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# THE USE OF ARTIFICIAL INTELLIGENCE IN WASTE MANAGEMENT

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**Abstract—**Throughout this paper, we will describe the billions of tons of annual solid waste that are generated globally, along with the problem this poses. In addition, we will discuss the technological innovation that is deep learning using artificial intelligence. We will then discuss the potential uses of AI in the solid waste management industry as an opportunity to remove the human element from waste sorting and streamline the process. This paper will explore the usage of artificial intelligence-based sensor technology regarding waste management as an effective and sustainable means of sorting waste and reducing pollution, and its applications in effective recycling. We will examine how this technology can be efficiently implemented in a variety of differing cultures and environments, such as the United States, the United Kingdom, and Japan. Additionally, we will provide an objective analysis of this technology's environmental, social, and economic value, based on factors such as sustainability, accessibility, and costs.

**Key Words**— Artificial intelligence, Pollution control, Sensor systems, Waste management, Waste reduction

## AI-STREAMLINED WASTE MANAGEMENT: AN INTRODUCTION

Of the greenhouse gases that contribute to global warming, an estimated 25% originate from the decomposition of waste sitting in landfills [1]. Within that quantity of waste lies a significant portion of misidentified recyclable materials, as well as non-recyclable waste contaminated by organic materials that could potentially be converted into renewable energy. The issue in extracting these materials lies in the manual sorting and filtration of solid waste, a laborious process requiring direct human interaction.

The urgency of waste classification becomes apparent when examining the environmental repercussions of inadequate recycling. According to the U.S. Plastics Pact, a meager fraction—less than 10%—of plastics are recycled in the United States alone, contributing to improper disposal practices that contaminate surrounding waste streams, including organic waste and rubber [2]. This underscores the imperative for a robust waste sorting process to ensure the application of appropriate recycling methods and mitigate the environmental impact of improper waste disposal.

## SOLID WASTE AND THE IMPORTANCE OF THE SOLID WASTE MANAGEMENT PROCESS

Prior to discussing the technological innovation of streamlining waste management with artificial intelligence, the foundation of the solid waste management process (SWM) shall be explored. This is in order to have an understanding of what waste really is, how it is currently being handled, and why proper handling is important.

### Defining Waste

When using the term "waste," there are several different types that can be considered. These include solid, liquid, or gaseous waste, [3] and in this paper we will focus on solid waste materials. These materials are defined as "any variety of solid materials… which are discarded or rejected as being spent, useless, worthless, or in excess" [4]. Further, these materials are categorized by their ability to be fit for land disposal and are either degradable or non-degradable [3].

It's also important to note that there are several different sources of solid waste and ways that it can be produced. In general, these can be described by the following categories: residential, commercial, institutional, industrial, and more [4]. All of these sources can produce types of waste that are all drastically different from one another such as food, paper, tin cans, glass, wood, and even hazardous waste products, as well as many others [4]. These distinctions are important since each of the above materials has incredibly different processes for proper disposal, though they often are lumped together as one pile which is titled “garbage” and end up in the same locations regardless.

## Defining Solid Waste Management

Solid waste management (SWM) refers to the organized process by which solid waste is handled, generally in a way that does not cause harm to humans or the natural environment [5]. There is no concrete or “one size fits all” process to speak of here, as the SWM process can differ from country-to-country, state-to-state, or even city-to-city. However, SWM generally consists of six different stages: identification, handling, collection, transport, processing, and disposal [5]; and every step has its own purpose and importance for the sake of sustainably managing waste. For the purposes of this paper, we will primarily be considering waste management at the “Processing” stage, as this stage is where items are identified and subsequently sorted into proper containers for disposal or reuse.

## SWM at the Processing Stage

The processing stage of waste management comes after the waste has been collected and transported to a transfer station. Essentially, the processing stage of SWM is where different pieces of waste are sorted into their respective categories for proper disposal, or reuse or recycling. This stage is very critical to sustainably managing waste. As previously mentioned, many different types of waste have their own processes for proper waste management. For example, many types of plastics and other materials like glass should be recycled, while some materials like paper, wood, or other natural materials that are considered biodegradable should be decomposed or composted to reduce volume of waste or to reuse it as fertilizer. Note that the phrase “should be” is used to describe the way in which these products are generally handled so as to maximize sustainability and/or efficiency. In sum, the processing stage can effectively be described as the sortation of different kinds of materials so they can be properly disposed of use for another purpose. This is important to know for the purposes of the technology that will be described in a later section of this paper.

## Why Waste Management Matters

According to estimates from the United Nations, about 1.3 billion metric tons (about 2.9 trillion pounds) of solid waste were collected annually in 2013. This number was expected to rise to 2.2 billion metric tons (about 4.8 trillion pounds) by next year, 2025 [6]. Data from the World Bank supports this claim, since in the year 2020, their data suggests that the number was over 2.01 billion metric tons, and they estimate that that number could reach over 3.4 metric tons by 2050 [7]. These are staggeringly large numbers, and, for some intuition on what 2.2 billion metric tons means, considering a blue whale, which is the largest mammal that has ever existed on planet Earth, weighs 300,000 pounds, this over 16,000,000 blue whales’ worth of solid waste produced by humans every single year.

There are many reasons why managing waste is an important endeavor. On the personal level, managing waste is important to individual homes or businesses since they can generate a lot of waste, and need somewhere reliable to put it. For example, in an average household, about 3.5 pounds per capita per day are generated [4]. This is only one of the many sources that can generate waste on a daily basis. Figure 1 gives some more insight into what kind of sources produce waste and how much. From Figure 1, we can see that there are many different sources of sources of waste that produce a considerable amount of waste per unit per day. It must also be noted that Figure 1 is by no means a comprehensive list of solid waste sources.

| Source of Waste | Unit | lb/unit · day |
|---|---|---|
| Municipal | Capita | 4.0 |
| Household | Capita | 3.5 |
| Apartment building | Capita per sleeping room | 4.0 |
| Seasonal home | Capita | 2.5 |
| Resort | Capita | 3.5 |
| Camp | Capita | 1.5 |
| School | | |
| With cafeteria | Capita | 1.0 |
| Without cafeteria | Capita | 0.5 |
| University | Student | 0.86 to 1.0 |
| Institution, general | Bed | 2.5 |
| Hospital | Bed | 12–15 |
| | Occupied bed and 3.7 if staff added | 9.5 |
| Nurses’ or interns’ home | Bed | 3.0 |
| Home for aged | Bed | 3.0 |
| Rest home | Bed | 3.0 |
| Nursing home, retirement | Bed | 5.0 |
| Infectious waste | | |
| Hospital | Bed | 4.0 |
| Residential health care facility | Bed | 0.5 |
| Diagnostic and treatment center | Patient per week | 0–6.5 |
| Hotel | | |
| First class | Room | 3.0 |
| Medium class | Room | 1.5 |
| Motels | Room | 2.0 |
| Day use facility, resort | Capita | 0.5 |
| Trailer camp | trailer | 6–10 |
| Commercial building, office | 100 $ft^2$ | 1.0 |
| Office building | Worker | 1.5 |
| Department store | 100 $ft^2$ | 40 |
| Shopping center | Survey required | Survey required |
| Supermarket | 100 $ft^2$ | 9.0 |
| Supermarket | Person | 2.4 |
| Restaurant | Meal | 2.0 |
| Cafeteria | Capita | 1 |
| Fast food | Capita | 0.5 |
| Drugstore | 100 $ft^2$ | 5.0 |

**Figure 1 [4]**

**Examples of sources of solid waste and how much they produce on average.**

However, there is more to why we should care about managing waste. Improper waste disposal can lead to many issues in the natural environment and for surrounding people and animals. Without proper disposal systems, waste can be found filling both the natural and built environment, such as in drainage systems, shrubbery, and rivers [5]. On top of this, the degradation of these wastes can cause the spread of bacteria and diseases through water sources, resulting in poor public health in both the short and long term [5]. Improperly managed waste has impacts on more than just local environments. This waste very often ends up in, and contaminates, the oceans of the world [7].

Thus, it is evident to see that, if left unmanaged, waste could become a serious problem in the future that has consequences on the planet and those inhabiting it. With growing amounts of waste produced every year, the need for reliable systems to manage waste will be ever more abundant.

### Integrating Artificial Intelligence into the Solid Waste Management Industry

With the advent of new artificial intelligence technology, it is possible for this human component to be substituted with digital systems that use sensors to categorize and filtrate waste, streamlining the process.

Artificial intelligence "understands" data by drawing comparisons between a given input and a vast database of "training data," sample inputs with assigned meanings from which the program can assign a conclusion. This data can take various forms, such as text, video, or audio, provided the system's training data matches it. Based on this principle, artificial intelligence can understand digital video through processing, detecting, and recognizing objects based on example data and training, and then classifying the images based on what it recognizes. After this, the data can be sent to an AI workflow to streamline this process. According to researchers at NC State University, "While it takes a lot of data to train such a system, it can start producing results almost immediately. There isn't much need for human interaction once the algorithms are in place and functioning" [1]. This shows that with sufficient training data, artificial intelligence can detect, categorize, and comprehend virtually any image.

Once the computer identifies an object, it can decide what to do with it. In a waste management setting, the computer can classify the presented item into a specific type of waste, and the item is then sorted as recycling, organic, general waste, or another type of waste. This process allows for the proper disposal of materials with special disposal needs, such as batteries, different types of plastics or metals, electronic components, and more.

## AN OVERVIEW OF ARTIFICIAL INTELLIGENCE

Recent times have shown a drastic uptake in the amount of artificial intelligence (AI) applications [8]. In recent years, AI has been very prevalent and accessible to the general public due to the rise in technological advancements [8]. Some popular examples of AI would be ChatGPT, Google Gemini, and Apple's Siri, along with many others. However, AI has been around for a considerable time, and has applications and uses in numerous fields of study. AI has commonly been used in the medical field, banking, marketing, entertainment [8], and so much more due to its incredible thinking and working speed.

### Why AI?

The reason for the dependence on AI is evident when you consider that AI is essentially combining the speed and precision that is brought along by computers, with the ability to think and use previous knowledge that makes humans such dominant creatures [9]. Previously, computer technology was limited by its almost "straightforward" approach; this is when humans take a problem and break it into smaller pieces, and address each of those pieces to arrive at a solution [9]. This approach would require people to have a specific problem in mind, then design programs that work to solve said problem. The use of artificial intelligence has changed the way this works, making it much more reliable for solving different kinds of problems.

One of the most common types of artificial intelligence, known as deep learning, is a prime example of this [9]. In deep learning applications, the computer is essentially "taught" by taking information from huge databases and using it as a reference when solving problems. According to Amazon Web Services, "Deep learning is a method in artificial intelligence (AI) that teaches computers to process data in a way that is inspired by the human brain. Deep learning models can recognize complex patterns in pictures, text, sounds, and other data to produce accurate insights and predictions." [10] This is similar to how people use their past experiences and information gained from said experiences to gain further insight into a problem, or to come up with a solution. In professional settings, it is often seen that "experts make rapid, often intuitive, diagnoses by beginning with a few hypotheses selected by experience, followed by clinical or laboratory observations that further refine the differential diagnosis" [11]. Thus, experience and prior information play a huge role in being able to address problems quickly and accurately, which are then backed by further research and testing. This is why the use of artificial intelligence is so powerful and has become so widespread so quickly.

An example of how powerful this type of technology can be is seen in OpenAI's ChatGPT. ChatGPT uses this exact type of deep learning technique to solve most any type of problem. According to their own website, "We build our generative models using a technology called deep learning, which leverages large amounts of data to train an AI system to perform a task" [12]. Also, according to their website, these tasks can include quizzing people on vocabulary, explaining code, building budgets, planning trips, explaining tough concepts to kindergarteners, along with so much more [12]. Truly, it seems that this type of technology can be used for most any task.

**The Fine Details of Deep Learning**

Deep learning is a truly fascinating feat and is often categorized as a subsection of what is known as machine learning [9]. Deep learning, in general, is a method which attempts to mimic the human brain to "learn" different concepts that can then be applied to solve specific problems [11]. The way the machine learns is in one of several fashions: supervised, unsupervised, semi-supervised, and reinforcement [9]. In general, the vast majority of AI systems are trained using the supervised method, in which it is given an input, as well as the correct output, and changes its procedures based on its computed expected output, and the real output [9]. Additionally, this is the type of training that will be focused on for the remainder of
this paper, as it relates to how the technology works described herein.

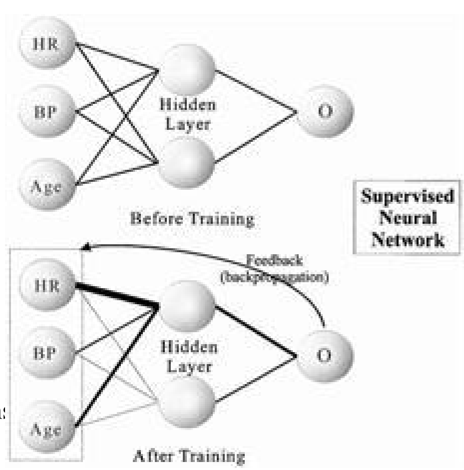


**Figure 2 [11]**
**General representation of a neural network**

At the core of deep learning is the neural network, which is often considered as a collection of "neurons" or "nodes" which receive different inputs and return different outputs [9]. An example of a representation of a neural network can be seen in Figure 2. Neural networks are comprised of at least one input at the input layer, followed by one or several layers known as the "hidden layers" which are primarily responsible for the math behind the output. Lastly comes the output layer, which usually consists of one node – i.e., the output of the system. Between each of the nodes are a series of connections which each carry a specific "weight" value. These weights take the input and transform it, hopefully to the desired output; initially, the weights are often set arbitrarily. Over time and through training, these weights are refined so as to give a value that is closer to the desired output.

We can see from Figure 2 that this particular neural network takes in three different inputs at the input layer, has one hidden layer with two nodes, and one output node at the output layer. Prior to training, the nodes are not very refined; they all appear to be to about the same width, though this is not necessarily always the case, and are often almost random.

During the training process, the neural network is given input from a large database – the larger the better, as more data results in more refined weight values, and thus more accurate output. The neural network then takes information from one of these data and applies transformations using the weight values at the hidden layer or layers. Any output from a previous layer is taken as the input at the next layer in a process called "forward propagation". As the data travels through the layers, it is transformed more and more until it reaches a completely new value or piece of information. Finally, this result is output. Since the weight values are initially unrefined, the output is not expected to be similar to the true value. Thus, the computer's output data is compared to the true data to see how accurate it was. This comparison is then taken into account in the next cycle of training and is used to refine the weight values in the network in a process known as "backpropagation".

Referring to Figure 2 once again, this process is hinted at. After the training process, we can see that the connections between the nodes have different widths than they started with, and different widths than each other. This suggests a change in the weight value of each of these connections throughout the training as a result of backpropagation, which the figure also suggests.

The final stage of the deep learning process is essentially a “fact-checking” or “testing” stage, in which the effectiveness of the network is tested. In this stage, the neural network is tested on sample data separate from the training data. The neural network’s output is evaluated based on the true output. Essentially, this stage is no different from the rest of the training stage, except the neural network is expected to be fully trained, and capable of handling the input to achieve a desired output.

### Deep Learning: Summary

Stated in plain words, deep learning is an iterative process which uses data to “teach” an AI to perform specific tasks. When the AI has been trained enough, it is expected to be able to give desired outputs based on any number of inputs. Deep learning is a truly fascinating process which pulls inspiration from the human brain and applies it to a computer. Since computers are capable of running computations at speed thousands of times faster than a human, deep learning is the intersection of what makes both humans and computers so powerful. As such, it’s no wonder that humans have begun to rely so heavily on AI.

## AMP ROBOTICS - REVOLUTIONIZING WASTE MANAGEMENT

In the realm of solid waste management, the integration of artificial intelligence (AI) stands out as a transformative force, with one compelling example being the implementation of AMP AI, an artificial intelligence platform specifically built by AMP Robotics. This advanced technology not only addresses the perennial challenges of waste sorting but also empowers leaders in the waste and recycling sector to streamline operations for maximum efficiency. The multifaceted benefits of AMP AI encompass substantial cost reductions, heightened resource recovery, and enhanced operational reliability, positioning it as a permanent solution to the complex dynamics of waste management.

At the core of AMP AI's effectiveness is its nuanced approach to collecting and sorting various types of materials. The AI-powered automation embedded in AMP AI enables real-time material characterization, allowing for precise configuration to capture the most relevant materials from a given ‘material stream.’ According to their own website, “AMP Neuron encompasses the largest known real-world dataset of recyclable materials for machine learning, with the ability to classify more than 100 different categories and characteristics of recyclables across single-stream recycling, e-scrap and construction and demolition debris” [13]. The importance of such precision cannot be overstated, given that each type of solid waste exhibits distinct properties requiring specific recycling technologies. For instance, organic waste necessitates a dedicated composting process, while plastics and metals may demand higher-level chemical procedures for proper disposal. Thankfully, “the AI platform that guides AMP’s robotic sorting systems can differentiate objects found in the waste stream by color, size, shape, opacity, brand, and more, contextualizing and storing information about each item it perceives” [2]. This allows the AI platform, AMP Neuron, to be able to properly recognize and categorize waste into a variety of categories.

The inadequate recycling of plastics has led to the accumulation of plastic waste in landfills and oceans, posing a severe threat to ecosystems and wildlife. In response to the pressing need for effective waste management, innovative solutions such as the automated facility design by AMP Robotics play a crucial role. The advanced secondary sortation system developed by AMP Robotics allows for the efficient aggregation of small volumes of challenging-to-recycle mixed plastics, paper, and metals [2]. By targeting these difficult-to-handle materials, the system addresses a significant gap in the recycling process, ensuring that a larger portion of the waste stream is properly sorted and redirected for appropriate recycling methods.

The efficiency of AMP AI's CortexTM is particularly noteworthy, boasting the capability to sort recyclables at a remarkable rate of 80 items per minute with an accuracy reaching up to 99% [14]. The AMP CortexTM serves as the body to AMP Neuron’s brain, which is the primary sorting system. Cortex is a high-speed intelligence that performs the physical tasks of collecting, sorting, picking, and placing material based off of the information that the ‘eyes and brain’ of AMP Neuron collect. This level of precision not only contributes to elevated recycling rates but also addresses the pressing need for sustainable waste management practices. By automating the sorting process with such precision, AMP AI significantly reduces reliance on manual labor, thereby increasing operational efficiency and minimizing costs. Real-time data drives operational decision making, and because of this, over 90% of the recovery occurs without touching human hands.

## EVALUATION OF AMP ROBOTICS

The influence of AMP Robotics has been widespread across the globe, especially over the past couple of years. According to Contrary Research, a platform that analyzes the effectiveness of different sustainability companies, “from June 2019 to May 2023, AMP Robotics deployed 300+ robotics systems across one hundred US, Europe, and Asia facilities. The company claims to have the largest fleet of robots and AI training datasets for sorting recyclables. AMP Robotics’ dataset is generated from its global fleet, which is designed to create a data advantage with the intention of enabling AMP Robotics’ robots to be more accurate and efficient compared to competitors” [15]. According to this excerpt, AMP has been able to help facilities across the globe, and several facilities at that. Not only does this show the widespread reach of AMP Robotics, but it also shows that AMP Robotics is able to help hundreds of different companies in said countries. Furthermore, these are only the companies that were able to deploy 300+ robotic systems, showcasing that there could be even more companies that were not mentioned that are receiving aid from AMP Robotics. All of this indicates that AMP Robotics has a widespread reach with a number of different companies across the globe, demonstrating its effectiveness in recent years.

Moreover, AMP Robotics can sort through a large portion of waste in these companies and countries. AMP has extended its object recognition run rate to more than 10 billion items annually thanks to its approximately 200 deployments across North America, Europe, and Japan. In the U.S. alone, AMP has robotic systems deployed in more than 25 states, recovering all types of plastics, along with paper, metals, and more” [15]. While it has been established that AMP Robotics has a wide outreach in different countries, this excerpt shows the efficiency and effectiveness of the robots that AMP deploys. The effectiveness of robotics is displayed in the fact that 10 billion items are sorted, and the utility of the robots is further proven by the hundreds of differing items that it can categorize. This also relates to industries that are present across the globe, such as single-stream recycling, e-scrap, and construction and demolition [13].

Furthermore, countries like Vietnam grapple with the intricate task of separating and identifying ‘valuable waste’ within mixed materials, such as food waste. Traditional sorting methods, reliant on sensors and human labor alone, prove insufficient in handling the colossal quantities of waste generated and sorted annually [2]. With over 90 billion objects recognized each year, the need for an efficient waste sorting process becomes increasingly evident, highlighting the global relevance of innovative solutions like AMP AI [2].

While viewing the current applications of AMP Robotics, it is all but imperative to look at the future of the company and its role in society. Currently, the company has been able to revolutionize itself past 2019, despite its founding in 2014. However, viewing the current and future markets for AMP Robotics is imperative to viewing the effectiveness of the company. According to the Ellen MacArthur Foundation, the “demand for robotics to retrofit existing recycling infrastructure continues to thrive; among historic demand for recycled commodities of all types, the industry needs capacity to meet the 2025 goals of consumer-packaged goods companies that have committed to the use of post-consumer recycled (PCR) content. We see growth in a number of areas, from the breadth and precision of our material characterization capabilities to new sortation verticals, like e-scrap, construction and demolition debris, and organics, to increasing use of data to improve recycling operations and help achieve sustainability targets” [14]. This showcases that the industry can grow far beyond its current situation. It can be integrated in a better way into industries such as construction and demolition, allowing for its role in society to flourish. In addition, as the population continues to increase, it will become even more necessary to categorize and dispose of waste. Because of this, AMP Robotics seems to have a presence in both the present and the future, allowing it to be an effective company that should be relevant for decades to come.

Furthermore, the industry seems to be able to adapt to any future situations that are present. One example of this is with the company Evergreen, a shipping company that is expanding to energy development, air transportation, hotels, and resorts. Such a large company generates waste, but AMP’s technology has allowed it to be more sustainable than ever. According to Jake Gong and Sachin Maini, two authors who conducted research on the application of AMP Robotics, “AMP’s technology identifies and sorts green and clear PET from post-consumer bales of plastic soft drink bottles at speeds up to three times faster and at a higher accuracy than manual sorters can achieve. Evergreen then recycles the material into reusable flakes or pellets, which it sells to end markets as feedstock for new containers and packaging. With AMP’s robots focused on refining the quality of material, separating plastics more precisely by color, Evergreen has seen a notable improvement in purity along with pick rates of up to

120 bottles per minute—an increase of up to 200%. The robots are removing up to 90% of contamination, on average, across different lines at Evergreen's Clyde facility" [15]. This indicates that the company will be able to adapt to any situation in the future, as it is able to get integrated into several companies in a seamless fashion, showcasing the utility of robots. Not only that, but it also rapidly increased the purity of the companies' products, allowing for their revenue to increase and their quality to increase as well.

Mentioning the costs, both the robot and maintenance costs, will help to determine whether AMP Robotics is an effective company. Currently, purchasing one singular robot will cost about $300,000, as of 2020 [15]. This price indicates that is might not be as affordable to startups and smaller companies, but this is significantly cheaper than hiring a singular worker for waste management in the long term. This does not account for the maintenance of the robot, or the electricity and energy to power it. However, AMP's robots complete the work of four humans over two shifts, saving any company around $120,000 to $200,000 a year. This replaces any hiring and liability costs that a human worker would incur, as recycling laborers have around a 50% turnover every three months [15]. While it is tough to view the long-term cost of a robot versus a human, as the product has only truly been integrated within the past 4-6 years, it does prove to be more effective than a human worker, despite the initially higher cost. The company still creates jobs, as there must be supervisors and maintenance workers for any issues that the robot may go through, but overall, artificial intelligence still is hurting the job market for potential employees of waste management companies.

While waste management jobs are essential for every country to function, they are often associated with a stigma. According to Elise Rio, a writer from the University of California, Berkley, "Society does not pay much heed to workers in the trash industry. Trash is dirty and ugly, and it reminds us of our never-ending waste. It makes us feel guilty, so we turn a blind eye to anything related to trash, including the people who work among the trash" [16]. While these biases may be completely unintentional, they often lead to a negative connotation in the profession of waste management. However, with AMP Robotics, they provide a managerial role supervising machines that do the "dirty work," leading to more of a positive view of the job. In addition, these roles are often compensated in a larger way, as the responsibilities that can into a managerial position are typically larger than the average role of a garbage person collecting waste. Because of this, more individuals may favor a job in AMP Robotics as a supervisor, as it allows them to go for a "better" position while still having a large impact that benefits the environment and the world around them.

Overall, there are a ton of factors that can go into the evaluation process of AMP Robotics that determine whether the company is effective or not. Despite the higher initial costs, it seems that AMP Robotics is more efficient and effective than the average human worker, allowing established companies to devote those resources towards other projects that they might be conducting [15]. Moreover, the implementation of their AI-driven systems contributes significantly to environmental sustainability by enhancing recycling rates and reducing the environmental impact of improper waste disposal, aligning with global initiatives towards an eco-friendlier future [14]. This highlights AMP Robotics' commitment to not only current operational efficiency, but also long-term goals focused on positive environmental contributions. However, it is important to note that the job market for employers is more likely to decrease in the future, as most, if not all humans, are unable to compete with the capabilities of robots and the AI scanning system [13]. Despite this shift, AMP Robotics is at the forefront of reshaping industries, urging a reevaluation of workforce skills and fostering innovation in tandem with automation. The adaptability of AMP Robotics technology positions it as a strategic investment for companies navigating the dynamic landscape of waste management. The scalability and potential for customization allow businesses to tailor the system to their specific needs, ensuring a seamless integration with existing processes and optimizing overall waste management strategies [15]. This company, therefore, is hoping to augment the waste management system in a more effective way, in both the present and the future. It seems that the AI can help companies in the present and cut down on costs in the future, and AMP Robotics seems to have plans to advance their company in the future, showcasing that they are an effective company with bright aspirations.

## CONCLUSION

### AI in Waste Management: An Overview

The integration of AI into waste management processes has brought about a range of positive effects, fundamentally transforming the industry. Artificial intelligence is primarily utilized for solid waste materials, which encompass discarded or rejected items considered spent, useless, worthless, or in excess. Various sources, such as residential, commercial, institutional, and industrial, contribute to the production of diverse solid waste materials. Solid waste management (SWM) is an organized process aimed at handling waste in a manner that minimizes harm to humans and the environment, consisting of six stages: identification, handling, collection, transport, processing, and disposal. The processing stage of SWM is imperative, where waste is sorted into categories for proper disposal or potential reuse, highlighting the critical importance of waste management as global estimates predict a significant increase in solid waste production over the coming years.

By employing AI to categorize waste at a speed surpassing human capabilities, with greater accuracy and efficiency, waste management practices have experienced a revolutionary shift. AMP Robotics stands as a testament to the potential of AI in this field, particularly through its AMP Cortex and AMP Neuron technologies, which contribute to the seamless collection and sorting of waste. This technological advancement has found widespread implementation across diverse companies in various countries, underscoring its efficacy and adaptability.

Employing the capabilities of AMP Robotics into the SWM system has remarkable implications on the process overall. Specifically at the processing level, AMP has managed to make one of the most labor-intensive and grueling tasks in the process and transformed it into a streamlined process which can be done by computers in a manner that is much quicker and effective in nature.

The success of AMP Robotics, evident in its extensive deployment of robotic systems globally, highlights the current indispensability of AI in waste management. The integration of these technologies streamlines waste processing operations, ensuring a faster and more precise sorting process. The company's ambitious plans to expand into various fields further underscore the integral role AI plays in these companies' day-to-day operations. As AMP Robotics continues to demonstrate success and evolve, it solidifies the notion that artificial intelligence has become an intrinsic and indispensable component of contemporary waste management practices.

Moreover, the positive impacts extend beyond mere efficiency gains. AI-driven waste management facilitates a more sustainable and environmentally conscious approach. The ability of AI systems to recognize and sort recyclable materials with high accuracy contributes to the reduction of waste contamination and the promotion of recycling efforts. The incorporation of AI aligns with global initiatives toward sustainable practices, offering a sophisticated solution to the challenges posed by escalating waste volumes.

In essence, the usage of artificial intelligence in waste management has not only optimized operational processes but has also ushered in a new era of environmental responsibility. The continued success and expansion of companies like AMP Robotics further solidify the notion that AI is not just a key component but a transformative force in shaping the future landscape of waste management practices globally.

## Aspects of Sustainability

While companies worldwide, including AMP Robotics, reap the benefits of artificial intelligence (AI) in waste management, it is crucial to examine the overarching impact on sustainability. The University of Pittsburgh provides a defining perspective, describing sustainability as "balancing equity, environment, & economics so current and future generations can thrive" [17]. In alignment with this definition, AI in waste management proves to be inherently sustainable, fostering efficiency and environmental consciousness among companies globally.

Despite variations in the effects of AI across regions, a consistent theme emerges – companies adopting AI technologies tend to enhance their effectiveness and awareness regarding waste byproducts. An illustrative example is Evergreen, which achieved a remarkable over 200% increase in efficiency rates for waste collection through AI implementation [15]. Moreover, the utilization of artificial intelligence contributes to a reduction in cross-contamination, as evidenced by the quote, "AI-guided sortation ensures a higher-quality end product that isn't contaminated by other materials, and a larger volume of recycled material" [2]. This observation resonates with the University of Pittsburgh's sustainability definition, emphasizing that by diminishing cross-contamination and refining waste collection processes, AI actively promotes the thriving of both current and future generations.

In summary, the positive impact of AI on sustainability goals is evident in the increased efficiency and waste-conscious practices of companies globally. As AI in waste management continues to evolve, its contribution to sustainability becomes increasingly pronounced, aligning with the imperative of balancing equity, environment, and economics for the benefit of current and future generations.

## The Future of AI

While the effective integration of Artificial Intelligence (AI) in Waste Management is evident, a critical consideration lies in the trajectory of these programs and their adaptability to future challenges. The global urgency for strategic waste management solutions is underscored by the rapid rate of urbanization, turning waste management into a worldwide challenge. As emphasized, "there is a need to strategically design low-cost AI-based waste management systems, which can be installed in low-income countries, thus providing better health conditions there" [18]. This acknowledgment signifies the imperative role AI could play in addressing global waste issues, particularly in regions facing economic constraints.

Noteworthy advancements, such as AMP Robotics' AMP Neuron software, showcase the potential trajectory of AI in waste management. The software's ability to utilize pattern recognition for diverse waste streams suggests a promising path forward. However, it is acknowledged that "further research is required to focus on designing cost-effective tools based on AI to ensure the maximum utilization of these tools" [16]. This statement indicates the necessity for ongoing innovation and refinement to make AI-based waste management solutions more accessible and efficient, especially in resource-constrained environments.

Despite the need for continued research and improvement, current findings from experts suggest a positive outlook for the future of AI in waste management. The evolving capabilities of AI, coupled with ongoing efforts to enhance cost-effectiveness, position these technologies as potential catalysts for positive global change. As we navigate the trajectory of AI in waste management, there is optimism that these innovations can contribute significantly to shaping a more sustainable and efficient world.

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## WRITERS’ NOTE

Dear Katy,

Our group is glad that you enjoyed the rough draft of our paper. While there were quite a few issues that we had to touch up, it was nice to see our paper come together. This entire process allowed us to refine our thoughts and come together for a good final effort. Your email also provided great clarification and allowed us to work on our presentation in a great way.

You suggested differentiating between two different types of AI. We decided not to do this as we felt that it did not add to our discussion of AI. We have a tidbit which mentions that deep learning in particular is relevant to our topic which helps readers to know this and implicitly says that other types of AI are not particularly relevant.

Thanks, Team 162

FYEC Team 162
Professor Katy Rank Lev

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**Overall Comment:**

**Grade:**

Grade Scale: 100, 99 A+ 98-93 A 92-89 A- 88-85 B+ 84-79 B 78-75 B- 74-71 C+ 70-65 C 64-61 C- 60 D 59-below F

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