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Zero-Plastic Model: A Comprehensive Framework for Eliminating Plastic Dependency in Modern Society

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Abstract. This paper proposes a "Zero-Plastic Model" that focuses on the complete elimination and systematic replacement of plastic products. The model represents the deviation from the "reduce, reuse, recycle" framework, emphasizing prevention over treatment and introducing innovative technological solutions for plastic alternatives. The paper illustrates the limitations of existing recycling systems. The paper presents three aspects, including (1) the systematic reduction of plastic dependency through frameworks and behavioral interventions, (2) the development and implementation of sustainable replacement materials, and (3) the integration of technologies to facilitate this transition. The proposed "Zero Plastic Model" establishes sustainability frameworks while introducing a novel approach focused on complete plastic elimination rather than recycling. The framework integrates circular economy principles and draws inspiration from pre-plastic era solutions to achieve zero residual plastic in the system. The research contributes to the growing body of knowledge on sustainable practices and offers a practical framework for organizations and communities seeking to eliminate their plastic dependency.

Keywords. zero-plastic, model, framework, plastic alternative, sustainability, reduce, reuse, environment, circular economy

1. Introduction

The global plastic crisis has evolved into one of the most environmental challenges of the 21st century, with far-reaching implications for ecological sustainability, human health, and economic stability. Since the commercialization of plastic production in the 1950s, humanity has generated an estimated 8.3 billion metric tons of plastic, with annual production reaching an unprecedented 400 million tons in 2022 [1]. More alarmingly, approximately 40% of this production comprises single-use plastics, contributing to a massive waste management crisis [2].

This crisis is evident in many countries including Thailand, which ranks as the world's sixth-largest contributor to ocean plastic pollution [3]. Thailand generates approximately 2 million tons of plastic waste annually, with only 25% being properly

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recycled [4]. The average Thai citizen uses about eight plastic bags daily, contributing to the country's severe marine pollution, where an average of 300 marine animals died each year from plastic ingestion [5]. In contrast, Japan, despite being one of the world's largest per capita users of plastic packaging, has developed sophisticated waste management systems, achieving an 84% plastic recycling rate through strict segregation policies and advanced recycling technologies [6]. The situation is critical in popular tourist destinations like Phuket, where daily waste generation has reached alarming levels. Recent studies indicate that Phuket's daily waste production has increased dramatically from 850 tons to over 1,000 tons during peak tourist seasons, with plastic waste comprising approximately 20% of the total [7,8]. The island's beautiful beaches are increasingly plagued by plastic debris, with recent surveys showing a 30% increase in beach plastic pollution over the past five years [9]. It indicates that plastic waste does not threaten only the marine ecosystem but also the tourism industry, which is important to Thailand's economy.

While recycling has been widely promoted as a solution to plastic pollution, recent investigations have exposed fundamental flaws in global recycling systems. A study by Greenpeace (2022) revealed that only 5-6% of plastic waste in the United States was actually recycled in 2021, despite decades of public recycling programs. The investigation further exposed that many types of plastic, including those labeled as recyclable, are economically impractical to recycle. The Ellen MacArthur Foundation reports that the economics of plastic recycling are severely challenged, with only 2% of plastic packaging being effectively recycled in a "closed loop" system. Additionally, the expose by NPR and PBS Frontline (2020) uncovered that the plastic industry promoted recycling despite knowing its limitations, using it as a strategy to continue plastic production while shifting responsibility to consumers.

The traditional "reduce, reuse, recycle" framework has proven insufficient in addressing the magnitude of the plastic crisis. This paper proposes the "Zero-Plastic Model" that focuses on the elimination and systematic replacement of plastic products across various sectors. The model represents a deviation from conventional waste management strategies, and introducing innovative technological solutions for plastic alternatives.

Our research addresses three critical aspects: (1) the systematic reduction of plastic dependency through policy frameworks and behavioral interventions, (2) the development and implementation of sustainable replacement materials, and (3) the integration of emerging technologies to facilitate this transition. This comprehensive approach considers both the technical and socioeconomic factors necessary for successful implementation.

The rest of the paper is organized as follows. Sections 2 and 3 introduce the current waste management approach and contemporary theoretical framework. Section 4 presents the proposed zero-plastic model. Sections 5 and 6 depict the reverse technology and origami technology as our proposed solution, followed by the implementation plan in Section 7. Sections 8 and 9 are the expected outcome impact and conclusion.

2. Current Plastic Waste Management Approach

Current recycling systems show a wide variation in operational strategies and system effectiveness. In some developed countries, typical waste management infrastructure includes collection, sorting, and processing facilities, but successful recycling rates remain a challenge. It only recycles 9% of plastics in the United States, with approximately 27 million tons of plastics entering landfills each year. The European Union performs slightly better, with an average recycling rate of 32.5%, supported by a comprehensive waste hierarchy framework and strict regulations. However, these recycling systems face a number of challenges, including excessive waste mixing with recycled materials (over 25%), uncertain prices for recycled materials, and increasing costs for sorting and processing goods.

International policies and regulations on plastic waste management have evolved significantly, particularly after China's 2018 National Sword policy, which disrupted global recycling markets. The 2019 revisions to the Basel Convention introduced stricter controls on the plastic waste trade, requiring explicit consent to move contaminated, mixed, or non-recyclable plastic waste across borders. The 2022 United Nations Environment Assembly resolution to develop an act on plastic pollution by 2024 was an essential step in global coordination. However, not all countries are implementing these rules in the same way, and some countries enforce them more strictly than others.

Japan's waste management system acts as a notable success story, achieving an 84% plastic recycling rate by a combination of policy measures and technological innovation. The country's Container and Packaging Recycling Law provides source separation into distinct categories, while advanced sorting technologies and thermal recycling facilities ensure maximum resource recovery. The system is supported by extensive public education programs and strict enforcement mechanisms, resulting in a recycling culture that has become deeply embedded in daily life. However, Japan counts burning waste for energy as recycling. Many experts disagree with this and say it shouldn't be considered accurate recycling. The system is supported by extensive public education programs and strict enforcement mechanisms, resulting in a recycling culture that has become deeply embedded in daily life. However, Japan counts burning waste for energy as recycling. Many experts disagree with this and say it shouldn't be considered accurate recycling.

Thailand's waste management system is different from the challenges faced by developing countries. Even though they initiated many policies, such as the Plastic Waste Management Roadmap (2018-2030), the implementation still faces significant obstacles. The country's waste management infrastructure struggles to face the increasing volume of waste, particularly in tourist destinations such as Phuket. A recent study indicated that only 25% of Thailand's plastic waste is recycled correctly, with the informal sector playing a key role in waste collection and sorting. The government is working with private companies to manage plastic waste better. While this collaboration has yielded positive results, making it successful on a larger scale is challenging.

3. Contemporary Theoretical Framework

The circular economy model, according to the Ellen MacArthur Foundation, focuses on three main goals: eliminating waste and pollution, reusing products and materials, and restoring natural environments [10]. It is different from the old "take-make-throw away" approach, as it turns waste into useful resources. Research shows that using circular economy methods for plastic management could cut plastic waste by 80% and save $200 billion each year [11]. The idea of a "circular plastic economy" specifically looks at creating closed-loop systems for plastic use, focusing on making plastics that are easier to recycle and developing better systems to collect and process used plastics [12].

Sustainability frameworks provide crucial theoretical support, mainly through the viewpoints of the Triple Bottom Line (TBL) approach and the United Nations Sustainable Development Goals (SDGs). The TBL framework emphasizes the interconnection between environmental protection, social equity, and economic viability. This research aligns explicitly with SDG 12 (Responsible Consumption and Production) and SDG 14 (Life Below Water) while incorporating the broader sustainability assessment framework developed by the United Nations Environment Program. The Natural Step Framework further complements this approach by providing systematic principles for environmental sustainability, particularly relevant to plastic waste reduction strategies.

Two critical theories about human behavior guide this research, the Theory of Planned Behavior (TPB) and Social Practice Theory (SPT). TPB, created by Ajzen, explains that people's actions are shaped by their attitudes, social pressures, and belief in their ability to act. Recent studies using TPB found that when people believe they can reduce plastic use, they're more likely to try. SPT looks at how daily habits form through the combination of available materials, skills, and cultural meanings. Research using SPT shows that plastic use is deeply rooted in our everyday habits, suggesting we need to change entire systems, not just individual behaviors, to solve plastic pollution.

4. Zero-Plastic Through Reduction and Replacement Model

The proposed "Zero Plastic Model" builds upon established sustainability frameworks while introducing a novel approach focused on complete plastic elimination rather than recycling. The model is based on the fundamental equation:

"Residual = Existing + Incoming - Outgoing"

where the goal is to achieve zero residual plastic in the system, this approach acknowledges the failure of traditional recycling methods and shifts focus to two primary strategies: reduction and replacement. The framework integrates circular economy principles not for recycling but for designing systems that eliminate plastic usage, drawing inspiration from pre-plastic-era solutions.

The Existing (E) component includes all the plastic items that are currently being used. It can be things like containers, packaging, equipment, and even parts of buildings like pipes. For example, a typical household might have around 100 plastic containers that they use regularly.

The Incoming (I) component refers to new plastic items that come into the household. It includes things bought from stores, packaging from products, and the latest equipment. In a typical household, this might mean adding about 10 new plastic items each month.

The Outgoing (O) component helps reduce the amount of plastic by using two main strategies: reduction and replacement. Reduction strategies involve cutting down on the use of plastic items. It can be done by refusing plastic bags when shopping, using reusable containers instead of disposable ones, and switching to digital documents instead of laminated ones. By doing these things, you can significantly reduce the amount of new plastic you bring into your home, such as cutting down from buying 10 new plastic items each month to just 2. Replacement strategies involve swapping plastic items for more sustainable options, like using glass containers instead of plastic ones, paper or cloth bags instead of plastic bags, bamboo utensils instead of plastic ones, and metal water bottles instead of plastic ones. For example, replacing five plastic containers with glass ones is an effective way to implement a replacement strategy.

To understand how effective this model is, let's look at the following example. Initially, you might have 100 plastic items already at home (Existing), get 10 new ones each month (Incoming), and get rid of 7 (Outgoing), leaving you with 103 plastic items (Residual). The goal is to have no plastic items at all. It can be achieved by using old-fashioned solutions that have worked well in the past. For example, people used clay pots, glass jars, and wooden boxes for storing food, paper, cloth bags, and wax paper for packaging, and metal, wood, or bamboo for utensils. Buildings were made with materials like wood, metal, and natural fibers.

To measure success, we use two critical numbers. The Plastic Reduction Rate (PRR) shows how much plastic you've reduced compared to when you started. The Replacement Efficiency Index (REI) helps decide which new items are best by considering their cost, how good they are for the environment, and how long they last. These tools help track progress and make wise choices to reduce plastic use. By combining old ideas with new ones, this model offers a practical way to create a plastic-free environment.

5. The Reverse Technology

The concept of “Reverse Technology” in plastic replacement represents a fundamental shift in our approach to solving the plastic crisis. Instead of seeking new technological solutions, this approach advocates for examining and adapting pre-plastic-era solutions that sustained human civilization for millennia. By studying historical practices and traditional wisdom, we can rediscover sustainable alternatives that were effectively used before the advent of plastic in the 1950s. Historical analysis reveals rich diversity in packaging and container solutions across different cultures. In Southeast Asia, for instance, banana leaves served as natural food wrappers, providing water-resistant and biodegradable packaging solutions. These leaves, along with bamboo containers and coconut shells, formed an intricate system of sustainable packaging that left no permanent environmental impact. Similarly, East Asian cultures developed sophisticated systems using lacquerware, wooden containers, and cloth wrapping (Furoshiki in Japan), demonstrating that advanced civilizations could thrive without plastic dependency.

The traditional materials used across various cultures share remarkable properties that make them practical alternatives to modern plastic. Banana leaves, for example, possess natural water resistance and antibacterial properties, while clay pottery offers durability and temperature resistance. Bamboo combines strength and flexibility with complete biodegradability. These materials not only served their purpose effectively but also maintained ecological balance through their natural lifecycle.

A modern adaptation of these traditional solutions requires a systematic approach. The first step involves comprehensive documentation of conventional practices and materials, followed by scientific analysis of their properties. The next phase focuses on enhancing these materials through modern technology while maintaining their fundamental sustainable characteristics. For instance, traditional banana leaf packaging could be enhanced through modern processing techniques to improve durability while retaining its biodegradable nature.

Implementation of these solutions in contemporary contexts has shown promising results. In Thailand, traditional food packaging methods are being revived and enhanced for modern street food vending. Japanese bento box traditions are being adapted with treated wood and bio-based materials, proving that traditional solutions can meet modern standards of hygiene and convenience. These examples demonstrate the viability of conventional solutions in contemporary settings as depicted in Figure 1.

Figure 1. Examples of pre-plastic era containers (left) and plastic era (right).

6. The Origami Technology

The Origami technology is a plastic alternative that refers to innovative folding techniques inspired by the traditional Japanese art of paper folding. The origami technology is being applied to create sustainable packaging and other solutions. These packaging solutions include designs like self-locking boxes that reduce the need for tape or adhesives, expandable protective sleeves that adapt to different product sizes, and collapsible containers that minimize storage space when not in use. Dell and HP have implemented origami packaging for electronics. They apply biodegradable materials that can be easily folded to provide cushioning and protection. The technology has also reformed food packaging with designs that maintain structural integrity while being fully recyclable, such as origami-based pizza boxes that improve breathability and prevent sogginess.

There are a lot of environmental benefits of origami-based packaging. The folding techniques provide excellent structural strength while using minimal material, which makes them both cost-effective and resource-efficient. The origami packaging can be folded flat when not in use, which can save valuable storage and transportation space, which in turn reduces carbon emissions. These innovations can be manufactured using existing paper-processing equipment, which can make them commercially viable alternatives to traditional plastic packaging. Unlike modern alternatives that often substitute one type of environmental impact for another, these conventional solutions are genuinely biodegradable and have proven their sustainability through centuries of use. It is a renewable resource to support the local ecosystem.

This approach represents a paradigm shift in how we address environmental challenges. Instead of constantly looking forward to new solutions, sometimes the most effective strategy is to look backward, understand what worked before, and adapt those solutions for contemporary use. The wisdom of our ancestors, combined with modern knowledge and capabilities, may hold the key to solving our current environmental challenges.

7. The Faculty's Implementation Plan

The Faculty of Data Science plans to conduct a 12-month program to reduce single-use plastics. We designed to serve as a model for future university-wide expansion. Beginning with a 3-month preparation phase, we'll first analyze our faculty's plastic consumption patterns, focusing on daily items like water bottles, coffee cups, and food packaging in our offices, labs, and common areas. The following quarter involves implementing simple solutions like faculty-wide reusable tumbler adoption, installing water refill stations, and introducing a shared eco-bag system for our department's 200+ members. The third quarter centers on measuring impact and refining our approach, using our data science expertise to track adoption rates and waste reduction. The final phase focuses on documenting our successes, challenges, and lessons learned, creating a comprehensive implementation guide that other faculties can follow. Throughout the year, we'll maintain detailed metrics and feedback from our faculty members, requiring only modest resources, including tracking systems, sustainable products, and active participation from our department's students and staff. This focused approach within our faculty will serve as a proof-of-concept for future university-wide implementation across departments.

8. The Expected Outcome and Impacts

The Faculty of Data Science's Sustainability Initiative aims to achieve immediate, measurable outcomes, including a 50% reduction in single-use plastic consumption, significant cost savings from reduced disposable items procurement, and implementation of a comprehensive waste tracking system. The initiative will deliver broader environmental benefits through reduced plastic waste and carbon footprint while providing students with hands-on experience in sustainability data analysis and research opportunities. From the tangible outcomes, the project is looking to promote a cultural shift through sustainable practices within the faculty, serving as a data-backed model that can be scaled across other departments. This proof-of-concept will demonstrate how a single faculty can create meaningful environmental impact while generating valuable data to support more considerable institutional changes.

9. Conclusion

This paper proposes a framework for transitioning towards a zero-plastic society through an integrated approach combining waste management strategies, theoretical frameworks, and innovative technologies. The proposed Zero-plastic through Reduction & Replacement Model, supported by the "Residual = Existing + Incoming - Outgoing" formula, provides a quantifiable method for tracking and managing plastic reduction efforts. The integration of Reverse Technology and Origami Technology demonstrates how innovative solutions can address both existing plastic waste and future packaging needs. The implementation plan will be a case study to support the applicability in real settings. The framework implies that achieving a zero-plastic society is not only theoretically possible but practically achievable through the systematic implementation of policy frameworks, behavioral interventions, and technological innovations. The expected outcomes and impacts indicate that this model can be effectively scaled from institutional to societal levels and provides a roadmap for sustainable plastic reduction while maintaining functionality and economic viability. This research contributes to the growing body of knowledge on sustainable practices and offers a practical framework for organizations and communities seeking to eliminate their plastic dependency.

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