



Application of Conjoint Analysis in Waste Collection Systems as a Preference Testing Method

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Abstract

Municipal solid waste management has become one of the major environmental challenges faced by rapidly growing urban areas, particularly in developing countries. Population growth, urban expansion, and changing consumption patterns have significantly increased the volume of municipal solid waste, placing substantial pressure on existing waste management systems. Among the various stages of municipal solid waste management, waste collection is recognized as the most critical operational component because it directly influences the effectiveness of transportation, treatment, and final disposal processes. Meulaboh City, Aceh Barat Regency, Indonesia, has experienced considerable urban development following the post-tsunami reconstruction period, resulting in increased waste generation and more complex waste collection requirements. This study aims to identify the characteristics of the existing waste collection and transfer system and to determine stakeholder preferences for improving waste collection services through the application of Conjoint Analysis. The research employed a mixed-method approach involving field observations, structured questionnaires, interviews, and secondary data analysis. A total of 400 household respondents were selected using Slovin's formula with a 5% margin of error. The identified attributes influencing waste collection performance include collection frequency, accessibility to temporary storage facilities, transportation infrastructure, service reliability, and community participation. These attributes form the basis for constructing preference scenarios evaluated using Conjoint Analysis. The findings are expected to support local governments in designing waste collection systems that better reflect stakeholder preferences while improving operational efficiency and environmental sustainability. The study also demonstrates the applicability of Conjoint Analysis as a decision-support tool for municipal waste management planning in rapidly developing urban areas.

1. Introduction

Municipal solid waste management (MSWM) has become one of the most significant environmental challenges in urban areas worldwide. Rapid urbanization, population growth, economic development, and changing consumption patterns have contributed to a continuous increase in municipal solid waste generation. Without effective management, accumulated waste can cause environmental pollution, greenhouse gas emissions, degradation of urban aesthetics, and adverse impacts on public health (Guerrero et al., 2013; Kaza et al., 2018).

Globally, the World Bank estimates that municipal solid waste generation will increase from approximately 2.01 billion tonnes annually to 3.40 billion tonnes by 2050 if current consumption patterns continue. Developing countries are expected to experience the highest growth due to rapid urban expansion and limited waste management infrastructure (Kaza et al., 2018). These conditions require municipalities to develop integrated waste management systems capable of maintaining environmental quality while providing efficient public services. Municipal solid waste management consists of several interconnected stages, including waste generation, storage, collection, transportation, treatment, recycling, resource recovery, and final disposal (Tchobanoglous & Kreith, 2002). “Among these stages, waste collection represents the most critical operational activity because it serves as the primary interface between waste generators and the formal waste management system. Inefficient collection services often lead to illegal dumping, waste accumulation, unpleasant odors, blocked drainage systems, and increased operational costs” (Wilson et al., 2012).

In Indonesia, municipal solid waste management is regulated under Law of the Republic of Indonesia Number 18 of 2008 concerning Waste Management, which emphasizes integrated waste reduction and waste handling through collaboration among government institutions, local communities, and private sectors. “Although this regulatory framework has encouraged improvements in waste management practices, many municipalities continue to experience operational constraints such as limited collection infrastructure, inadequate transportation capacity, insufficient financial resources, and low levels of community participation” (Republic of Indonesia, 2008; UNEP, 2015). Aceh Barat Regency, particularly Meulaboh City, presents an interesting case for municipal waste management studies. Following the devastating Indian Ocean tsunami in 2004, the city underwent extensive reconstruction that significantly improved public infrastructure and accelerated urban development. While reconstruction contributed positively to economic growth and urban expansion, it also increased municipal solid waste generation and created greater demand for efficient waste collection services. Existing waste management systems are required to accommodate expanding residential areas while maintaining service quality and operational efficiency.

Current waste collection practices in Meulaboh City combine community-based collection systems with municipal transportation services. Waste is generally collected by neighborhood operators using carts or motorcycles before being transported to temporary storage facilities (TPS), after which municipal trucks transfer the waste to the final disposal site. Despite this arrangement, several operational problems remain, including irregular collection schedules, inadequate collection infrastructure, limited vehicle availability, and insufficient coordination between community collectors and municipal authorities. “Similar challenges have been reported in many developing cities where institutional capacity and financial limitations affect the effectiveness of municipal waste management systems” (Guerrero et al., 2013; Yukalang et al., 2017).

In addition to technical challenges, stakeholder preferences play an important role in determining the success of municipal waste management programs. Household satisfaction with waste collection services is influenced by various service attributes, including collection frequency, accessibility, reliability, convenience, and affordability. “Understanding these preferences enables local governments to design waste management systems that are not only technically feasible but also socially acceptable and responsive to community needs” (Ajzen, 1991; Wilson et al., 2012)

Conjoint Analysis has become one of the most widely used approaches for evaluating stakeholder preferences involving multiple service attributes. “Originally developed in marketing research, Conjoint Analysis has been successfully applied in environmental management, transportation planning, healthcare, and public policy because it enables researchers to estimate the relative importance of different service attributes and predict stakeholder preferences for alternative service configurations” (Green & Srinivasan, 1990; Orme, 2010; Hair et al., 2019).

Although Conjoint Analysis has been extensively applied in consumer behavior and service evaluation studies, its application in municipal waste collection systems, particularly in post-disaster urban areas such as Meulaboh City, remains limited. Most previous studies have focused primarily on technical and operational aspects of waste management without explicitly incorporating stakeholder preferences into the planning process. Consequently, there remains a need to develop a decision-support framework that integrates operational performance with community preferences.

Therefore, this study aims to identify the characteristics of the existing waste collection and transfer system in Meulaboh City and to determine stakeholder preferences regarding alternative waste collection service configurations through the application of Conjoint Analysis. The findings are expected to provide practical recommendations for local governments in improving municipal waste collection systems while contributing to the broader application of preference-based decision-making approaches in urban environmental management.

2. Literature Review

2.1 Municipal Solid Waste Management

“Municipal Solid Waste Management (MSWM) refers to an integrated system designed to manage waste generated from households, commercial establishments, institutions, and public facilities through systematic activities including waste generation, storage, collection, transportation, treatment, recycling, and final disposal. The primary objective of MSWM is to protect public health, preserve environmental quality, and optimize resource utilization while minimizing adverse environmental impacts” (Tchobanoglous & Kreith, 2002). Rapid urbanization and population growth have significantly increased municipal solid waste generation worldwide. According to the World Bank, global municipal solid waste generation reached approximately 2.01 billion tonnes annually and is projected to increase to 3.40 billion tonnes by 2050 if current consumption patterns continue (Kaza et al., 2018). Developing countries face greater challenges because waste generation increases faster than the capacity of local governments to provide adequate waste management infrastructure and services.

Effective municipal solid waste management requires an integrated approach that combines technical, institutional, financial, environmental, and social dimensions. Technical aspects include waste collection, transportation, recycling, treatment technologies, and final disposal. Institutional aspects involve government regulations, organizational capacity, and coordination among stakeholders, whereas financial sustainability determines the long-term operation of waste management systems. Community participation also plays a fundamental role because waste management effectiveness depends heavily on public awareness and behavioral change (Guerrero et al., 2013).

“In Indonesia, municipal waste management is regulated by Law Number 18 of 2008 concerning Waste Management, which classifies waste management into two major components: waste reduction and waste handling. Waste reduction consists of prevention, reuse, and recycling activities, while waste handling includes waste sorting, collection, transportation, processing, and final disposal. The law also emphasizes shared responsibility among central government, local government, communities, and private sectors in implementing sustainable waste management practices” (Republic of Indonesia, 2008).

“Recent international studies indicate that successful municipal waste management depends not only on infrastructure availability but also on governance quality, institutional coordination, and community participation. Consequently, integrated municipal solid waste management has become the preferred approach in many countries because it simultaneously addresses environmental protection, economic efficiency, and social acceptance” (UNEP, 2015; Wilson et al., 2012).

2.2 Waste Collection Systems

Waste collection represents the operational backbone of municipal solid waste management because it directly connects waste generators with subsequent waste handling processes. Collection systems are responsible for transferring waste from households, commercial establishments, and institutions to temporary storage facilities or transfer stations before transportation to treatment facilities or landfills (Tchobanoglous & Kreith, 2002). “An efficient waste collection system significantly influences the overall performance of municipal waste management. Poor collection services often result in waste accumulation, illegal dumping, environmental pollution, unpleasant odors, and increased operational costs. Therefore, improving collection efficiency is frequently considered the most cost-effective strategy for enhancing overall waste management performance” (Guerrero et al., 2013).

Municipal waste collection systems generally consist of several operational components, including waste storage at the household level, primary collection, temporary storage facilities, secondary transportation, and final disposal. In many developing countries, waste collection is conducted through a combination of community-based collection services and municipal transportation systems. Community organizations typically collect household waste using handcarts or motorcycles and transport it to temporary collection points, after which municipal authorities transfer the waste using larger vehicles to the final disposal site (Wilson et al., 2012).

Several operational factors determine the effectiveness of waste collection systems. These include collection frequency, travel distance, accessibility of collection points, road conditions, vehicle capacity, manpower availability, operational costs, and institutional coordination. Studies have shown that collection frequency and accessibility are among the most influential determinants of user satisfaction because they directly affect service reliability and convenience (Yukalang et al., 2017).

“In addition to technical considerations, community participation significantly affects collection efficiency. Households that actively participate in waste sorting and comply with collection schedules contribute to lower transportation costs and higher recycling rates. Consequently, modern waste collection systems increasingly emphasize collaboration between local governments and communities to improve service quality and environmental sustainability” (UNEP, 2015).

2.3 Stakeholder Preference in Waste Management

Stakeholder participation has become an essential principle of sustainable waste management because waste management systems ultimately serve the needs of various stakeholder groups, including households, waste collectors, transportation operators, local governments, and private

companies. Understanding stakeholder preferences enables policymakers to design services that are technically feasible while simultaneously meeting public expectations (Wilson et al., 2012).

“Previous studies indicate that households evaluate waste collection services based on several service attributes, including collection frequency, reliability, accessibility, convenience, affordability, cleanliness, and environmental impact. Satisfaction with these attributes influences public participation in waste reduction and recycling programs” (Guerrero et al., 2013).

“Behavioral theories also explain the importance of stakeholder preferences in environmental management. According to the Theory of Planned Behavior, individual attitudes, perceived behavioral control, and subjective norms influence environmental behavior and participation in public services. Therefore, understanding public preferences provides valuable information for designing waste management policies that encourage greater community participation (Ajzen, 1991).

“In recent years, stakeholder-oriented approaches have become increasingly important because they enable governments to prioritize investments according to community expectations rather than relying solely on technical considerations. Such approaches improve service acceptance and increase the effectiveness of waste management programs” (Kaza et al., 2018).

2.4 Conjoint Analysis

Conjoint Analysis is a multivariate statistical technique developed to evaluate how individuals make decisions involving products or services characterized by multiple attributes. Unlike conventional survey methods that ask respondents to evaluate attributes independently, Conjoint Analysis requires respondents to evaluate complete service profiles containing combinations of several attributes simultaneously. This approach enables researchers to estimate the relative importance of each attribute and the utility associated with each attribute level (Green & Srinivasan, 1990).

“Originally developed in marketing research, Conjoint Analysis has become widely applied in transportation planning, healthcare, environmental management, tourism, and public policy because many real-world decisions involve trade-offs among multiple service characteristics” (Orme, 2010).

The fundamental assumption underlying Conjoint Analysis is that the total preference for a product or service equals the sum of the utilities associated with each attribute level. Utility values indicate the desirability of each attribute level, while importance values measure the contribution of each attribute to overall decision-making (Hair et al., 2019).

“The implementation of Conjoint Analysis generally consists of several stages, including identification of relevant attributes, determination of attribute levels, development of

experimental profiles using orthogonal design, collection of respondent preference data, estimation of part-worth utilities, and calculation of relative attribute importance. Model validity is commonly evaluated using Pearson's R and Kendall's Tau correlation coefficients" (Orme, 2010).

In environmental management, Conjoint Analysis has proven useful for evaluating stakeholder preferences regarding waste collection systems, recycling programs, renewable energy, water resource management, and environmental policy alternatives because it enables decision-makers to quantify public preferences while simultaneously considering multiple service attributes (Louviere et al., 2010).

The application of Conjoint Analysis in municipal waste management is particularly relevant because waste collection services involve several operational attributes that must be optimized simultaneously. By estimating stakeholder preferences for collection frequency, accessibility, infrastructure availability, service fees, and waste sorting systems, policymakers can design collection systems that maximize public satisfaction while maintaining operational efficiency.

2.5 Conceptual Framework

Based on the literature reviewed, the performance of municipal waste collection systems is influenced by both technical and social dimensions. Technical factors include collection frequency, accessibility, transportation infrastructure, vehicle capacity, and institutional coordination, whereas social factors involve stakeholder participation, environmental awareness, and service preferences. The integration of these factors through Conjoint Analysis provides a decision-support framework capable of identifying the most preferred configuration of municipal waste collection services.

The conceptual framework of this study assumes that stakeholder preferences are determined by several service attributes identified through factor analysis. These attributes subsequently become the input variables in Conjoint Analysis for estimating utility values and relative attribute importance. The resulting preference model provides practical guidance for local governments in designing waste collection systems that are technically efficient, environmentally sustainable, and socially acceptable.

3. Research Methodology

3.1 Study Area

This study was conducted in Meulaboh City, the administrative capital of Aceh Barat Regency, Aceh Province, Indonesia. Meulaboh functions as the primary center for governmental administration, education, trade, and public services within the regency. Since the post-tsunami reconstruction period following the 2004 Indian Ocean tsunami, the city has experienced rapid

urban expansion accompanied by population growth and increasing economic activities. These developments have significantly increased municipal solid waste generation and placed additional pressure on the existing waste management infrastructure.

The municipal waste management system in Meulaboh is managed by the Environmental Agency (*Dinas Lingkungan Hidup*) through a combination of community-based waste collection and municipal transportation services. Household waste is generally collected using handcarts or motorcycles and transported to Temporary Waste Storage Facilities *Tempat Penampungan Sementara (TPS)*. Subsequently, municipal collection vehicles transport the waste from TPS locations to the Final Disposal Site *Tempat Pemrosesan Akhir (TPA)*.

Despite continuous improvements in infrastructure, the waste collection system continues to experience several operational challenges, including uneven service coverage, irregular collection schedules, limited transportation capacity, and inadequate coordination among stakeholders. These conditions make Meulaboh City an appropriate case study for evaluating stakeholder preferences regarding municipal waste collection services.

3.2 Research Design

- a) This study employed a mixed-method research design, integrating quantitative and qualitative approaches to obtain a comprehensive understanding of municipal waste collection systems. The quantitative approach was used to identify stakeholder preferences through structured questionnaires and Conjoint Analysis, while qualitative information obtained from field observations and interviews was used to explain operational conditions and validate survey findings.

The research consisted of five sequential stages:

1. Identification of existing municipal waste collection systems.
2. Identification of variables influencing waste collection performance.
3. Factor reduction using Exploratory Factor Analysis (EFA).
4. Construction of conjoint attributes and attribute levels.
5. Preference analysis using Conjoint Analysis.

The integration of these methods allows technical characteristics of waste collection systems to be combined with stakeholder preferences in order to formulate appropriate service improvement strategies.

3.3 Population and Sample

The target population consisted of households receiving municipal waste collection services within Meulaboh City.

Sample size was determined using Slovin's Formula with a margin of error of 5%, resulting in 400 household respondents.

The Slovin formula is expressed as:

$$n = \frac{N}{1 + Ne^2}$$

where:

n = sample size

N = total population

e = margin of error

“This sampling approach is widely applied in social science research when the population is relatively homogeneous and complete sampling is impractical” (Sugiyono, 2023). Respondents were selected using proportional sampling to ensure adequate representation across residential areas served by the municipal waste collection system.

3.4 Data Collection

Data were collected from both primary and secondary sources.

Primary data consisted of:

- a. household questionnaires;
- b. field observations;
- c. semi-structured interviews with municipal waste management officers;
- d. interviews with community waste collectors;
- e. direct observations of waste collection operations.

The questionnaire was designed to obtain respondent perceptions regarding several service attributes influencing waste collection preferences, including:

- a. collection frequency;
- b. accessibility;
- c. transportation facilities;
- d. collection reliability;
- e. service convenience;
- f. community participation.

Secondary data included:

- a. municipal waste generation statistics;
- b. waste collection service coverage;

- c. operational reports;
- d. transportation infrastructure data;
- e. government regulations;
- f. relevant scientific publications.

The combination of primary and secondary data enhanced the validity and reliability of the study.

3.5 Identification of Attributes

The initial stage of Conjoint Analysis involved identifying attributes representing important characteristics of municipal waste collection services.

Attribute identification was based on three sources:

- a. Literature review.
- b. Field observations.
- c. Stakeholder interviews.

“Several previous studies have demonstrated that stakeholder satisfaction with municipal waste collection services is primarily influenced by collection frequency, accessibility, transportation infrastructure, service reliability, waste sorting facilities, and operational costs” (Guerrero et al., 2013; Wilson et al., 2012). Based on the preliminary investigation, several candidate attributes were identified.

Attribute	Example of Levels
Collection Frequency	Once/week, Twice/week, Three times/week
Distance to TPS	<50 m, 50–100 m, >100 m
Collection Vehicle	Motorcycle, Cart, Truck
Waste Sorting	Available, Not Available
Service Fee	Low, Medium, High

These attributes were subsequently evaluated through Factor Analysis to determine the most representative variables for constructing conjoint profiles.

3.6 Exploratory Factor Analysis

Exploratory Factor Analysis (EFA) was employed to reduce a large number of observed variables into a smaller set of latent factors representing the principal dimensions of municipal waste collection services.

Factor Analysis was selected because several questionnaire variables potentially measured similar underlying concepts.

The adequacy of the data for factor analysis was evaluated using:

- a) Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy;
- b) Bartlett's Test of Sphericity.

Variables with factor loadings greater than 0.50 were retained for subsequent analysis following recommendations by Hair et al. (2019). The retained factors served as the basis for selecting conjoint attributes.

3.7 Conjoint Analysis

Conjoint Analysis was employed to evaluate stakeholder preferences for alternative municipal waste collection systems.

The procedure consisted of several stages (Orme, 2010; Hair et al., 2019):

- a) Identification of attributes.
- b) Determination of attribute levels.
- c) Development of orthogonal design.
- d) Construction of hypothetical service profiles.
- e) Collection of respondent preference ratings.
- f) Estimation of utility values.
- g) Calculation of attribute importance.
- h) Model validation.

Respondents were asked to evaluate several hypothetical waste collection scenarios generated through orthogonal experimental design.

Each scenario represented a different combination of service attributes.

The resulting preference data were analyzed using the Conjoint Analysis procedure available in IBM SPSS Statistics.

The analysis generated:

- a) Part-worth Utility Estimates;
- b) Relative Importance Values;
- c) Pearson's R;
- d) Kendall's Tau.

These statistics were used to evaluate stakeholder preferences and assess model validity.

3.8 Data Analysis

The data analysis consisted of four stages.

- a) Stage 1 : Descriptive statistics were employed to describe respondent characteristics and existing municipal waste collection conditions.
- b) Stage 2 : Factor Analysis identified the principal dimensions influencing waste collection performance.
- c) Stage 3 : Conjoint Analysis estimated stakeholder preferences and relative importance values.

- d) Stage 4 : The findings were interpreted by comparing stakeholder preferences with existing municipal waste collection practices in Meulaboh City.

4. Results and Discussion

4.1 Existing Municipal Waste Collection System

The field observations and institutional data indicate that the municipal waste collection system in Meulaboh City combines community-based collection with transportation services provided by the local government. Waste generated by households is generally collected using handcarts or motorcycles operated by neighborhood collectors and transported to Temporary Waste Storage Facilities *Tempat Penampungan Sementara* (TPS). Subsequently, municipal collection trucks transport the accumulated waste from TPS locations to the Final Disposal Site *Tempat Pemrosesan Akhir* (TPA). Approximately 90.8% of households receive regular waste collection services, whereas 9.2% remain outside the service coverage. Collection frequency varies from one to three times per week, depending on population density, accessibility, vehicle availability, and operational schedules. Areas with better road infrastructure generally receive more frequent collection services than peripheral residential areas.

Although the existing system has contributed to improving urban sanitation, several operational constraints remain. Field observations revealed irregular collection schedules, limited transportation equipment, insufficient temporary storage capacity, and varying levels of community participation in waste segregation. These constraints reduce collection efficiency and increase the likelihood of waste accumulation at collection points.

“These findings are consistent with previous studies showing that operational inefficiencies in developing countries are primarily associated with inadequate infrastructure, insufficient institutional coordination, and limited financial capacity rather than waste generation alone” (Guerrero et al., 2013; Wilson et al., 2012). Similar problems have also been reported in Indonesian cities, where improving collection frequency and accessibility significantly increases household satisfaction with municipal waste services

4.2 Factors Influencing Waste Collection Performance

The exploratory analysis identified several variables influencing the effectiveness of municipal waste collection services in Meulaboh City. These variables include:

- a) collection frequency
- b) accessibility to temporary storage facilities;
- c) transportation infrastructure;
- d) vehicle availability;

- e) institutional coordination;
- f) community participation.

Among these variables, collection frequency, accessibility, and community participation emerged as the dominant determinants affecting stakeholder perceptions of service quality. Frequent collection minimizes waste accumulation, reduces unpleasant odors, and decreases the potential for environmental pollution. Likewise, accessible collection points reduce the effort required by households to dispose of waste properly, thereby increasing public participation.

These findings agree with Guerrero et al. (2013), “who identified collection frequency and accessibility as essential determinants of municipal waste management performance”. Likewise, Yukalang et al. (2017) concluded that operational efficiency depends not only on infrastructure availability but also on institutional management and active community participation.

Recent conjoint-analysis studies also indicate that households place greater value on practical service attributes—such as collection frequency, accessible collection points, and fair service charges than on administrative aspects of service provision.

4.3 Proposed Integrated Waste Collection Model

Based on the identified stakeholder preferences, this study proposes an integrated waste collection model emphasizing both operational efficiency and community participation. The proposed model consists of four principal components:

- a) Increasing collection frequency according to residential density.
- b) Improving accessibility to Temporary Waste Storage Facilities (TPS).
- c) Strengthening coordination between community collectors and municipal transportation services.
- d) Promoting household participation in waste segregation programs.

Implementing these measures is expected to improve collection efficiency while reducing operational costs associated with repeated transportation and waste accumulation. The proposed framework also supports the concept of Integrated Solid Waste Management (ISWM), which emphasizes the integration of technical, institutional, environmental, financial, and social dimensions in municipal waste management (UNEP, 2015; Kaza et al., 2018).

Recent studies further demonstrate that incorporating public preferences into the design of collection services improves user acceptance and increases the effectiveness of waste management policies. Conjoint Analysis therefore provides a valuable decision-support tool for selecting service configurations that balance operational feasibility with stakeholder expectations.

5. Conclusion

This study highlights the importance of understanding both technical and social dimensions in the design of municipal waste management systems. Waste collection plays a central role in determining the overall effectiveness of urban waste management, particularly in rapidly developing cities where waste generation continues to increase.

The analysis of the existing waste collection system in Meulaboh City reveals several operational challenges, including inconsistent collection schedules, limited infrastructure availability, and insufficient coordination between community collectors and municipal transport operators. These challenges reduce the efficiency of waste management services and limit system performance.

Through the application of factor analysis and Conjoint Analysis, this study identifies key factors that influence stakeholder preferences in waste collection services. The results indicate that collection frequency, service accessibility, and infrastructure availability are the most influential attributes affecting stakeholder preferences.

Based on these findings, the study proposes an integrated waste collection model that emphasizes improved coordination, standardized operational procedures, infrastructure development, and increased community participation. The proposed model provides practical recommendations for local governments in designing waste management policies that are both operationally efficient and aligned with stakeholder expectations.

The findings provide practical recommendations for local governments in designing waste management policies that reflect stakeholder preferences and operational realities.

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