

# The garbage problem and what can we do about it?

[Vision Statement - Extended Abstract]

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## ABSTRACT

Global waste production has doubled over the past ten years. By 2025, the world will produce garbage at a rate of 2.5 billion tonnes per year [5]. Poor waste management in many developing countries is a threat to human health and the environment. Many developing countries struggle towards a sustainable model for waste collection and disposal and despite large expenditures, very few countries have achieved a sustainable garbage collection system. We propose a community-sourced, data-driven, online service market as a sustainable and economic solution to the garbage problem.

## Categories and Subject Descriptors

H.4 [Information Systems Applications]: Miscellaneous

## Keywords

Online service markets, crowdsourcing, community sourcing, auction, recommendation systems, verification

## 1. THE PROBLEM

In developing countries, waste management usually accounts for 30-50% of municipal operational budgets. Despite these high expenses, many cities collect only 50-80% of wastes generated (30% collection in Karachi, 40% in Yangon, 50% in Cairo and Indian cities) [15]. In some cities, 80% of garbage collection and transportation equipment is out of service or in need of dire repair or maintenance [6]. These municipal expenses are typically paid for by benefiting and non-benefiting residents alike. For example in Cairo, the electric bill includes a garbage collection fee, yet contracted private sector firms do not collect garbage from slums and poorer neighborhoods [10].

With less than 50% refuse collection rates, residents are left with little choice other than to dump their garbage in nearby vacant lots, public spaces, rivers, etc. [15] (See Figure 1). Such open, in-city, dumping has significant



Figure 1: Poor waste collection in Cairo leads to sore trash sites on roads and public spaces. Source: Hassan Ibrahim [13]

negative environmental and health consequences. Uncollected garbage provides breeding grounds for insects, vermin and animals, which spread diseases including plague, dengue fever and diarrhea [6]. Unsanitary dumping sites increase greenhouse gas emissions and produce leachate that can contaminate ground and surface water sources [6]. Moreover, uncollected solid waste clog city flood drains causing flooding during heavy rains. In extreme cases of coordinated dumping over time like in Agbogbloshie, Ghana, entire suburbs can turn into toxic landfills [3].

The waste management sector is worth USD 390 billion in both OECD and emerging countries, and provides up to 5% of urban jobs in low-income countries [6]. It is thus, hard to imagine why waste management can be so challenging: after all, a city could just buy a fleet of garbage trucks, set up a pick-up schedule and pick up garbage. Many private firms already provide these services in developed countries and struggling cities could privatize waste management entirely by contracting to these foreign firms.

To illustrate the complexities of the problem, we use Cairo as an example. For brevity, we only present a simplified summary of the situation.

From the late 1980's to the 1990's, Cairo's municipal authorities employed a fleet of equipment and employees to clean the city's public spaces such as streets and marketplaces. The system "combined the worst of both worlds: a technologically sophisticated labour-saving fleet and a large

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**Figure 2: The informal private sector uses low-tech equipment to keep garbage collection costs low. Source: Alexander Heilner [1]**

workforce” [10]. Prior to the introduction of the ‘mechanized and modern’ fleet, the garbage collection service was in the hands of the *Zabbaleen* — members of an informal, domestic private sector [10]. The municipal labour to equipment ratio was 77:1 as compared to only 3:1 in the *Zabbaleen* system [10]. For this and other reasons, the *Zabbaleen* system was 5 times more cost-effective than the municipal system at waste removal [10]. The failure of the municipal system caused the Egyptian government in the early 2000’s to contract out Cairo’s waste management to several foreign firms. Individual contracts reached upwards of 400 million US dollars and mostly included European companies [10]. Part of the government’s objective, through these foreign deals, was to expropriate and eliminate the *backward, non-modern*, domestic, private sector represented by the *Zabbaleen* in favor of the foreign private sector [10]. This led to unforeseen problems: the *Zabbaleen* (and Egyptians) robbed and sabotaged the companies through waste-bin theft and swapping the containers with garbage. Consequently, some firms ended their contracts prematurely.

The takeaway from Cairo’s garbage problem is rather surprising: the garbage problem, at its heart, contains a *data sharing* or *transparency* problem. Residents are not aware of the newly introduced less cost-effective collection models. The local, informal, private sector is at odds with the foreign private sector firms but have little or no means to compete fairly and thus recourse to sabotage. Worse, the garbage collection pie is large enough to support both local and foreign sectors. Finally, there is a lack of appropriate regulatory frameworks to monitor and govern garbage collection. We propose a solution that decentralizes management of the problem and allows all stakeholders better access to information. We then discuss the challenges associated with our system and outline how our system could be designed to increase its chances of acceptance and use by all stakeholders.

## 2. A SOLUTION

We propose an online service market, *Zebalati*, to solve the garbage collection problem. The market system divides an entire neighborhood into fixed-size lots and initiates reverse-



**Figure 3: The *Zabbaleen* collect garbage and bring it into Cairo’s Garbage city. The *Zabbaleen* then extract reusables and recyclables for sale. Poor garbage handling and disposal strategies lead to garbage cities that people live in. Source: Ilya Stepanov [2]**

bid auctions on each lot [12]. The market has key three players: (i) cleaners bid their clean-up service fee for a given lot, (ii) *grantors* donate or pay money for a particular lot to be cleaned, and (iii) *auditors* verify that a lot awarded to a cleaner has indeed been cleaned within a fixed time-frame<sup>1</sup>. Organizations, firms and persons can sign-up in *Zebalati* in any role.

A second-price sealed bid auction is used to incentivize cleaners to bid their *true* clean-up service fees. Grantors are made aware of lots with active bids but do not know the lowest bid so far. Bidding lasts a few days after enough money is collected from grantors to pay a bid. Excess funds are returned to grantors in proportion to each grantor’s contribution to the overall fund. To ensure transparency, the value of the winning bid is made public.

*Zebalati* is closely related to *TaskRabbit* [4] — an online marketplace that allow users to outsource errands, like washing dishes, doing laundry, vacuuming, grocery shopping, etc, to others in their neighborhoods. Like *TaskRabbit*, *Zebalati* uses reverse-bid auctions and encourages community participation. Unlike *TaskRabbit*, the total grantor funds are not made public and multiple grantors typically pool funds to pay for lot clean-up. In our research, we did not encounter any game-theoretic analysis of auctions where there are multiple bidders and multiple grantors without a priori knowledge of the total funds available from all grantors. Thus, it is possible that our described auction has unforeseen consequences on truthful bidding.

The merits of our proposed solution are as follows:

1. All stakeholders involved can easily engage in a free and competitive market.
  - Both foreign and local private sector cleaners can engage in bidding without political (or even financial) barriers. In cities like Cairo, private sector cleaners, known

<sup>1</sup>In certain situations, for example, when grantors are community members, a single entity can play both roles of grantor and auditor.

as *Zabbaleen*, can clean lots at extremely low costs, for free or even for a fee, if they can re-use or recycle the collected waste. By using low technology tools such as donkey carts or open trucks (Fig 1) instead of expensive garbage compactor trucks, they can bid on lots with low costs [10]. Private sector firms can bid on lots that are more expensive to reach or clean due to volume.

- Grantors include NGOs, charitable organizations, members of the affected neighborhood and municipalities. In certain neighborhoods, community members can contribute enough funds to clean affected lots. Lots within slums or lower economic neighborhoods can be sponsored by NGO's, donors or municipalities.
2. Fixed time-frames mean that a clean-up job is completed immediately or no money is transferred to cleaners. This ensures steady progress towards cleaner cities. Special mechanisms also ensure that cleaners do not continuously win bids and default. We discuss these mechanisms later.
  3. Auditors verify that clean-up jobs are indeed completed and that waste collected is properly disposed of outside the city and into legal landfills.

## 2.1 Challenges

The proposed solution carries with it a multitude of technical and social challenges. Here, we focus on the challenges internal to our proposed system and propose refinements to the basic *Zabalati* system describe above. Most refinements try to incentivize good behavior from all participating agents or minimize dependence on an agent's trust-worthiness.

### 2.1.1 Corrupt single agents.

The following scenarios are possible: (i) a grantor reneges on a payment after a clean-up job completes, (ii) a cleaner wins the bid on a lot but fails to clean it, (iii) an auditor either claims a lot to be dirty when clean or vice-versa, (iv) an auditor fails to ensure that garbage collected has indeed been properly disposed. The last scenario could occur when a cleaner simply pushes aside garbage from one lot to a neighboring lot.

To ensure grantors do not renege on payments, once granted, money cannot be refunded<sup>2</sup>. Partial refunds are possible if the bid is much lower than the money collected. To avoid loss of funds, a cleaner is only paid the bid amount upon successful completion of a clean-up job.

To avoid the loss of funds, money is only transferred to a cleaner after successful job completion. We still need, however, to discourage repeat offenses from cleaners who win bids and fail to complete jobs. The following data-driven solutions deal with some of the problems due to corrupt agents. Unfortunately, they also introduce a few issues.

### *Technological, data-driven, solutions.*

**Reputation Systems.** Each cleaner receives a score that depends on task completion rate. Grantors can chose to only fund cleaners above a certain score threshold. This incentivizes cleaners to maintain high task completion rates. However, reputation systems are prone to sybil attacks where cleaners create multiple identifies to start with a

<sup>2</sup>It is possible that such a solution will hinder some grantors from participation.

fresh, identity every time the reputation score falls below the threshold [11]. Systems where newly registered users have lower scores create barriers to entry into the online market. A reputation system where cleaners need to register with government issued documentation also creates barrier to entry as cleaners from low, socioeconomic backgrounds often do not have such documentation. For example, only 38% of boys and 27% of girls in the Kibera Slum, Nairobi have national IDs [9]. Moreover, a reputation system can put cleaners at the mercy of auditors, who can exploit them. In online service markets, such as TaskRabbit, small-scale service providers have reported instances where reputation systems are unfairly biased against them [16].

**Satellite Imaging.** Open and illegal dump sites within a neighborhood that are at least half a meter deep, are easily visible in high resolution satellite images (approx. 0.5 m resolution). Images from such satellites, however, can be expensive or government-protected. These images are often available on a daily basis allowing quick verification of lot clean-up.

**Timestamped & Geo-tagged Images.** Auditors take through a secure application a geo-tagged and timestamped before and after image of each cleaned lot. In the presence of before and after shots, image analysis algorithms can automatically verify clean-up. With only after images, crowdsourced verification is a viable alternative<sup>3</sup>. To incentivize auditors to take such images, a flat audit fee can be included for each lot. A secure application that encrypts geo-tagging and timestamps is necessary to ensure auditors do not manipulate this data.

**Landfill Monitors.** To ensure the proper disposal of collected garbage into designated landfills, landfill monitors can estimate the weight of garbage dumped. Unfortunately, corrupt landfill monitors can exploit cleaners by refusing to accurately estimate weights. Alternatively, corrupt cleaners can improperly dispose of garbage into nearby lots and then move sand bags to the landfill.

**Trackers.** A random sample of garbage lots can be fitted with GPS tags or cheaper RFID tags. This allows garbage to be tracked from lot to landfill. However, many cleaners financially benefit from scavenging garbage for reusables and recyclables and can extract these tags before disposal [15].

As clean-up verification becomes fully automated through the use of advanced remote imaging or tracking technology, auditors are no longer required to ensure the functioning of *Zabalati*.

### 2.1.2 Corrupt colluding agents.

The following scenarios are possible: (i) auditors and cleaners collude to force continuous funding from an external grantor, (ii) grantors and auditors collude to not pay cleaners who have completed a clean-up job, forcing continuous clean-up of a lot with no payment. Solutions that ensure auditor honesty can break such collusions.

<sup>3</sup>It is still possible for the crowd to act as corrupt agents here; By removing geo-tags and timestamps from each image and using foreign crowds to verify images, one can reduce this possibility.

### 2.1.3 Ensuring health, safety and service standards

A decentralized model, in general, makes it difficult to ensure health, safety and service standards. However, a system like Zebalati can incentivize better compliance with standards if grantors can, along with their grants, specify a compliance level threshold that cleaners must satisfy to win a bid. A pathway to better health and safety standards is crucial (and challenging to implement): an epidemiological study of a community around an improper waste-disposal site in Manila, Philippines, found a high incidence of 35-different diseases including TB, anthrax, poliomyelitis and cholera [15]. Infant mortality in the Zabbaleen community, who live in garbage cities, is around 60%.

### 2.1.4 Enabling a steady stream of grants.

The pressing issue in many cities is the sheer amount of trash accumulated on roads, vacant lots and public spaces. After the initial clean up, Zebalati needs to move from a one-time bidding model to a subscription model, where grantors grant funds on a monthly basis and cleaners win longer-term bids. Once a neighborhood is cleaned, individual grantors are less incentivized to pay a regular garbage collection fee until garbage accumulates again.

### 2.1.5 Accessibility & Usability

“Appropriate technology” refers to the idea that a technology should meet “the constraints of the local populations it was meant for” [17]. In order for Zebalati to succeed, all stakeholders need to be able to easily access and use the system. This is a particularly challenging problem for both system and interaction design due to the infrastructural and socio-economic constraints of our users.

Grantors (particularly large organizations) are likely to have good Internet access and would prefer to interact with our system using an online web portal. Designing an accessible and usable system for them should be fairly straightforward. However, in certain contexts (e.g. peri-urban or remote regions) cleaners and possibly grantors may have unreliable or costly Internet access or only a simple “brick” phone with limited credit. This severely constrains the information conveyance mechanism (e.g. only SMS) and also the interaction modalities that are available. Zebalati needs to be designed in a way that allows its features to continue functioning in such challenging contexts. Substantial recent research has focused on understanding how to build systems that work in a variety of low-infrastructure environments [7], and we hope to leverage some of these ideas in the design of Zebalati.

Zebalati targets a diverse demographic with large socio-economic, educational and literacy differences. Recent research has begun to explore how to design interfaces that are usable by less educated populations [14] and we hope to borrow from these works in Zebalati’s user-interface design.

## 3. CURRENT AND FUTURE WORK

As we continue to develop Zebalati, we are working to get the support of economists, NGO’s and local authorities to finesse the system and actively deploy it. Designing a system to be introduced appropriately into an existing, socio-economic structure is an extremely challenging practical hurdle. Will communities actually accept and use Zebalati? The technology acceptance model [8] provides a framework for understanding whether a particular user community will

adopt a new technological system and we intend to refer to this model as we design Zebalati.

We believe a well-designed, online service market has the potential to minimize corruption, decentralize authority and allow for efficient municipal services in developing countries, whether it be for the purpose of garbage collection, public gardening, graffiti removal, city beautification, road maintenance, and potentially many other public works.

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