-time Waste Characterisations.

3.2 Concept Generation

Based on the data and trends observed in the waste characterisation that was conducted, concepts for a waste sorting machine were generated. After screening rough initial concepts, three concepts were selected for further development. The three concepts share two common components/sections which are a trommel which removes the organics and small particles and a magnetic and eddy current separator which removed the metals.

The first concept (Linear Separator) utilised one unique property of the required material to remove it from each stage of the separation process. Its sorting process was linear (straight line) and took advantage of the unique properties that the required recyclables have to remove them. It used the following properties, size of organics, magnetic properties of metals, the bending strength of plastic bottles and the density and permeability of paper and plastic to automatically identify each material for sorting. Each property was considered in turn to remove the materials that possessed that specific property. Figure 3 shows the Linear Separator.

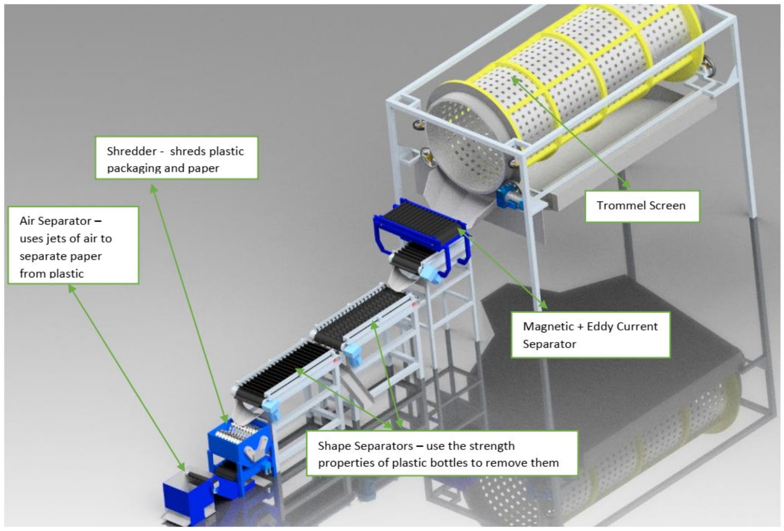


Figure 3. Linear Separator

The second concept (Colour and Density Separator) used the colour and the density to accurately remove recyclables from the waste. After the waste passed through the trommel and the magnetic and eddy current separator, the waste then moved to the colour and density separator. Initially, a colour sensitive laser identified objects of a particular colour (for example red) and triggered a jet of compressed air to remove the object from the stream. At this point the only information known was the colour, the object then landed on a scale which now separated the objects of the same colour by their density. An example of how it worked is as follows: Suppose the waste characterisation revealed that there were mainly 4 materials that were red – plastic bottles, paper, cans and plastic packaging. The cans are removed by the magnetic separator leaving 3 possible red objects – plastic bottles, paper and plastic packing, which all have unique density ranges. These objects will be shot off the waste stream and land on a scale which uses their density ranges to sort them. This process was repeated for different colours, with the entire process being automated. The machine acted like an optical sorter but with cheaper hardware and software. Figure 4 shows the Colour and Density Separator:

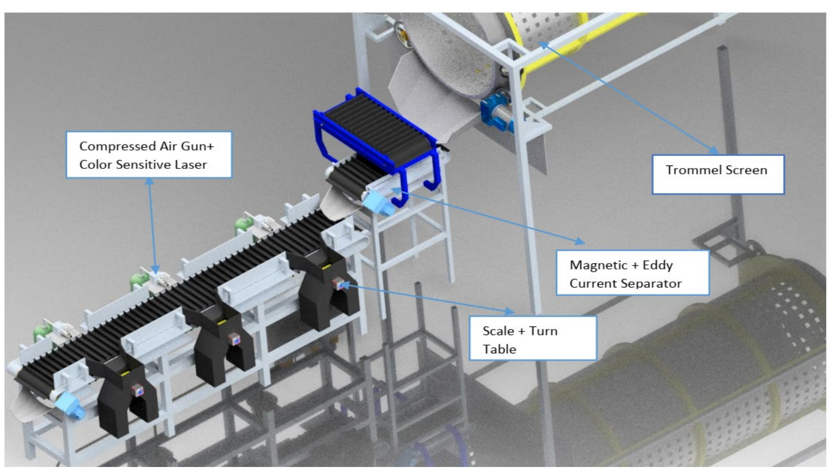


Figure 4. Colour and Density Separator

The third concept used the density and aerodynamic properties of objects in the waste stream to sort them. After passing through the trommel and magnetic and eddy current separator, the waste was fed into the air separator where centrifugal fans blow air upwards creating air flow which lifts objects in the waste and then directional fans blow the objects into collection chambers positioned above the conveyor belt. If the materials passing over a fan are of the right density, they will be blown upwards and collected in the chambers above. This concept was inspired by the machines found in the food industry that are used to blow away unwanted particles from the produce being processed such as sticks, small stones and leaves being blown away from tomatoes or tobacco in a processing plant. But unlike these air separators, much stronger air flow was created to lift larger objects within a pre-calibrated density range, first upwards then sideways into collection chambers. The entire process is continuous and can be fully automated with real-time waste characterisations being generated. Figure 5 shows the Air Separator:

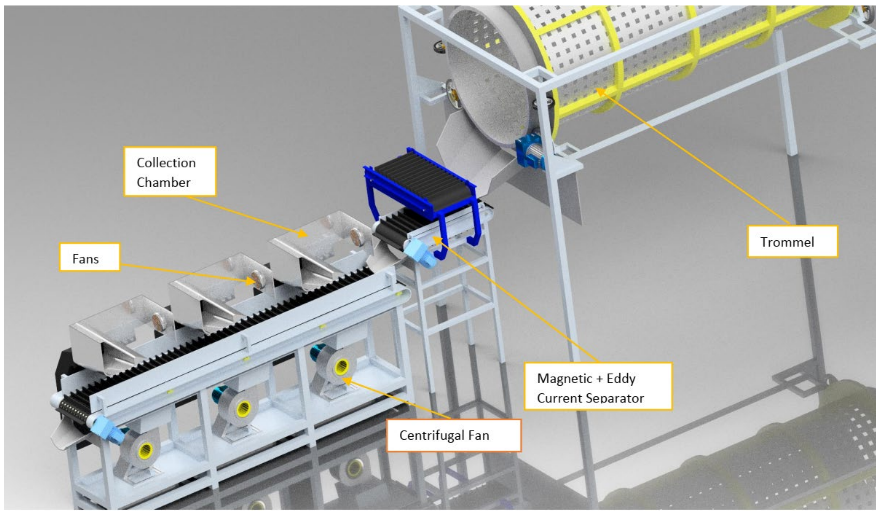


Figure 5. Air Separator

3.3 Concept Selection

Based on the project objectives, research data and waste characterisation, multiple rough concepts were generated. Three concepts were then selected for further development using Concept Screening. During the concept screening, the rough initial concepts were evaluated using a screening matrix. The selection criteria were made up of key factors that affected manufacture, performance, cost, maintenance and reliability among other factors. The resulting concepts after screening were: a linear separator, a colour and density separator and an air separator, which were developed in greater detail. The three concepts were then compared using a Concept Scoring Matrix as shown in Table 1 and based on the critical criteria derived from the end user needs, performance, cost, manufacturability, ease of maintenance, operational costs and maintainability, the Air Separator Concept was chosen as the optimal concept.

Table 1. Concept Scoring Matrix

Criteria	Weight	Concept 1 (Linear Separator)	Concept 2 (Colour and Density Separator)	Concept 3 (Air Separator)
Quality of Sorting	0.2	2	4	4
Maintainability	0.15	3	2	3
Durability	0.15	3	3	4
Power Consumption	0.1	3	3	2
Maximum Sorting Speed	0.2	4	2	3
Ease of Calibration	0.1	0	1	4
Modularity	0.1	1	5	5
Total	1.0	2.5	2.85	3.55
RANK*		3	2	1

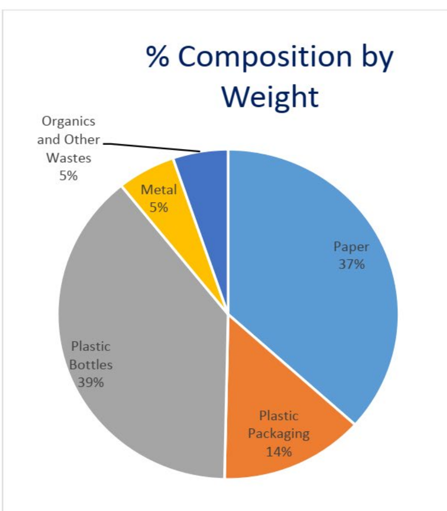
4. Results and Development of Optimal Solution

4.1 Waste Characterisation

The waste characterisation conducted showed that the waste being produced at the university was not random but showed definite and observable trends allowing for extrapolation and prediction of future waste from the current waste. The waste was found to contain a high percentage of recyclables and the physical condition, colour, size and weight were noted. The average composition of the waste by weight that was observed is shown in Table 2 and Figure 6, with the exclusion of waste from the dining and cafeteria.

Table 2. Waste Characterisation Analysis on Composition by Weight and Volume

Type of Waste	**% Composition by Weight**				**% Composition by Volume**			
	Sample 1 (Nov 2019)	Sample 2 (Dec 2019)	Sample 3 (Feb 2020)	Sample 4 (Mar 2020)	Sample 1 (Nov 2019)	Sample 2 (Dec 2019)	Sample 3 (Feb 2020)	Sample 4 (Mar 2020)
Paper	47.2 %	44.6 %	40.4 %	18.9 %	46.3 %	49.3 %	32.4 %	21.3 %
Plastic Packaging	13.6 %	9.7 %	17.9 %	15.1 %	33.3 %	26.8 %	42.3 %	42.6 %
Plastic Bottles	31.9 %	35.9 %	42.1 %	50.4 %	11.1 %	14.1 %	14.1 %	20.2 %
Metal	3.5 %	4.8 %	5.6 %	8.8 %	1.9 %	2.8 %	2.8 %	5.3 %
Organics and Other Waste	3.8 %	5.1 %	6.0 %	6.6 %	7.4 %	7.0 %	8.5 %	10.6 %



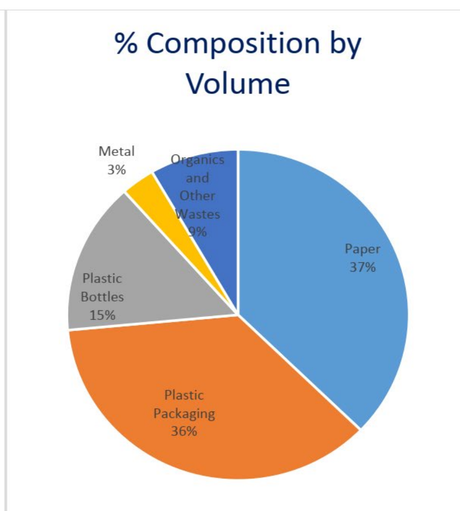


Figure 6. Average Composition by Weight and Volume for the University

Colour trends were noted, with the different types of waste observed to have different colour distributions. Additionally, the physical condition of the objects in the waste were noted and the findings recorded. An important note on the physical condition of the waste is that the objects in the waste **were not compressed** at collection and at the dump hence they retained the state they were in when thrown away i.e. *bottles found to be mostly intact and empty; paper was found to be mostly in a crumpled state; plastic packaging was found to be empty whilst cans were mostly crushed.* In addition, there was little to no soiling of the objects in the waste. All of this data was collected and compiled into a detailed waste characterisation unlike is commonly seen so that the data could be used in the design phase, which required as much information as possible about the waste.

4.2 Waste Sorting Machine Design

The final design was a fully calibratable, custom and modular waste sorting machine that consisted of three distinct sections: a trommel to remove organics, a magnetic and eddy current separator to remove metals and an air separator to sort the remaining waste. The trommel was designed based on object size distribution from the waste characterisation. Magnetic field theory was used to design and size the magnetic and eddy current separator based on the data regarding metals in the waste stream from the waste characterisation. Computational Fluid Dynamics was used to design the air separator to sort waste using the density and aerodynamic properties. Finally, Finite Element Analysis was used to test the machine for stability under expected direct loads, overloads and vibrational loads, that were expected to occur during normal operation of the machine. All components were designed and selected based on a Factor of Safety of 2. The machine was modular, capable of multiple similar sections connected based on the requirements for example new trends in waste may see an increase in electronic waste which can be profiled and the data used to calibrate the air separator to collect this waste. The entire process is automated except for the initial loading and the machine can be configured to automatically generate waste characterisations.

4.3 Simulation Results

The design was tested and simulated on a model developed using Inventor Professional software. The parameters for the simulations were based on the waste characterisation, material properties, expected operating conditions, existing physical constraints in the system and component specifications. The simulations were carried out to definitively demonstrate how the machine operated (i.e. how the waste was sorted), the accuracy of the sorting process and how the machine responded to stresses and vibrations during operation. Upon completion of the detailed design of the optimal solution, the design was tested using Finite Element Analysis and simulated using Inventor 2019. The results showed that the design was stable under the expected loading and operating conditions, with Von Misses stress not exceeding 0.168 MPa. Additionally, the design was found to be efficient with the maximum travel distance of sorted waste being 12m thus minimizing the processing time and costs. The simulations also predicted a minimum sorting accuracy of 85% which took into account any deviations from the waste characterisation. The waste types were colour coded as shown in Figure 7. The simulations for the trommel, magnetic and eddy current separator and air separator are shown in Figures 8, 9 and 10.

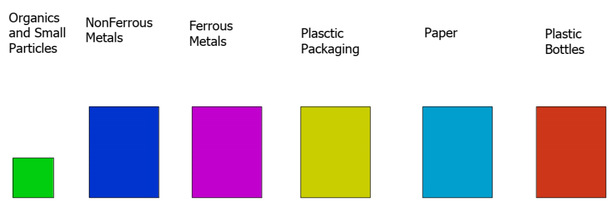


Figure 7. Simulation Key

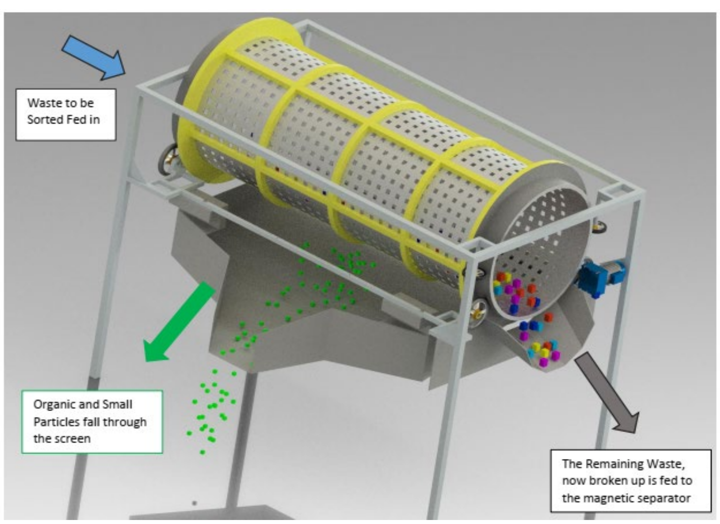


Figure 8. Trommel Simulation

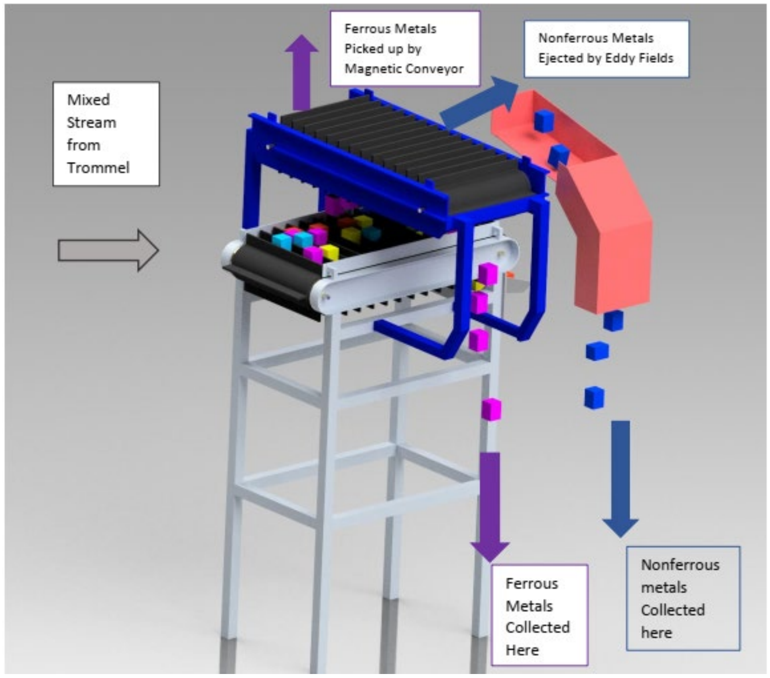


Figure 9. Magnetic and Eddy Current Separator Simulation

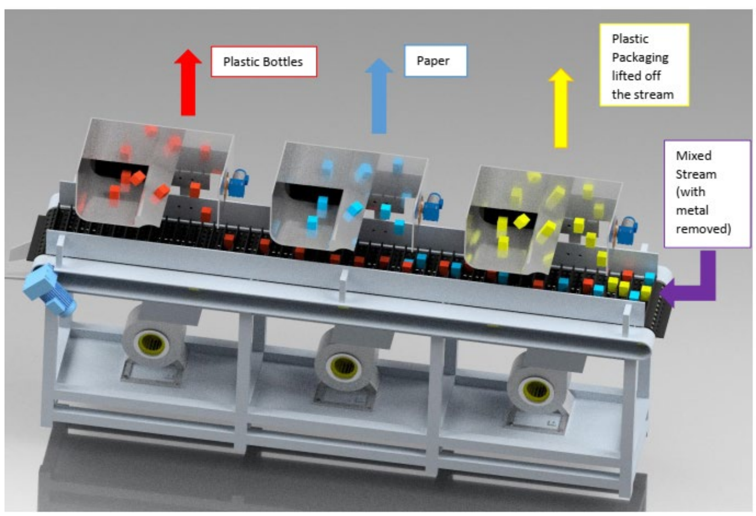


Figure 10. Air Separator Simulation

5. Design Costing

The total cost of production for the waste sorting machine was based on the materials costs, manufacturing cost, pre-made component costs, expected maintenance costs and amortization and/or depreciation cost of the machine over its working life. The costs were calculated as per current international and local prices and are presented using the US dollar currency (USD). Table 3 shows the summarized costs and including a description breaking down each cost.

Table 3. Design Costing

COST	DESCRIPTION	TOTAL (USD)
Material Costs	The material costs presented are only for those components that are unique to the machine and will be made from raw material (such as sheet steel). Examples of such components are the frames, funnels, ducts etc.	3,077.49
Manufacturing Costs	the manufacturing costs required to transform the materials into the required components were calculated based on: the manufacturing method and material workability. This cost is includes the labour and manufacturing overheads.	729.50
Pre-made Components	These are components that will be purchased from manufacturers based on the requirements of the machine that were calculated. The costs were based on supplier catalogues and include the shipping costs for components not available locally	1,232.00
Maintenance Costs per Annum	The maintenance costs were calculated assuming a Preventive Maintenance (PM) scheme which should maximize the life of the machine which in turn will reduce its straight line depreciation	266.00
Annual Depreciation Costs	A straight line depreciation was used to represent how the machine will depreciate over its life. It is to be noted that much of the depreciation can be negated through maintenance with the maintenance costs being lower than the depreciation.	661.73
GRAND TOTAL		5,966.72

6. Discussion and Recommendations

After the testing and simulation of the machine, the research should have progressed to the prototyping phase. However, suspension of normal activities due to the COVID-19 pandemic restricted access to the resources needed to produce a prototype. As a result, the design of the waste sorting machine could not be physically tested. Hence the simulations had to be stepped up, completely replacing the physical prototype with a digital version of the machine to demonstrate how the machine worked. The results of the simulations were promising and showed that the machine worked as intended.

After the simulation of the machine, it was observed that the machine itself could be equipped with data loggers to produce real-time and highly accurate waste characterisations. Additionally, the calibration of the machine could be continuously adjusted using a simple learning algorithm that uses data collected after each cycle to automatically adjust the calibration for the next sorting cycle. However, large bottles and card boxes cannot be fed into the machine, therefore, to increase the range of materials that can be sorted, it was recommended that a shredder could added in a pre-sorting phase to break large objects into manageable sizes for sorting.

7. Conclusion

This project has revealed the role that waste characterisation at large institutions (such as universities, hospitals and business parks) can play in encouraging recycling through use of waste sorting machines designed to make use of this data. The waste sorting machine that was designed can be calibrated to sort new types of waste and respond to trends in the waste stream. Additionally, once in use, the machine can automatically provide accurate waste characterisation meaning institutions can observe the effectiveness of any waste management plans they have in place and identify any trends in their waste streams. The total cost of the machine was calculated to be USD 5,966.72, based on the current market and labour prices both locally and internationally. Though no prototype of the machine was produced, detailed simulations were carried to demonstrate the functioning of the machine.

Recycling can play a major role in dealing with environmental problems and reducing natural resource shortages. Using waste sorting machines at large institutions (such as universities) can greatly increase the amount of waste being recycled. The physical state of the waste being produced at these institutions allows for relatively simple waste sorting techniques to be used which cannot be used with municipal solid waste, allowing for simpler waste sorting machine design. The waste sorting machine is anticipated to reduce/eliminate the transportation of recyclables to dumps, and instead recyclables can be sorted from the mixed waste by the machine and then transported or sold to recycling centres. As a result, large institutions can play an active role in reducing the amount of waste going to landfills and increasing the amount of waste being recycled. Incorporation of the Internet of Things and Big Data can go a long way in encouraging the adoption of this waste sorting machine on a large scale by making real-time analysis easily available.

Acknowledgements

The project "Automated Waste Characterisation and Sorting for Large Institutions through Conceptualisation, Design and Simulation" has received funding for registration in the conference from the Royal Academy of Engineering through the Higher Education Partnerships for Sub Saharan Africa (HEP SSA).

References

Baxi, R., Why championing recycling can help to combat climate change, Combat Climate Change, Available: https://www.openaccessgovernment.org/combat-climate-change/66087/, Accessed: 15 December 2019, 2019.

CalRecycle, What is Waste Characterisation? Available: https://www2.calrecycle.ca.gov/WasteCharacterisation/General, Accessed 12 December 2019, 2019.

Colman, J., ROCycle is the eco robot taking recycling up a gear, Available: https://www.redbull.com/int-en/mit-rocycle-recycling-robot, Accessed: 26 August 2020, 2019.

Environmental Protection Agency, *Municipal Waste Characterisation,* Wexford, Ireland: Environmental Protection Agency, 1996.

Environmental Protection Agency, *Waste Reduction Model*, Available: https://www.epa.gov/warm/documentation-waste-reduction-model-warm, Accessed: 10 December 2019, 2017.

European Parliament, *Understanding waste streams: Treatment of specific waste*, Available: http://www.europarl.europa.eu/EPRS/EPRS-Briefing-564398-Understanding-waste-streams-FINAL.pdf, Accessed: 12 December 2019, 2015.

Kaza, S., Yao, L., Bhada-Tata, P. and Woerden, F. V., *What a Waste 2.0*, *A Global Snapshot of Solid Waste Management to 2050*, Washington: The World Bank, 2018.

Leblac, R., What is Wrong? *The Problems for Recycling*, Available: https://www.thebalancesmb.com/almost-everything-about-recycling-is-wrong-2878020, 2018.

McKinnon, D., Fazakerley, J. & Hultermans, R., *Waste sorting plants - extracting value from waste*. Vienna: International Solid Waste Associatuion, 2017.

Stephen, L., Planet or Plastic? *National Geographic*, Available: https://www.nationalgeographic.com/news/2018/05/zero-waste-families-plastic-culture/, Acessed 10 December 2019.

Subramanian, K. R., The Crisis of Consumption of Natural Resources, *International Journal of Recent Innovations in Academic Research*, Vol. 2, No. 4, pp. 8-19, 2018.

Biographies

Sudhir S Zhuwawu just completed a BSc Honours degree in Mechanical Engineering at the University of Zimbabwe. He has a keen interest in robotics where he plans to start a career. His research interests include robotics, simulation and modelling of engineering systems, environmental waste management, machine learning, artificial intelligence and human-machine interface design.

Wilson R. Nyemba is a Senior Lecturer in Mechanical Engineering at the University of Zimbabwe with over 30 years of experience both in industry and academia. He designed and developed a wide range of engineering products in different capacities in industry from product development to engineering management. He also formulated and led a number of successful ventures at the University of Zimbabwe where he served as Dean of Engineering as well as Chairman of WaterNet and Project Manager for the Royal Academy of Engineering projects for enhancing practical skills for engineering academics in Southern Africa. Wilson holds a BSc Honours degree in Mechanical Engineering from the University of Zimbabwe, an MSc degree in Advanced Mechanical Engineering from the University of Warwick in England through the Overseas Development Authority Scholarship and a Doctor of Engineering degree in Mechanical Engineering from the University of Johannesburg in South Africa where he was funded through the National Research Foundation (NRF), Research and Innovation Scholarship. He is also currently appointed as a Senior Research Associate in the Department of Quality Assurance and Operations Management at the University of Johannesburg. He has received awards and recognition for outstanding research papers at conferences such as the World Congress on Engineering in London in 2016, Industrial Engineering and Operations

Management in Bristol, UK in 2017 and Global Conference for Sustainable Manufacturing in Kentucky, USA in 2018.

Simon Chinguwa is currently a Lecturer in the Department of Mechanical Engineering at the University of Zimbabwe where he lectures in Thermodynamics and Solid Mechanics. He has over 28 years of engineering experience both in academia and industry. He holds a Bachelor of Engineering Honors degree in Industrial and Manufacturing Engineering from the National University of Science and Technology and an MSc degree in Manufacturing Systems and Operations Management from the University of Zimbabwe. His main areas of research and teaching are in Solid Mechanics, Thermodynamics and Total Quality Management. He is also currently registered as a Doctoral student at the University of Johannesburg in South Africa, pursuing research in energy efficiency in industrial machines. He has published many articles in refereed journals in the area of waste management, energy conservation and generation including internal combustion engines.