Cleaner Waste Systems 2 (2022) 100019

Contents lists available at ScienceDirect

Cleaner Waste Systems

journal homepage: www.journals.elsevier.com/cleaner-waste-systems

Cost-effectiveness of incentive schemes for waste material resource recovery

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ARTICLE INFO

Keywords:
Recovery
Revenue
Cost-effectiveness
Municipal Solid Waste
Resource
Options
Incentives
Recyclable

ABSTRACT

The use of incentives to support positive behaviors in waste separation and recycling has been renowned in the literature. However, empirical literature on waste separation has paid more attention to the characterization of waste and the potential use of incentives, neglecting the cost implications of employing incentives in recycling schemes. Although studies have pined incentives as having the potential to increase recycling rates, their cost implications may also constitute a disincentive for effective recycling schemes. This study was conducted to identify the most cost-effective incentive option for recovering waste materials to inform policy decisions on prioritizing incentive options for efficient recycling. A source separation scheme was piloted in Tamale, where different incentive schemes (bonus, prize and waste receptacles) were given to households. The cost implications of using the incentives were evaluated based on the cost and revenue of recovering separated material resources from households under each of the schemes. This was followed by the use of a cost-effectiveness model to assess the cost-effectiveness of the schemes. The institution of a "prize" as a reward, in addition to the provision of storage facilities to participating households, was identified as the most cost-effective incentive option that generated the highest amounts of separated material resources at a relatively lower cost. Again, the study showed that the cost-effectiveness of the schemes depended on the incentive type and the service zones where the schemes were instituted.

1. Introduction

The availability of funds for solid waste management in cities across countries is a challenge for city authorities (Lohri et al., 2014; Oteng-Ababio, 2010; Asase et al., 2009). In Ghana, studies have shown that many municipalities are financially constrained due to the huge budget needed for solid waste management in their jurisdiction (Oteng-Ababio, 2010; Asase et al., 2009). This problem has been mainly attributed to low-cost recovery in the country`s waste management system. In an attempt to overcome low-cost recovery in solid waste management in Ghana, a fixed monthly waste collection fee of Gh¢ 30 for a 240-l bin and Gh¢ 20 for a 120-l bin and variable charges for waste disposal at the communal skips has been instituted in some communities in the country. However, the payment systems are saddled with difficulties such as non-payment of user fees, inequitable charges and weak legal mechanisms to recover payment arrears (Oduro-Kwarteng et al., 2015; Asare et al., 2015). Furthermore, some municipalities in the country have not yet implemented a payment fee for the disposal of waste in communal skips in some communities. This has placed a huge financial burden on the Metropolitan, Municipalities and District Assemblies (MMDA`s) and has contributed to the ineffectiveness of the waste management services in the country.

Nonetheless, a report by the Department of Environmental Affairs of South Africa (2011) has specified that there is no defined modality for cost-effectiveness in solid waste management and for that matter, the cost structure depends on mixed modalities aimed at achieving cost-efficiency in the management system. Consequently, achieving cost efficiency in solid waste management requires a combination of schemes of service options that may lead to optimal service provision. A study by Wahabu et al. (2014) showed that the lifespan of landfills in Ghana can be prolonged through waste diversion from the landfills. There is also a potential benefit of revenues from source separation programs from the recoverable waste material resources that can support the management system (Tang, 2012). Again, the separation of waste at the source of generation is known to be a basic means of creating value and reducing costs in an integrated waste management

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https://doi.org/10.1016/j.clwas.2022.100019
Received 24 November 2021; Received in revised form 20 June 2022; Accepted 19 July 2022

system (Schübeler et al., 1996; Liebenberg, 2007; Hargreaves et al., 2008).

Studies have also shown that rewards schemes can be used to promote waste separation behavior and are preferred over fines used to promote positive recycling behavior (e.g., Asare et al., 2020; Amini et al., 2014; Shaw and Maynard, 2008; Thøgersen, 2003). However, economic incentives, although regarded as instruments that can motivate waste generators to recycle their waste and/or act according to the public interest (Thøgersen, 2003; Deci et al., 1999) come with financial implications. Happenhofer et al. (2017), asserted that, the financing of a reward in itself may constitute a cost factor in a recycling scheme.

According to Qiu (2012), and Inter-American Development Bank (2003) cited in Happenhofer et al. (2017), one of the criteria to consider in choosing instruments for sound environmental management is its economic cost-effectiveness.

Based on these conditions, a cost-effectiveness analysis of waste separation reward schemes is needed to guide and support city authorities in decision-making on the adoption of the most cost-effective motivational option that may support the recovery of waste resources in a recycling scheme. For this reason, the cost-effectiveness ratio is one of the valuable tools that allow for the comparison of different options to guide decision-makers and stakeholders to prioritize specific options and to help choose the most cost-effective and beneficial alternative to focus on to achieve a set of objectives (Murray et al., 2000).

In Ghana, most waste collected comprising of both recyclables and organics is dumped together in the landfills without any resource recovery. Almost all recycling activities in the country are informal with a low recovery rate of about 2 % (Thompson, 2010). The institution of recycling schemes across the MMDA`s in the country can be a means to reduce the volumes of waste that goes to landfills and contribute to the reduction of costs in the management system. However, the participation of households in recycling schemes is important for improving recycling rates. Therefore, information on how to improve recycling rates is crucial to help Metropolitan, Municipal and District Assemblies (MMDAs) to develop strategic plans directed at the source for optimum recycling. There have been several studies both internationally and in Ghana on solid waste characterization and solid waste source separation behavior, of which some of the studies identified the provision of incentives as motivation for household's participation in waste separation schemes and also, as a means to improve waste separation and recycling behavior (e.g., Abila and Kantola, 2019; Oduro-Kwarteng et al., 2016; Xu et al., 2015; Asare et al., 2015; Zen et al., 2014; Miezah et al., 2015; Owusua et al., 2013; Mensah, 2010). However, none of the studies investigated the cost implications of employing different incentive options in waste separation schemes in different income-class service zones and the options that can improve the material resources recovery rate in the service zones at minimum cost. The concentration has been on generation rates, compositional analysis and qualitative data on waste separation behavior, which is just part of the needed data input for the effective design of the source separation programmes. Therefore, there are limited records on the most cost-effective incentive option to support the recovery rate of materials resources at the household level. Empirically assessment of cost recovery potentials of different incentive schemes is therefore needed to ascertain how incentives affect cost and material resources recovery rate to inform interventions in the recycling sector. Hence, this study focus on four objectives 1. assess the cost and revenue of the different incentives, 2. evaluate the cost-effectiveness of incentive options and 3. Identify the most cost-effective incentive option that maximized the materials recovery rate. 4. assess the factors that influenced income in the scheme.

Though source separation may be perceived as cost-intensive, a systematic analysis within the local context is what is needed to either support or disprove this assertion. This study was designed to provide scientific-based information on the potential cost recovery and the cost-effectiveness of different incentives schemes for the recovery of material resources to inform policy decisions and interventions on the formalization of recycling schemes in Ghana. The study was designed to provide the necessary data that will inform policy decisions to advance incentives in organized recycling schemes in Ghana. Again, the objective was to assist city authorities, industries, governments, and waste management companies in implementing incentives and employing the most cost-effective incentives to achieve the recycling target in recycling schemes.

This study is one of the few studies conducted in Ghana that focused on assessing the cost effectiveness of different incentive schemes to recover Municipal Solid Waste (MSW) material resources. Again, empirical analysis of different incentive schemes and their influence on the cost of material recovery is limited in the literature. This study fills the knowledge gap in the literature on the cost recovery potentials of different incentive schemes for material-improved resource recovery in recycling schemes. The findings of this study are expected to be useful to city authorities, industry, waste management companies, academia, and the government on the incentives to use in a recycling scheme to ensure improved resource recovery, and material flow in recycling schemes.

2. Literature review

Earlier studies on motivation for waste separation indicated that external interventions may enhance internalized motivation (Deci et al., 1999; Nyborg, 1999). This is supported by Thøgersen (2003) who asserted that governmental regulations communicates norms and responsibilities and may enhance internalized motivation in the form of a moral norm. Gibovic and Bikfalvi (2021) study in Spain indicated that the varied incentives introduced influence households' recycling habits positively. Thøgersen (2003) study showed that weight-based garbage fees promoted more garden composting and materials recycling than fixed garbage collection fees. A study by Asare et al. (2020) established that the resource recovery rate for waste materials depend on incentive type and service zone. Again, Thøgersen (2003) study establishes that economic incentives had a positive effect on behavior, and this is facilitated through perceived self-efficacy. When the desired behavior is rewarded by incentive it produces positive feedback on the recipient`s competence vis-à-vis the behavior (Deci et al., 1999). The purpose of providing economic incentives is to affect the costs and benefits of producing sound environmental behavior to make it more profitable for the individual to behave per collective interest (Kinnaman and Fullerton, 2000).

According to Happenhofer et al. (2017) the setting up of a bring site (drop-off) could cause additional costs resulting from procurement and management of the reward scheme. However, this can be minimized through monitoring; and one way of doing this is to capture individual credit through a combination of a weighing system with an individualized chip card or allocation of a reward per piece or kilogram of material (Ehrengruber, 2016 cited in Happenhofer et al., 2017). Happenhofer et al. (2017), stated that reward is appropriate for a waste stream that generates revenues from its sale and concluded that thinking through financing mechanisms for waste separation could be a possible way of developing a more reasonable fee structure for the scheme. They also communicate that certain waste materials are valuable secondary resources and not costly by-products of society. Again, they indicated that the implementation of an innovative incentive scheme is reasonable to evaluate the actual effects of the incentive on recycling behavior and material quantities.

The Abila and Kantola (2019) study in Finland reported a significant effect of financial incentives on recycling. Kaden (2010) study in the US tested different variables on recycling participation and found a significant effect of economic incentives; bottle-bill and pay-as-you-throw systems on the recycling participation rate. However, the probability values differed, indicating that the contribution of the two incentives to participation in recycling was different. This means that different incentives may have different effects on recycling. Similar findings were

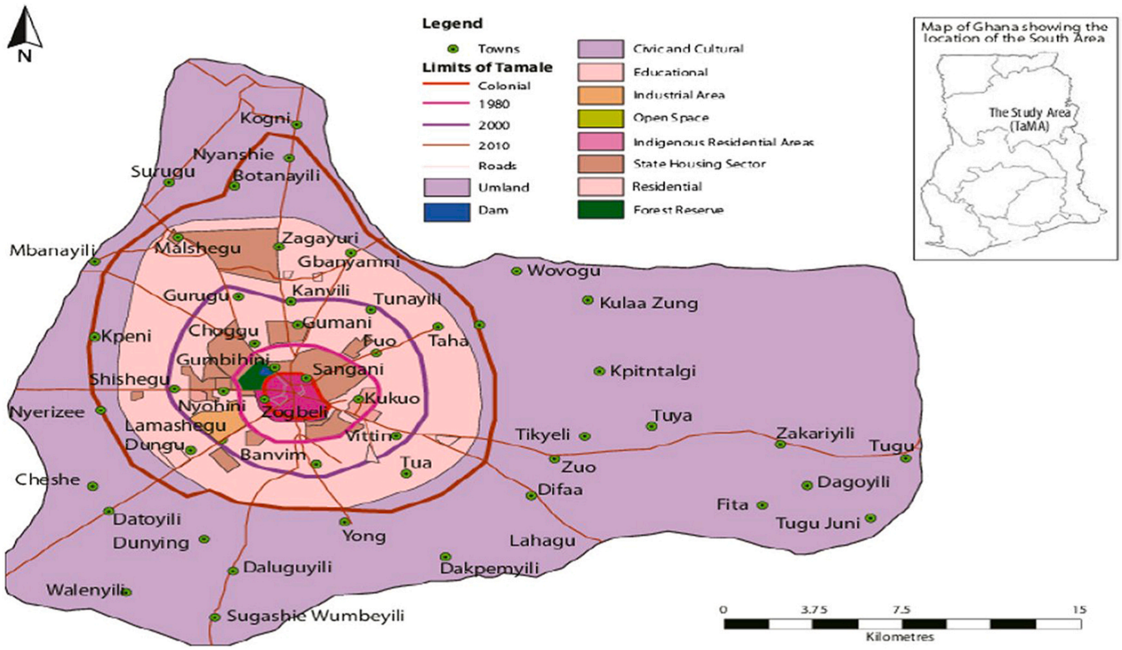


Fig. 1. Map of Tamale Metropolitan area
(Source: Gyasi et al. (2014)).

reported by Asare et al. (2020) in their study in Ghana. The earlier study by Hong and Adams (1999), investigated the role of waste disposal service fees and household characteristics in determining recycling rates and waste generation and found out that the choice of container size was not affected by the price of waste disposal services; however, within a given container size, households responded to the price increase by increasing recycling to avoid extra charges for increased volumes.

Tonjesa et al. (2018) modeled the estimate of system economics for paper products and found that the implementation of single-stream recycling can increase operator revenues. This shows that a critical analysis of incentives in economic terms is needed to support effective solid waste recycling. The Cialani and Mortazavi (2020) study in Italy indicated that cost implications in waste recycling depend on recycling rates and that as long as efficient levels are not exceeded, waste recycling is more cost-effective. Similar findings were reported by Tonjes and Mallikarjun (2013). Therefore, regulation of the recycling rate is needed at some point in recycling schemes to reduce costs. However, there may also be a need to ensure that the right incentive is in place that can be easily regulated to support effective recycling. Smith and Mazur (2014), stated that, a critical step in the development of policy toward product-based economic instruments is the selection of instruments that are appropriate to address particular environmental problems and the policy objectives. According to Smith and Mazur (2014), the instruments may have different strengths and weaknesses, and may only be suitable for use in certain contexts and applications. Therefore, in considering the potential scope for applying product-based economic instruments, "the limits to the effectiveness and cost efficiency of these instruments must be understood" (Smith and Mazur, 2014; page 22). Hence, context analysis of the cost of incentives for recycling is therefore needed to support policy decisions on solid waste recycling.

3. Materials and methods

3.1. Study area information

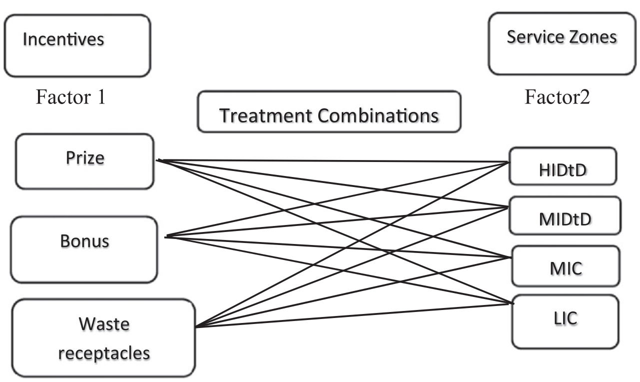
The study was conducted in the Tamale metropolis and Sagnarigu municipality due to the joint waste management system in these areas. Tamale is considered one of the fastest-growing cities in Ghana, with an annual population growth rate of 3.5 %. Tamale has a population of 223,252. The metropolis lies between latitudes 9°16 and 9°34 North and longitudes 0°36 and 0°57 west (Ghana statistical service, 2016). The study was centered on the urbanized areas in the metropolis due to the availability of waste management services in those areas as compared to the peri-urban areas. Again, a higher fraction (80.8 %) of the Tamale residents live in urban areas, and therefore the high population density in the city center may influence the waste generation and its management in the city.

The Metropolis employs two waste collection namely: communal collection using skips and house-to-house (door-to-door collection). Solid waste collection in the area is done through the government partnership with private solid waste management companies. However, commercial establishments, institutions and households have the option to opt for house-to-house waste collection and disposal services. For these services, they pay a monthly fee of GH20 for a 120-l waste bin and GH30 for a 240-l waste bin. However, those who depend on skips for waste disposal do not pay for the service. This in addition to delays in payment of waste disposal fees by door-to-door subscribers as well as the delay in the disbursement of funds by the central government to the Assembly has presented the challenge of ineffective solid waste management in the Metropolis. Thousand five hundred (1500) tons of solid waste are estimated to be generated daily, with monthly expenditure of GH 120,000 on solid waste management in the Metropolis (WMD TMa (Waste Management Department data, Tamale Metropolitan Assembly), 2017). However, waste generated in the Metropolis is hauled to the landfill without any formalized system of material resource recovery. Interestingly, the informal sector waste materials deals are very active in the waste buying business in the area. This represents opportunity for city authorities to institute a formalized material recovery system to support efficient solid waste management in the area. Though some studies have been done in Tamale on waste separation however, this study is the only study that has used the random-effect model to explain the factors that can influence revenue in a recycling scheme. Fig. 1 shows the map of the study areas.

3.2. Data collection

3.2.1. Waste characterization and quantification in the service zones

A separate waste collection scheme was piloted in 12 communities in three different income residential class service areas under two main waste collection modes (door-to-door and communal) in four solid waste management service zones for 12 weeks. Thus, high-income door-to-door (HI), middle-income door-to-door (MI), middle-income communal (MIC), and low-income communal (LIC) services zones. Three communities were selected from each service zone and thirty households from each community. The study employed factorial analysis where service zones (four levels) and incentives (three levels) were the factors. Therefore, the study comprised 12 treatment combinations of service zones and incentives options. Thus, thirty (30) households for each combination. The sample size used for the combinations was based on the sample size used for previous studies (Dagadu and Nunoo, 2011; Asase, 2011). Three incentive options were given to households: incentive 1 = waste storage facilities for each household (waste receptacles), incentive 2 = waste storage facilities for each household and a cash prize of Gh¢ 2.50 a week to three households with the highest recyclables, and incentive 3 = a 30% bonus on salable recyclables and a storage facility for each household. The incentives provided was based on the findings of previous studies which reported incentives as potential motivation to aid households' waste separation (eg. Oduro-Kwarteng et al., 2016; Asare et al., 2015, Owusua et al., 2013; Asase, 2011). The schematic representation of the study is shown below.



Schematic representation of the study design

A multistage sampling technique was used for the study, involving a purposive selection of the service zones and communities based on service modes in the areas and a stratified random sampling technique of households that participated in the program. A waste characterization study was conducted on primary separated waste materials collected from households. Two category separation modes were used in the scheme where households were given two bins (for door-to-door service zones) and sacks for communal service zones to separate the materials into food waste and dry recyclables (paper, metals, glass and plastics). The primary sorted materials from the households were then collected, categorized, and quantified for the various incentive options. Dry recyclables were collected twice a week while food waste was collected daily. This was done to aid the assessment of materials quantities and revenue for each of the incentive options. To make the discussion of results easier, incentives two and three are stated as the prize and the bonus in the text.

3.2.2. The estimation of the cost, revenue, and cost-effectiveness of the incentive options and factors that influence revenue in the waste separation scheme

The unit cost method was used to estimate the costs and revenue generated under each option following other studies (Greco et al., 2015; Christensen and Dysert, 2003). The revenue generated was based on the unit price per kilogram of salable recyclable materials at the informal market centers. Cost-effectiveness analysis was used to assess the cost and effects associated with each incentive option.

The cost-effectiveness (CE) of the incentive options were estimated from the total cost and the total outcome (materials yield) for each option. The CEA measures costs in a common monetary value (in Gh¢) and the effectiveness of an option in terms of physical units (waste material resource yield (kg)). Cost-effective ratio = $\frac{C}{E}$ where: C is the cost of the option (in GH¢), and E is the effects of the option. The option with the lowest cost-effectiveness (CE) value was considered the most cost-effective option for waste material resource recovery.

A random effect model was developed to establish the factors that influence household revenue from separated waste resources. This was done to assess how incentives and household characteristics can improve revenue in recycling scheme. Revenue was set as the dependent variable against incentives, services zones, and other explanatory variables such as household socioeconomic variables. The experimental data (revenue) for the study were collected weekly for 12 weeks for the same households, making it panel data. We therefore have data on n $(i = 1, 2, \ldots, 398)$ households over time t $(t = 1,2,\ldots,12)$. The difference in characteristics in 12 weeks may influence the revenue households generate from waste separation. This makes the random-effects model more appropriate for analyzing the factors that affect the revenues of households who participated in the experiment. The underlying assumption for estimating a random-effect model is that the variation between households is random and uncorrelated with the independent variables included in the model.

In this study, y_{it} denotes the revenues that household i generates from waste separation in week t. The interest was to assess the effects of four key explanatory variables on the revenue generated. These variables were the incentive (prize offered (X1), bonus paid (X2)), house type (X3), and service zone (X4). Other variables (Z) were also controlled in the model. The prize offered (X1) and the bonuses paid (X2) are continuous variables. The house type (X3) has four classes (semi-detached, compound, detached, and story-building), while the service zone (X4) also has four categories (middle-income door-to-door, high-income door-to-door, middle-income communal, low-income communal,). The full specification of the random-effects model is as follows:

$$y_{it} = a + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it} + \sum \delta_k Z_{kit} + (\mu_i + v_{it}) \qquad (1)$$

β_1–β_4 and δ_k are unknown parameters we want to estimate, μ_i is a random effect specific to a household while v_t is a random error that is independently and identically distributed with mean zero and constant variance $[v_{it} \sim IID(0, \ \sigma_v^2)]$.

β_1 measures the effect of the prize offered on the amount of revenues generated. A positive value means that a higher prize is associated with a higher revenue generation. In the same way, β_2 measures how much revenue changes given an increase in the bonus paid. A positive value shows that higher bonuses paid are associated with higher revenue generation. In the case of the housing types, β_3 has three forms because of the categorical nature of the variable. In the estimation, three dummy variables were included for three house types, while the last category was used as a benchmark, and so not included in the model. The coefficients associated with the three included dummy variables are interpreted with reference to the omitted category. In this case, a positive coefficient means that households in each included housing type generate revenues that are higher than revenues generated by households in the compound housing type; all other things held constant. A negative coefficient means that households in each included housing type generate revenues less than revenues generated by households in the compound housing type category. A similar interpretation of the parameters can be offered for the type of service zone types. The model was estimated using a generalized least-squares procedure. In all, four (4) different versions of the random effect models were estimated based on the number of the control variables included in the model. This was done as a sensitivity analysis to check whether the extent of the effects of service zones and incentive options would vary as the control variables change.

3.3. Data analysis

Stata 14.0, formulae and estimations were used to analyze the data for averages, separation efficiency of materials recovered, cost, revenue, and the cost-effectiveness of incentive options. A random-effects regression model was used to determine the factors that influence revenue in the recycling scheme. The results obtained from the analysis are presented in tables and graphs.

4. Results and discussions

4.1. Waste composition and generation in the service zones

A waste characterization study was conducted in the service zones for two weeks prior to introducing incentives into the system. The main fractions of waste recorded for the pre-assessment study were food waste, plastics, papers, metals, glass, and other waste. Other waste included inert materials such as ash, sand, and other components such as batteries, spray cans, among others. Food waste was the highest component followed by other waste and plastics.

Food waste was found to be the highest waste component in highand middle-income door-to-door zones, recording higher percentages of 58.72 % and 39.82 %, respectively. Miscellaneous waste materials were high in the low-income communal service zone. This could be due to the inclusion of ashes from local stoves and coal pots and the dust swept from the compounds into the waste stream by the residents in this zone. These findings are in line with other studies by Miezah et al. (2015), Asare et al. (2015), Asase (2011) and Mensah (2010), which found more organic content in the waste stream.

The per capita/day waste generation determined for the service zones indicated a higher per capita/day waste generation rate for the low-income communal zone (0.22 kg) compared to the middle-income door-to-door zone (0.17 kg), middle-income communal (0.15 kg) and the high-income door-to-door (0.16 kg). The higher per capita waste generation recorded for the low-income service zone in the study differed from that of Mensah (2010) and Asase (2011). This may be due to differences in geographical location, household characteristics and other factors (Tchobanoglous and Kreith, 2002). Fig. 2 shows the waste composition in the service zone.

4.2. Material resource recovered and separation efficiency of materials for the incentive options

The results in Fig. 3 show the average waste resources retrieved from the incentive schemes. The results of the study indicate that the reward (prize) as an incentive option produced the highest food waste materials per household during the study period. However, the waste receptacles produced more dry recyclables and food waste materials compared to the bonus, the two incentives(prize and waste receptacles) produced more dry recyclables waste materials per household than food

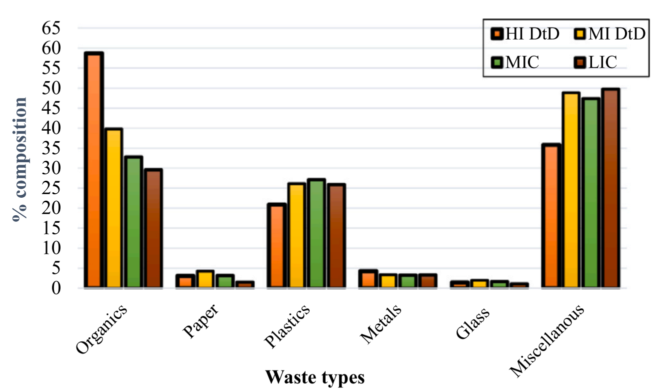


Fig. 2. Waste composition in the service zones.

waste materials resources. In terms of dry recyclable components, the highest quantity of plastics, metals and paper were produced by prize while the least quantities of the materials were produced under bonus. However, the bonus produces more glass waste material resource compared to waste receptacle and the prize. Average material quantities differ for the incentive options.

The observed variations in the average amount of material due to the incentives in this study can be attributed to the effects of the different incentives used and differences in the characteristics of the service zones. This finding is comparable with studies by Kaza et al. (2018) and Hoornweg and Bhada-Tata (2012) which reported differences in waste composition across income levels. The finding of the study is also similar to that of the study by Boonroda et al. (2015), which reported differences in food waste quantities produced by communities and observed high food waste quantities produced under a reward scheme compare to a traditional source separation system.

The recovery of waste materials through the incentive options provide information on the type of incentive to employ to achieve realistic quantities of targeted materials to support material flow in recycling schemes. It also provides information on the amount of material that can be retrieved in time to support a recycling scheme and may be relevant in supporting decisions on incentives choices for improved materials recovery in recycling schemes.

From Table 1, there were variations in separation efficiencies of the target materials in the scheme. The results indicate that incentive option waste receptacles recorded the highest separation efficiency (SE) for food waste and dry recyclables thus, 45.02 %, and 97.87 % respectively. This is followed by the bonus of 41.42 % SE for food waste and 82.31 % separation efficiency for dry recyclables. From the result in Table 1, it can be deduced that the separation efficiency was high for dry recyclables for incentive options compared to that of food waste. This implies that incentives have an influence on materials separation efficiency and therefore can influence the quality of materials separated by households in a recycling scheme. The findings of this study differ from that of Boonroda et al. (2015), which reported higher separation efficiency for food waste in Thailand.The high separation efficiency for dry recyclables can be attributed to the incentives and convenience resulting from the two category separation modes and drop-off collection for households in the communal service areas and the door-to-door collection option for those in the door-to-door collection who participated in the scheme. It can also be attribute to the existence of market for these materials.

Chen et al. (2017) study in China reported the two-way separation mode as the option that yields more effects compared to complex separation modes (e.g. four-category separation modes) for communities. The findings are also in line with studies by Bernstad (2014), Yau (2010), Saphores et al. (2006) who reported economic incentives and convenience as motivation for households' waste separation.

4.3. Economic analysis of the incentive options used in the Waste Separation Programme

The economic value of the recovered waste material resource was estimated for the various incentive options used in the scheme. The materials recovered aligned with the quality of the materials that were in demand in the informal sector and therefore were sold to the informal sector buyers. Revenue was calculated from the unity price (price/kg) of the various materials in the informal waste marketing centers. The revenues are quoted in Ghana cedis with its equivalent in US dollars. The results in Table 2 indicate that prize produced the highest saleable material resources (6656.1 kg) (41.79 %) and revenue of Gh¢ 2909.00 ($484.33). The bonus had the lowest income of Gh¢ 1350.63 ($224.87) and dry recyclables quantity of 3915.1 kg (24.58%) per the study. Estimation of percentage differences showed that the reward produced 22.42 % higher revenue compared to waste receptacles. However, waste receptacles produced 20.08 % more revenue

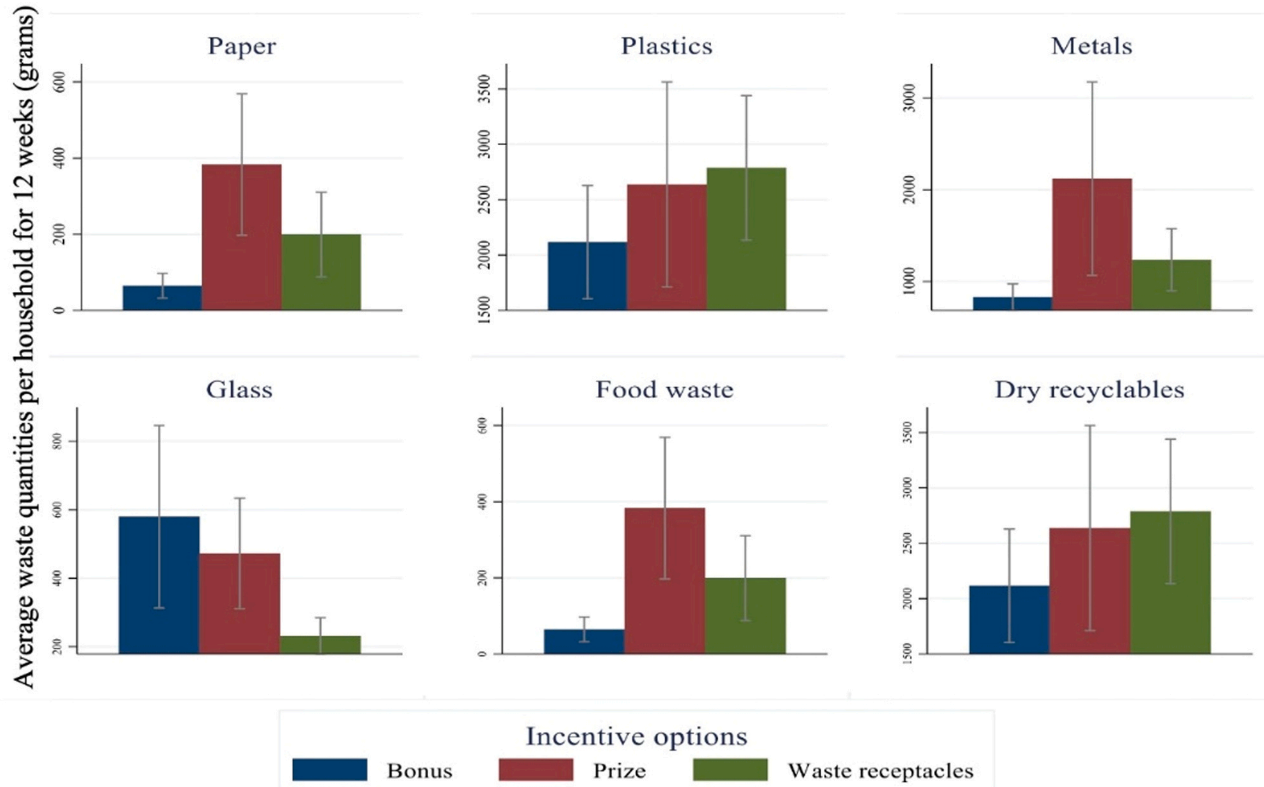


Fig. 3. Separated material resource per household from the incentive options.

Table 1
Separation efficiencies for separated material resources per Incentive options.

Incentive options	Variable	Mean ± SD
Waste receptacles	SE for FW	45.02 ± 45.20
	SE for DR	92.87 ± 8.81
Bonus	SE for FW	41.42 ± 35.10
	SE for DR	82.31 ± 26.48
Prize	SE for FW	36.72 ± 30.39
	SE for DR	65.77 ± 27.06

SE-DR is separation efficiency for dry recyclables, SE-FW is separation efficiency for food waste.

compared to the bonus, while the prize produced 43.47 % more revenue than the bonus. Differences in revenue generation for the incentives indicate that the prize as an incentive has the potential to produce more revenue in recycling schemes compared to waste receptacles and the bonus. In contrast, the estimated revenue from saleable materials per incentive in the service zones shows that the bonus gave the highest revenue of Gh¢328.69 ($54.61) based on 687.6 kg of saleable materials in the high-income door-to-door zone. The revenue generated by the bonus in this zone was 82.98 % higher than that of the prize and 14.51 % higher than that of the waste receptacles. However, the waste receptacles produced 70.59 % more revenue than the reward. In the middle-income door-to-door zone, bonus again produced the highest revenue of Gh ¢ 361.28 ($ 60.03) with 961.7 kg of marketable materials. The revenue produced by the waste receptacles was 41.26% lower than that of the bonus, while that of the prize was 48.37 % lower than that of the bonus. However, waste receptacles produced 7.48 % more revenue than the prize.

The prize realized the highest revenue of Gh¢ 870.20 ($144.59) in the middle-income communal service zone with saleable materials of 1718.7 kg. The revenue produced by the prize in this zone was 33.07 % higher than that of waste receptacles and 75.54 % higher than that of the bonus. The low-income communal zone recorded its highest revenue from prize which produced Gh¢1682.41 ($ 279.54) with 3738.8 kg of saleable materials. The prize produced 50.17 % more revenue compared to waste receptacles in this zone, while the bonus produced 60.77 % less revenue compared to the prize. The difference in revenue generation between the waste receptacles and the bonus was 39.77 %. In terms of revenue generated from materials retrieved per collection mode, the drop-off collection produced 57.26 % more revenue than the door-to-door collection.

The scheme generated an estimated revenue of Gh¢ 6289.06 ($1044.97) from 15,927.5 kg of saleable dry recyclables material; thus, 62.74 % of the total recyclable waste recovered constituting an estimated revenue of Gh¢ 27,252.59 per year, equivalent to the US $ 147,436.51. About 32.26 % of the recovered materials comprising paper, glass and food waste did not have market value due to the nonavailability of a market for these materials in the study area. Furthermore, revenue generated through the sale of material resources was 10.4 % of the total cost of the scheme however, based on the total quantity of waste resources recovered, an avoided waste removal cost savings of Gh¢ 484.16 ($80.45) was made based on cost per ton of materials (Gh¢ 15 = $2.49) disposed at the landfill. This increased the total revenue of the scheme to 11.2% of cost input. These findings imply that substantial cost savings on disposal can be made through recycling. Similar to the report by other studies on the economic benefits of recycling; Kaseva et al. (2002) study in Tanzania found out that, out of the 14,600 kg of recyclable waste generated annually, 8030 kg representing 55 % of recyclables produced per capita income of Tsh 834,000 for waste recyclers.

Batool et al. (2008) study in Lahore in Pakistan reported 271 million rupee (Rs) per annum equivalent to US$4.5 million for 21.2 % of the total recyclables generated through informal sector recycling. The finding is also consistent with a report by Hosetti (2006), in which the University of Massachusetts model recycling scheme saved $200,000 of expenditure that otherwise would have been spent on waste disposal.

Table 2
Marketable Materials and revenues generated under the incentive schemes.

Incentive option	Waste material type	Quantities recovered (kg)	Unit price (Gh¢)/kg	Revenue (Gh¢)
Waste receptacles	Plastics			
	HDPE	206.2	0.4	82.48
	LDPE	1307.4	0.7	915.18
	PET BOTTLE	1808.1	0. 2 × 301.35	60.27
	PP	379.4	0.4	151.76
	Metals	1655.2	0.4	662.08
Total		**5356.3 (5.4 tons)**		**2029.33 ($337.19) that is (Gh¢ 375.80 /ton ≅ USD 62.46/ton)**
Prize	Plastics			
	HDPE	1070.3	0.4	428.12
	LDPE	1273.2	0.7	891.24
	PET BOTTLE	941.4	0. 2 × 156.9	31.38
	PP	398.4	0.4	159.36
	Metals	2972.8	0.4	1189.12
Total		**6656.1 (6.7 tons)**		**2909.1($ 483.36) that is (434.19 Gh¢/ton≅ US$ 72.14/ton)**
Bonus	Plastics			
	HDPE	24.6	0.4	9.84
	LDPE	682.3	0.7	477.61
	PET BOTTLE	1604.8	0. 2 × 267.46	53.5
	PP	510.2	0.4	204.08
	Metals	1093.2	0.4	437.28
Total		**3915.1 (3.9 tons)**		**1350.63 ($224.42) that is (346.31 Gh¢/ton≅ US $ 57.54/ton)**
Total / 12 weeks		**15,927.5 (15.93 tons)**		**6289.06 ($1044.97) that is (394.79 Gh¢ ≈ US $65.95/ton)**

The exchange rate was 1 USD = GHC6.0195; 5 of 0.5 l PET bottles = Gh¢ 0.2.

Revenue generated was realized to vary among incentives. For instance, while the bonus performed better in terms of revenue generation in door-to-door service zones, the prize was best in revenue generation in communal serviced zones. According to this study, a recycling scheme that uses economic incentives (bonus and prize) as a reward scheme may achieve better results in terms of revenue than a scheme that relies solely on the provision of waste receptacles to households for waste separation. However, it can be deduced from the result that the type of service zone and incentive type employed in the scheme may influence revenue generation from waste resources recovered in a scheme.

Table 3 shows the results of the cost estimations for the various incentives. The result indicates that the waste receptacles had the highest cost of Gh¢ 23,129 ($3842.34) for material resources recovered. This was followed by the prize with the cost of G¢ 18,745.12 ($3114.06). However, the prize had the highest quantity (10,589.8 kg) of waste resources recovered during the study period. This was followed by waste receptacles with a waste resource quantity of 78.98.1 kg while the bonus recovered the least amount (6899.7 kg) of waste resources at the cost of Gh¢ 18,629 ($3094.77). A similar trend was seen for the quantity of material resources produces per household and the cost involved.

Estimation of cost per kilogram (kg) of waste resource retrieved and cost per materials retrieved per household revealed that the reward (prize) as incentive produces the highest waste resources (kg/HH) and the lowest cost of one cedi and seventy-eight pesewas (Gh¢ 1.78) ($ 0.30). This was followed by the bonus, which registered a cost of two cedis and seven pesewas (Gh¢ 2.7) ($0.04) per kg of the waste resource recovered. The provision of waste receptacles had the highest cost per kg of waste resource retrieval compared to the prize and bonus. From the cost estimation, a cost savings of Gh¢ 1($0.17) would be made when the bonus is chosen over the provision of waste receptacles in recycling schemes, however, Gh¢ 11.51 would be made when the prize is chosen over the provision of waste receptacles.

Judging from findings, the provision of a prize as a reward in the recycling scheme maximized resource recovery with minimum cost. Furthermore, the bonus supported more resource recovery with less cost compared to waste receptacles. This implies that it is more economically advantageous to employ a prize or bonus as a reward in a recycling scheme compared to the sole provision of storage facilities. The ranking in terms of cost savings in materials recovery in the scheme is prize > bonus > waste receptacles.

The cost per kg of materials was also estimated for the service zones. In high-income zones, waste receptacles produced the highest cost (Gh¢ 4.3) ($0.71) per kilogram of materials retrieved while the bonus registered the lowest cost (Gh¢ 3.5) ($0.58) cost per kg of materials retrieved. This indicates that the bonus would be the best incentive to use in this service zone for material recovery to save costs. However, between the incentive option waste receptacles and the prize, the prize had a lower cost per kg of materials. This implies that employing the prize in a high-income door-to-door zone would be better in terms of cost savings compared to the provision of waste receptacles.

In the middle-income door-to-door zone, the prize produced the lowest cost per kg of materials retrieved. This was followed by the bonus, while the waste receptacles again registered the highest cost per kg of materials (Table 4). This means that the prize is the best incentive option to use in this zone to save money. According to the result in

Table 3
Cost (Gh¢) of materials recovered from the incentive options used in the waste separation schemes.

Incentive options	Quantity of materials (kg)	Cost (Gh¢)	Quantity of materials/ HH (kg)	Cost/ HH (Gh¢)	Cost/kg of materials (Gh¢)
Waste receptacles	7898.1	23,129	71.15	208.37	2.93
Prize	10,589.8	18,745.12	96.71	171.97	1.78
Bonus	6899.7	18,629	63.3	170.91	2.7
Totals	**25,387.6**	**60,503.12**	**231.16**	**551.25**	**7.41**

The exchange rate was 1 USD = GHC 6.0195; HIDtD-high income door-to-door; MIDtD-middle-income door-to-door; MIC-middle-income communal; LIC- low-income communal zone.

Table 4
Cost of a kilogram of materials (Gh¢) of the incentive in the service zones.

Incentive options	Service zones			
	HIDtD (Gh¢)	MIDtD (Gh¢)	MIC (Gh¢)	LIC (Gh¢)
Waste receptacles	4.3	7.8	1.96	1.5
Prize	3.8	3.5	1.1	1.2
Bonus	3.5	4.1	3.9	1.5
Totals	11.6	15.4	6.9	4.2

The exchange rate was 1 USD = GHC6.0195, HIDtD – high income door-to-door; MIDtD-middle-income door-to-door; MIC-middle-income communal; LIC-low-income communal zone.

Table 2, the cost per kg of material recovery was lower in the high-income door-to-door service zone compared to the middle-income door-to-door zone.

The bonus had the highest cost per kg of materials recovered in the middle-income communal zone. This was followed by waste receptacles with a per kg cost of 1.96 ($ 0.33) while the prize had the lowest cost of Gh¢ 1.1 ($0.18) per kg of materials resources. It can be deduced from the result that the reward is the best incentive for the recovery of waste resources in this zone when the cost per kg of material recovered is compared to waste receptacles, it has made a cost savings of 86 pesewas. Again, when the prize as a reward is compared to the bonus, it made a cost savings of Gh¢ 2.8 ($0.17) per kg of waste resources.

In the low-income communal service zone, the waste receptacles and the bonus had the same cost per kg of waste resources retrieved. This indicates that the two incentives may have similar effects in terms of cost savings for the recovery of waste resources. On the other hand, the reward again registered the lowest cost per kg of waste resources and, therefore, the best option to support the recovery of waste resources in this zone. The comparison between the middle-income communal zone and the low-income communal zone shows that the low-income communal zone had the lowest cost (Gh¢ 4.2) ($0.70) per kg of recovered materials. This indicated that it will be more advantageous to recover more waste resources in the low-income communal zone than in the middle-income communal service zone in terms of financial resources needed to recover the materials.

4.4. Cost-effectiveness of incentive options and determinants of revenue in the scheme

From Table 5, the estimation of cost per tonne of materials recovered showed that prize recorded the least cost per tonnes of materials recovered compared to bonus and waste receptacles. The cost-effectiveness (CE) ratios computed for the incentive options also, shows that the prize registered the lowest CE value of 1.77 and therefore was the most cost-effective option among the incentives used. The CE values of waste receptacles and bonus were 2.93 and 2.69 respectively. Comparing the CE values of bonus and waste receptacles indicates that it may be more cost-effective to use the bonus as an incentive to improve waste resource recovery than the provision of waste receptacles (Table 5).

In the high-income door-to-door zone, the prize had the lowest (3.77) CE value, indicating that the use of a reward scheme "prize" would be more cost-effective for waste resource recovery in this zone compared to the provision of waste receptacles and the bonus. However, between waste receptacles and the bonus, waste receptacles would be a better option in terms of cost-effectiveness for materials recovery in this service zone. In the middle-income door-to-door zone, the prize again recorded the lowest CE value of 3.52 representing the most cost-effective option in this zone. However, among the two other options, it would be more cost-effective to employ a bonus as an incentive in this zone for the recovery of the waste resources than the provision of waste receptacles.

In the middle-income communal zone, the prize registered the lowest CE ratio of 1.41 and can, therefore be considered the most cost-effect option for the zone. Waste receptacles followed with a CE ratio of 1.96 while bonus recorded the highest CE ratio of 3.91 in the zone. In the low-income service zone prize again was the most cost-effective option among the incentives with the lowest CE ratio of 1.18 as indicated in Table 5. Employing a bonus in recycling schemes in this zone may yield a better outcome in terms of cost and waste resource quantities.

The results show lower CE ratios for the incentives in the communal collection (drop-off) zones accept that of bonus in the middle-income communal zone. This means that employing these incentives in recycling schemes in communal collection zones (drop-off mode) may be more cost-effective compared to door-to-door zones(door-to-door collection mode), indicating that, the use of a reward scheme "prize" in the communal service zones may favor the recovery of waste resources in terms of cost.

The high performance of the "prize" as an incentive for waste resource recovery in the scheme may be attributed to the fact that it set competition among households which encouraged the households to increase their waste recycling effort to win the prize that was associated with the scheme. The study observed that it may be more cost effective to operate a recycling scheme in communal service zones (drop-off collection) compared to door-to-door service zones(door-to-door collection mode) in terms of cost and material yield, since the communal collection mode registered the lowest cost-effectiveness ratio for three of the incentive options used in the scheme.

After robustness check for the developed random-effect estimates. Model four (4) which included all the explanatory variables was used to describe the results. The model equation is specified below;

$$\begin{aligned} \mathit{Revenue}\ 4 &= 0.111 + 1.160\mathit{Prize} + 2.130\mathit{detached} + 1.216\mathit{semi} - \mathit{detached} \\ &\quad + 4.301\mathit{LIC} + 2.723\mathit{MIC} + 6.316\mathit{week}1 + 1.913\mathit{week}2 + 1.756\mathit{week}3 \\ &\quad + 2.793\mathit{week}5 + 1.345\mathit{week}6 + 0.531\mathit{week}7 - 0.655\mathit{week}9 \\ &\quad - 0.503\mathit{week}10 + 1.077\mathit{edu.\ level}3 + 1.013\mathit{edu.\ level}4 + 1.149 \end{aligned} \tag{2}$$

The result of the random-effect estimate (model 4) showed an adjusted r^2 of 0.188, and x^2 of 476.2 indicating that incentive, service zone, and households characteristics significantly explained about 18.8 % of variations in revenue (Table 6 attached). In addition, when comparing the incentive option 'prize' with waste receptacles (base category), the prize generates Gh¢1.16 more revenue than waste

Table 5
Cost-effectiveness among the incentive options used in the scheme.

Incentive options	Quantities of materials (kg)	Cost of materials (Gh¢)	Cost per tonne of materials Gh¢)	CE ratio	CE ratio per service zones			
					HIDtD	MIDtD	MIC	LIC
Waste receptacles	7898.1	23,129	2928.42	2.93	4.29	7.84	1.96	1.5
Prize	10,589.8	18,745.12	1770.1	1.77	3.77	3.52	1.14	1.18
Bonus	6899.7	18,629	2699.9	2.69	4.49	4.12	3.91	1.46

HIDtD-high income door-to-door; MIDtD-middle-income door-to-door; MIC-middle-income communal; LIC- low-income communal zone.

Table 6
Result of Random effects estimate of determinants of revenue from household`s waste separation.

VARIABLES	(1) Revenue	(2) Revenue	(3) Revenue	(4) Revenue
Prize	1.135***(0.362)	1.130***(0.362)	1.158***(0.350)	1.160***(0.351)
Bonus	-0.638*(0.384)	-0.642*(0.384)	-0.552(0.378)	-0.553(0.377)
House type				
Detached	2.047***(0.542)	2.055***(0.541)	2.190***(0.542)	2.130***(0.570)
Semi detached	1.215*(0.728)	1.221*(0.729)	1.305*(0.739)	1.271*(0.758)
Story	0.966 (1.261)	0.963 (1.259)	1.267 (1.286)	1.216 (1.303)
Service zones				
Low income communal	3.745***(0.732)	3.743***(0.732)	4.407***(0.846)	4.301***(0.870)
Middle income door-to-door	0.753(0.721)	0.748 (0.722)	1.232(0.790)	1.125 (0.828)
Middle income communal	2.084***(0.618)	2.073***(0.618)	2.799***(0.742)	2.723***(0.770)
Other variables				
income in thousands	0.427(0.293)	0.434 (0.292)	0.397(0.313)	0.383(0.314)
Gender	0.226(0.482)	0.229(0.483)	0.486(0.496)	0.454(0.495)
Age (years)	-0.013(0.009)	-0.013(0.009)	-0.006(0.009)	-0.006(0.009)
Household size	-0.076(0.056)	-0.074(0.056)	-0.071(0.056)	-0.072 (0.056)
Week 1		6.316***(0.680)	6.316***(0.681)	6.316***(0.681)
Week 2		1.913***(0.492)	1.913***(0.493)	1.913***(0.493)
Week 3		1.756***(0.404)	1.756***(0.404)	1.756***(0.404)
Week 4		0.568(0.430)	0.568(0.430)	0.568(0.431)
Week 5		2.793***(0.356)	2.793***(0.356)	2.793***(0.356)
Week 6		1.344***(0.394)	1.345***(0.394)	1.345***(0.394)
Week 7		0.515*(0.309)	0.515*(0.309)	0.515*(0.309)
Week 8		0.531*(0.298)	0.531*(0.299)	0.531*(0.299)
Week 9		-0.655**(0.288)	-0.655**(0.288)	-0.655**(0.288)
Week 10		-0.503*(0.269)	-0.503*(0.269)	-0.503*(0.269)
Week 11		0.248(0.249)	0.248(0.249)	0.248 (0.249)
Educational level_1 = No education			0.056(0.601)	0.096 (0.600)
Educational level_2 = Primary			0.225 (0.452)	0.248(0.457)
Educational level_3 = Middle/JHS			1.076*(0.581)	1.097*(0.585)
Educational level_4 = Secondary/Voc.			0.918*(0.550)	1.013*(0.594)
Week	-0.397***(0.045)			
Occupation				0.171 (0.372)
Constant	5.217***(1.039)	1.381(0.945)	-0.108(1.149)	-0.111(1.149)
Model diagnostics				
Observations	3086	3086	3086	3086
N of clusters	258	258	258	258
r2 overall	0.142	0.185	0.188	0.188
r2 between	0.329	0.332	0.344	0.345
r2 within	0.0764	0.133	0.133	0.133
chi2	331.5	466.7	476.2	478.7
p > chi2	0.000	0.000	0.000	0.000
sigma u	1.973	1.996	1.988	1.992
sigma e	4.969	4.821	4.821	4.821
Sigma	5.346	5.218	5.215	5.217
Rho	0.136	0.146	0.145	0.146

Robust standard errors in parentheses. Key: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

receptacles and was significant at $p < 0.01$(SE 0.35). However, the bonus generates less revenue (0.55pesewas) than waste receptacles therefore, among the three incentive options, the prize earned the highest revenue, and so can be said to be more profitable (holding operational cost constant).

In the case of the service zones, the low-income communal service zone (LIC) and the middle-income communal service zone (MIC) generated the highest revenues compared to the high-income door-to-door service zone (HIDtD). The income generated by the low-income communal zones was significant at $p < 0.01$ (SE = 0.87) and that of the middle-income communal zone was significant at $P < 0.05$ (SE = 0.77). From the result in Table 6, it can be observed that the communal service zones generated more revenues than the door-to-door zones. This is because more materials were recovered in the communal service zones compared to the door-to-door service zones.

The revenues generated in the second week of the investigation were significantly higher at $p < 0.01$ (SE = 0.49) than in the remaining weeks. Therefore, revenues were affected by the weeks of separated waste collection, which could be due to the variations in types and amount of materials recovered throughout the weeks of collection. The result shows that age, sex, education and socio-economic variables (income, occupation) do not have any noticeable effect on revenue generation however revenues are influenced by incentive types, housing types, service zones and the period (time) of waste collection. Therefore, when these factors are considered in the planning and implementation of recycling schemes, they can improve revenue in the schemes. This finding differ from that of Afroz et al. (2010), Asare et al. (2015) and Alhassan et al. (2017) reports which identified socio-economic factors of households to influence their waste handling behavior. However, Alhassan et al. (2017) report on housing type as a factor that influences households' environmental behavior conforms to the findings of this study.

5. Conclusions

The most salient implication of this study is the need to set priority among incentives choices to support recycling schemes. We chose to conduct this research because incentives have been recognized as a means to improve household recycling behavior. However, there are some underlying questions regarding the adoption of incentives in recycling schemes that remain unanswered in the literature; “which incentive would be the most-cost-effective option for material resource recovery in different services zones? What are the cost implications of employing certain incentives in recycling schemes? 'How does revenue from recovered materials compare to its cost of recovery. This study attempted to answer these questions by highlighting incentive options that have a high propensity to support waste material resource recovery with minimum cost in different service zones.

From the findings of the study, it was realized that the reward scheme (prize and storage facility) improves materials recovery and revenue at a minimal cost compared to the provision of waste storage facilities (waste receptacles) and the provision of bonuses to households and was the most cost-effective incentive option for material recovery. In addition, it was realized that more materials were recovered in the communal service zones at a lower cost compared to door-to-door service zones. The implication is that it is more cost-effective to recover materials from communally served areas than door-to-door services areas. Furthermore, the random-effect estimates highlighted incentive options, housing types, service zones, and period (or time) of waste collection as factors that significantly explained revenue from recovered materials from the households.

The findings of this study has implications for practice and policy. The findings suggest that city authorities can employ a reward scheme that focuses on the provision of storage facilities and a prize to achieve high material recovery and cost effectiveness in recycling schemes. In addition, authorities can focus on recycling schemes in the communal services areas (drop-off schemes) to maximize materials yield and reduce cost. Again, the planning and designing of recycling schemes should consider incentives, services zones, and periods of separated waste collection to maximize revenue in the schemes.

This study provides scientific information on the type of incentives that can improve materials recovery rate at considerable cost and, therefore, supports the advancement of incentives in recycling schemes, most especially in Ghana. It also provides the necessary data to assist industry, city authorities, and waste management companies in making decisions and developing prudent strategies for effective solid waste management in different service zones. The findings of this study can be applied in other jurisdictions with little or no modification to support the recovery of waste material at minimum cost.

Based on the findings of the research, the authors recommend the following researches to further deepen the understanding of the cost implications of using incentives in recycling schemes; (1) assessment of the effects of seasons on cost and material recovery of the different incentive schemes and (2) evaluation of policy-driven incentives such as penalty fees for nonparticipation in recycling schemes and tax imposition on disposal of biodegradable (food waste).

5.1. Limitation of the study

This study was a piloted waste separation scheme that compared the cost implications of different incentives in a recycling scheme. The cost assessment, therefore, focused more on the incentive options given. In addition, due to the limited period and temporary structures used for the study, the cost estimation did not include the depreciation rate and salvage values of the structures used.

CRediT authorship contribution statement

Wilhemina Asare, Sampson Oduro-Kwarteng, and Emmanuel A. Donkor contributed to the conception and design of the study, literature review, and interpretation. Sampson Oduro-Kwarteng, Wilhemina Asare, Samuel Donkor and Mizpah A.D Rockson participated in the drafting of the manuscript and preparation of the final version. All Authors have read the manuscript and have agreed to submit it in its current form for consideration for publication. All read and approved the final manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.Acknowledgements

The study was funded by the Regional Center for Water and Environmental Sanitation (RWESCK) at Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, with funding from the Ghanaian Government through the World Bank under the Africa Centres of Excellence project. However, the views expressed in this study do not reflect those of the World Bank, the Ghana Government, and RWESCK, KNUST.

Conflict of Interest

The authors of this article have no competing interests.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.clwas.2022.100019.

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