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EVALUATING PLASTIC LEAKAGE INTERVENTION OPTIONS IN ZAMBOANGA PORT, PHILIPPINES WITH ANALYTICAL HIERARCHY PROCESS (AHP)

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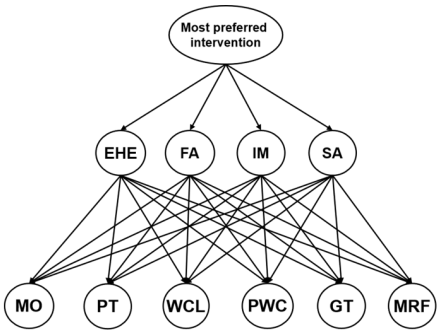
Graphical abstract



LEGEND:
Evaluation Criteria Cluster (C)
- ❑ Environmental & Health Effectiveness (EHE)
- ❑ Financial Affordability (FA)
- ❑ Implementability (IM)
- ❑ Social Acceptability (SA)

Alternatives Cluster (**A**)
- ❑ Memorandum Order (**MO**)
- ❑ Personnel Training (**PT**)
- ❑ Waste Container Labelling (**WCL**)
- ❑ Provision of Waste Containers (**PWC**)
- ❑ Procurement of Garbage Truck (**GT**)
- ❑ Establishment of Material Recovery Facility (**MRF**)

Abstract

Plastic wastes from ports may be leaked into oceans if it is not properly managed owing to its proximity to the sea, such as in the case of the port of Zamboanga in the Philippines - a government port with international standard certifications wherein plastic waste management remains a challenge to its management. This study aims to determine plastic leakage intervention options through the conduct of a Focus Group Discussion (FGD) and to propose the most preferred intervention using the Analytical Hierarchy Process (AHP) by incorporating the subjective judgment of different port key stakeholders and decision-makers. There were four criteria used for this AHP model to quantify the relative preference of each intervention namely environmental and health effectiveness (EHE), financial affordability (FA), implementability (IM), and social acceptability (SA). There were five (5) proposed possible management intervention alternatives, these are the memorandum order (MO) on proper waste segregation and collection, personnel training (PT) on plastic waste management, waste container labeling (WCL), provision of waste containers (PWC), procurement of garbage truck (GT), and establishment of a material recovery facility (MRF). The results of the AHP model suggest that most of the port's key stakeholders and decision-makers prioritize the MRF and PT among other management interventions.

Keywords: Marine debris, plastic wastes, plastic leakage interventions, AHP

1.0 INTRODUCTION

Marine debris/ litter is a complex environmental problem that is detrimental to human health [1], [2] with negative socio-economic implications such as being both hazardous and detrimental to shipping industries [3], [4], and comes with limited solutions [5].

These are persistent waste manufactured solid material that has been either discharged, abandoned, disposed, or discarded in the marine and coastal environments, resulting from anthropogenic activities from numerous land/sea-based sources [2], [6]–[8] and the majority of which are made up of plastics/ marine plastic waste [9] that derived from most coastal countries' rivers, drainage, wastewater run-off, and sewerage systems [8], [10].

Seaports are one of the important economic drivers for most coastal countries like the Philippines [11], [12] that provide services for the transport of goods, commodities, and people across places [13].

However, with the increasing number of cargoes, passengers' transit, and port calls [12], seaports frequently deal with ship-generated waste [14], [15], cargo-handling related waste, and waste leakages from reception facilities [16] that eventually leads to the increasing environmental concerns relating to these activities [11] such as coastal and marine plastic pollution.

The port of Zamboanga in the Philippines is one of the major ports of the country and serves as the main port of the Zamboanga Peninsula region and port hub for neighboring islands. It is a government-owned port that is under the jurisdiction of the Philippine Ports Authority (PPA) and has three (3) International Standard Organization (ISO) certifications namely the Integrated Management System (IMS) that ensures the provision of world-class quality service as a commitment that is: ISO 9001:2015 (Quality Management System), ISO 14001:2015 (Environmental Management System) and ISO 45001:2018 (Occupational Health and Safety Management Systems). Despite having these IMS certifications, solid waste management specifically plastic waste leakage remains a serious challenge due to poor implementation, financial constraints [17], lack of awareness and less cooperation by the public [18], and insufficient facilities for collection and disposal [19]–[22].

This study proposes the most preferred intervention for port plastic leakage strategy using the Analytical Hierarchy Process (AHP) through the evaluation of different options by incorporating the port stakeholders' subjective judgments and opinions based on their expertise in port operations and solid waste management.

2.0 METHODOLOGY

A major concern to solid waste management implementation is decision making [23], on the intervention options characterized by often contradicting and numerous criteria to choose from; a dilemma that requires the utilization of a specialized decision support tool- the Multi-Criteria Decision Analysis (MCDA) [24].

MCDA is designed to include multiple criteria in addressing complex decision problems [25], [26]. One of the known MCDA methods is the Analytical Hierarchy Process (AHP).

The AHP is a simple multi-criteria decision-making methodology developed to evaluate and analyze difficult problems or target systems using a hierarchical approach and qualitative analysis [27]–[33].

AHP can facilitate the whole process of decision-making by, emphasizing and reducing the inconsistency of judgment of decision-makers, stakeholders, and experts with different professional backgrounds in proposing solutions to specific target problems [34], [35] into a prioritized series of alternatives based on multiple set of criteria [36]. Priority scores from the pairwise comparison matrix are generated using the eigenvector method or normalized row geometric mean technique, which provides the measure of judgments and preference ratios [37].

This method has been successfully and widely used in various fields and sectors [30] in both developed and developing nations from education, to health, engineering and manufacturing, human resources, governance, and even politics [38]. Specifically in developing countries [31], this AHP technique has been suitably and effectively applied to propose decisions and execute solutions in the field of waste management [39].

In this study, the decision structure as shown in Figure 1 below was used. Multiple criteria evaluated were Environmental and Health Effectiveness (EHE), Financial Affordability (FA), Implementability (IM), and Social Acceptability (SA). Environmental and health effectiveness is the effectiveness of interventions to protect public health and the environment. Financial affordability pertains to the overall cost associated with the preparation and implementation of the interventions. Implementability considers the administrative and technological feasibility of the interventions for implementation while social acceptability considers the perception of port workers, users, and other stakeholders to the interventions.

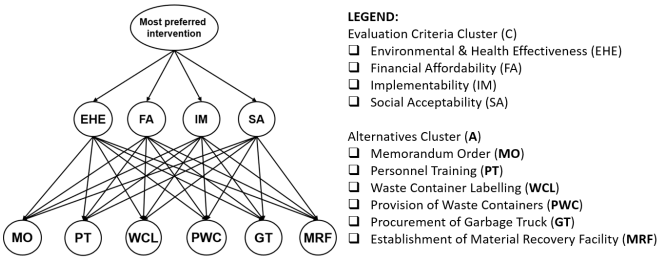


Figure 1. AHP Decision Structure used in this Study

The set of plastic leakage intervention alternatives was determined through a focus group discussion (FGD) with technical personnel directly involved in the implementation of the solid waste management system in the port of Zamboanga. Discussions were on the root causes of how and why plastic leaks out from the port waste management system and what are the possible management interventions/controls for such leakages based on the Hazard Identification Risk Assessment and Determination of Controls (HIRADC) of the port's Integrated Management System (IMS) procedure manual.

Proposed intervention alternatives were the issuance of a memorandum order (MO) on proper waste segregation and collection, personnel training (PT) or seminar on plastic waste management, waste container labeling (WCL), provision of waste containers (PWC), procurement of garbage truck (GT) or vehicle, and establishment of a material recovery facility (MRF).

A survey questionnaire was developed following Saaty's fundamental 9-point scale and linguistic equivalent [28] with the inclusion of the set of determined alternatives and criteria.

For the respondents of the study, fifteen (15) decision-makers or key stakeholders were identified namely: eight (8) managers and senior staff from the Philippine Ports Authority (PPA), five (5) managers/officials from cargo handling operator (CHO) and shore reception facility (SRF), one (1) representative from civil society organization (CSO) and one (1) from the local government unit (LGU). These respondents were selected due to their current ranks such as division managers and section chiefs who were directly involved in port operations and experts in the field of solid waste management. As such, they could provide value judgment on the study's decision structure.

The respondents' alternative intervention preference was calculated using the AHP model- Geometric Mean Method (GMM) since the study was a group preference. Wherein, the

group became an individual and their individual identities were disregarded [30]. While priority scores from the pairwise comparison matrix were generated using the eigenvector method [37].

AHP results in this study were validated using the consistency ratio (CR) that was calculated with the formula:

1) *CR= Consistency Index (CI) / Random Consistency Index (RI)*

The RI relates to the dimension of the matrices [40] used which were 4 and 6 with corresponding RI values of 0.89 and 1.24 respectively, while the CI values were derived from the formula below.

2) $CI= (\lambda_{max}- n)/ (n-1)$

Where λ_{max} is the maximum value of the matrix and *n* is the matrix size or the number of criteria being compared.

CR values not exceeding 10% or 0.10 are acceptable and verify the consistency of the matrices. However, a permissible CR value of 15% or 0.15 was used for the study. Decision-making biases were thereby reduced by validating the consistency of the different decision-makers and key stakeholders' opinions together with the AHP decision structure [28].

3.0 RESULTS AND DISCUSSION

Table 1 summarizes the respondents' aggregated weights in describing the relative importance of evaluated criteria for the different plastic leakage intervention options. The AHP model suggests that most of the port's key stakeholders and decision-makers prefer implementability as well as environmental & health impact. On the other hand, the financial affordability criteria were less prioritized.

Table 1. Respondents' aggregated weights to criteria evaluation

Criteria	Aggregated Weights*
Environmental & Health Effectiveness (EHE)	0.276
Financial Affordability (FA)	0.168
Implementability (IM)	0.316
Social Acceptability (SA)	0.240

*Consistency ratio (CR) = 0.009; CR<0.15 Tolerable

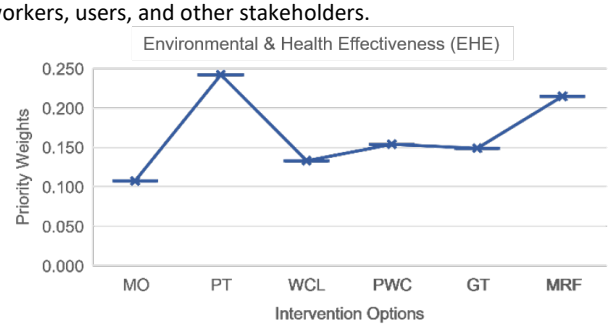
Figure 2 describes the weight variation among decision makers as to the preferred intervention options for plastic leakages with respect to each determined criterion. All of the respondents accepted all intervention options proposed by the technical team during the FGD as these were in accordance with the IMS procedure manual for environmental management.

In terms of environmental & health effectiveness (EHE), personnel training (PT) is the most preferred plastic leakage intervention option followed by the establishment of a material recovery facility (MRF). In contrast, the issuance of a memorandum order (MO) is their least preferred option. This indication suggests that port personnel lack training and technical knowledge on plastic waste management, as well as the need for a facility for waste minimization and recovery inside the port premises.

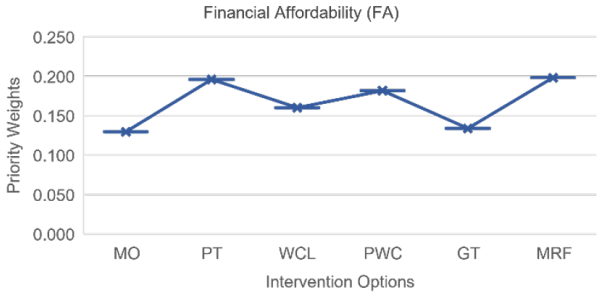
On the other hand, the establishment of a material recovery facility (MRF) and procurement of a garbage truck (GT) is the most preferred plastic leakage intervention option with respect to implementability (IM) criteria. In contrast, waste container labeling (WCL) and issuance of memorandum order (MO) were the least preferred options. Port operation respondents' preference lean towards engineering control which indicates the introduction of structural changes to the current work environment and the need for sophisticated mechanical aids for plastic waste management. WCL on the other hand was least preferred due to poor public participation in waste segregation.

For financial affordability, the most preferred options were the establishment of a material recovery facility (MRF) and personnel training (PT), while the procurement of a garbage truck (GT) and issuance of a memorandum order (MO) were their least preferred. This preference indicates that the respondents were leaning towards sustainable alternatives yet with lesser cost due to the prevailing procurement policy and budget constraints.

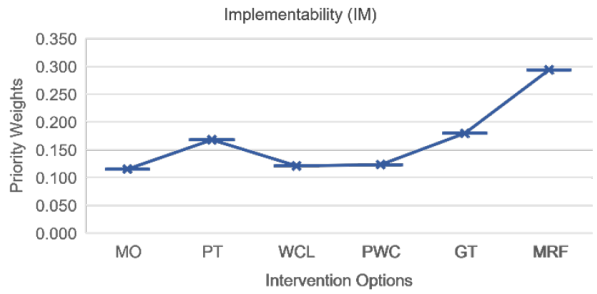
On the other hand, the most preferred options for the social acceptability (SA) criteria were the establishment of a material recovery facility (MRF) and personnel training (PT), and the least preferred was the issuance of a memorandum order. This is mainly due to the consideration of respondents to the future outcome on the perception of the Zamboanga port workers, users, and other stakeholders.



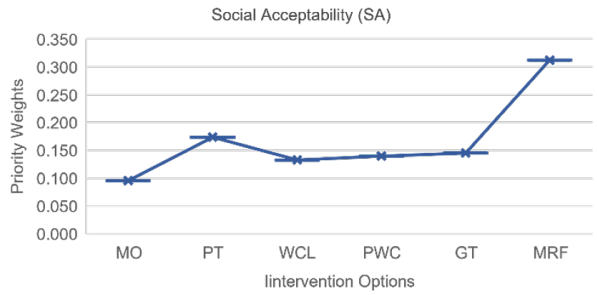
a.) Relative preference of intervention options with respect to EHE



b.) Relative preference of intervention options with respect to FA



c.) Relative preference of intervention options with respect to IM



d.) Relative preference of intervention options with respect to SA

Figure 2. The relative preference of plastic leakage intervention options with respect to each criterion

Table 2 summarizes the overall priority weights of plastic leakage intervention options at the port of Zamboanga.

The results of the AHP model suggest that the most preferred intervention/control options were the establishment of a material recovery facility and personnel training/seminar on plastic waste. On the other hand, the least preferred option was the issuance of a memorandum order on proper plastic waste segregation and collection, and waste container labeling. Aggregated priorities or the ranks of preferred intervention alternatives were computed using a weighted sum method.

Table 2. Overall priority weights of intervention options for plastic leakages at the Port of Zamboanga

Intervention/Control Options	Aggregated priorities (Rank)
Establishment of Material Recovery Facility (MRF)	0.260 (1)
Personnel Training (PT)	0.195 (2)
Procurement of Garbage Truck (GT)	0.155 (3)
Provision of Waste Container (PWC)	0.146 (4)
Waste Container Labeling (WCL)	0.134 (5)
Memorandum Order (MO)	0.111 (6)

4.0 CONCLUSION

Through the AHP, the value judgments of decision makers and key stakeholders of Zamboanga port were incorporated and facilitated thus allowing the prioritization of plastic leakage intervention strategies options in a manner that is well documented and transparent. This current study indicates the inclination of the key stakeholders and/or decision-makers in Zamboanga Port to prefer the establishment of a material recovery facility (MRF) more than the issuance of a memorandum order (MO) on plastic waste segregation and collection.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper

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