Underground Automated Vacuum Waste Collection System for Gwalior City (A Case Study)

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ABSTRACT-
Waste collection is one of the life cycle phases that influence the environmental sustainability of waste management. At present we follow with door-to-door collection, recycling and land-filling disposal. This system is highly flexible, however it has several drawbacks giving rise to important environment impacts and nuisances. One of its weak spots is found in collection process of waste streams following a conventional door-to-door collection using a combination of trucks and waste bins. Hygiene issues, efficiency shortfalls in waste collection, traffic disturbances and environment burdens in urban areas relating to the increased noise and air-emissions are some of its major disadvantages. This paper focuses on the underground automated vacuum waste collection system. Pneumatic waste collection system represents a new way of arranging waste collection in densely populated urban areas. The development of underground infrastructures for the efficient management and collection of urban waste streams offers great advantages and solutions in tackling problems relating to these activities. This paper presents the financial and environmental assessment of a proposed system in replacement of an existing conventional waste collection scheme in Gwalior city. The comparative financial assessment is undertaken using the equivalent annual cost methodology (EAC) where the capital expenditures and annual operational and maintenance costs for both alternatives are calculated. The findings show that these two systems have roughly the same cost performance using the equivalent annual cost analysis. Yet, they have noticeably differentiations in the operational and capital costs with the AVAC system having almost 40% lower operational cost requirements. Truck-based collection of municipal solid waste imposes significant negative externalities on cities and constrains the efficiency of separate collection of recyclables and organics and of unit-price-based waste-reduction systems. In recent decades, hundreds of municipal-scale pneumatic collection systems have been installed in Europe and Asia are running successfully.

Keywords- Automated vacuum waste collection system (AVAC), Equivalent annual cost methodology (EAC), Municipal solid waste management (MSWM).

1. Introduction-
The utilization of subsurface space is nowadays a key issue towards attaining an environmental friendly and sustainable development, especially in urban areas. Thus, activities or infrastructures that are difficult, impossible, environmentally undesirable or even less profitable to be installed above ground, can be relocated underground releasing valuable surface space for other uses and enhancing urban living conditions. Until recently, the management of municipal waste was relied on traditional collection and disposal activities, mainly associated with door-to-door collection, recycling and land-filling disposal. This system is highly flexible; however it has several drawbacks giving rise to important environmental impacts and nuisances. One of its weak spots is found in the collection process of the waste streams following a conventional door-to-door collection using a combination of trucks and waste bins. Hygiene issues, efficiency shortfalls in the waste collection, traffic disturbances and environmental burdens in urban areas relating to the increased noise and air-emissions are some of its major disadvantages. Waste management is one of the big issue of urban engineering. Today, the total amount of waste generated annually worldwide (municipal, industrial, hazardous) is more than 4 billion tons. Almost 45% of these are considered as municipal waste, while rest is industrial waste, including hazardous one. The introduction of underground and semi-underground collection systems presents strong potential in the efficient collection/management of the waste in an environmental friendly manner. The waste generated in Gwalior city is 380 tons per day. Gwalior city has 427 km² municipal area. The population of Gwalior city is 11 lakhs 59 thousand.
Total recurring expenditure on solid waste management done by Gwalior municipal corporation in one year is fifty crores.

Table 1- Details of vehicles and labours working for MSWM in Gwalior.

<table>
<thead>
<tr>
<th>wards</th>
<th>66</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sanitary zones</td>
<td>25</td>
</tr>
<tr>
<td>Cross tipper</td>
<td>1333(2 m³ each)</td>
</tr>
<tr>
<td>Dumpers</td>
<td>18</td>
</tr>
<tr>
<td>J.C.B</td>
<td>14</td>
</tr>
<tr>
<td>Dumper placer</td>
<td>7(2.5 m³), 2(5.5 m³)</td>
</tr>
<tr>
<td>Container</td>
<td>200(2.5 m³), 42(5.5 m³)</td>
</tr>
<tr>
<td>Tractor- Trolly</td>
<td>23</td>
</tr>
<tr>
<td>Hand-cart</td>
<td>800</td>
</tr>
<tr>
<td>Labour (permanent+ temporary) in each ward</td>
<td>20</td>
</tr>
<tr>
<td>Total permanent labour</td>
<td>1091</td>
</tr>
<tr>
<td>Total temporary labour</td>
<td>1020</td>
</tr>
<tr>
<td>Labour salary (permanent)</td>
<td>18000/-</td>
</tr>
</tbody>
</table>

The paper presents the current municipal waste collection process (conventional vehicle-operated method) and furthermore it introduces the design of the automated waste collection system (AVAC) required in order to properly facilitate users needs. It analyses the characteristics the systems and focuses on the comparison of the two alternatives available emphasizing on both their financial and environmental characteristics. Thus, the assessment of the most promising scheme could be brought forward allowing stakeholders to decide whether they should pursue the transition of the waste collection system to the underground fixed infrastructure.

2. Case study –
Gwalior city lies along 26° 14’ N latitude and 78° 10’ E longitudes on indo-Gangtic plains in the state of Madhya Pradesh. The city has a population of 1159000 (GMC, 2011). Gwalior municipal is responsible for the management of the MSW in the city. The fully operation of solid waste management (SWM) system is performed under four heads namely, cleaning, collection, transportation and disposal. In Gwalior city the cleaning and collection process involves collection of MSW from the street from wheel barrows and thereafter, it is dumped into depots. MSW is then loaded into the transportation vehicles, which transport the waste to different disposal sites. Solid waste in the City is mainly thrown on the ground and stored in temporary collection points that are official (recognized by the municipality) and unofficial (not recognized by the municipality). The temporary collection points are normally located along a defined road or near drainage channels. From the temporary collection points, GMC trucks and private operator trucks collect and transport the wastes to landfill sites. The city authority also introduced a system known as self-loading, where a truck moves into an area and people are allowed to load their waste on to the vehicle. The frequency of waste collection at the temporary collection points varies depending on waste deposited. Current routes are designed by the city authority based on where waste is deposited and the drivers also follow routes depending on their experience and knowledge of the area. In other words the trucks don’t work on a scheduled route time table. Most of the waste collection trucks in the city are
loaded manually by humans. When the truck is full to its capacity, it goes to dispose of the waste to the landfill. The economical comparison between a conventional collection system and a stationary vacuum system as carried out by SWECO(2005) IN Sweden and presented by Tomblom(2008). The purpose of the study was to identify best waste management practices for the development of a new housing project in Vastra Sjostaden, comprising of 2095 apartments.

3-Methodology-
The underground waste collection systems can be separated in two main categories; the stand-alone collection points (underground, semi-underground collection bins) and the automated vacuum collection systems (AVAC or automated waste collection systems – AWCS) or pneumatic stationery collection system. Regarding the first category, underground containers are placed in shaft-like excavations, having only their inlets in the surface environment. Thus, this particular system replaces above ground collection points offering increased storage capacity, compaction of waste and superior hygienic performance especially in summer time. Furthermore, using this scheme visual pollution issues are reduced, while on the same time, the waste collection points can be more easily integrated in the urban environment. Nevertheless, such underground systems are still relying on the typical collection process using specially adopted trucks.

Fig. 1. Schematic of the installation and operation of an underground automated waste collection system (Source: Excel Group of Companies).

4-Advantages-
1. AVAC system will minimized the operational cost of MSWM, therefore it provides long term savings.
2. This system has ability to collect efficiently all types of waste.
3. This system is flexible with the ability to easily adopts all types of changes.
4. This system minimizes the use of garbage collection trucks in urban areas.
5. This system minimizes air pollution, noise pollution, aesthetic pollution and odor nuisance from MSW.
6. This system releases the surface space for community needs or development.
7. This system is safe and hygiene for MSW collection workers.

5-Comparison on the basis of cost-

Table 2- Investment and operating cost comparison of two waste collection systems for the Vastra Sjostaden project (Sweco Viak AB, 2005- Tomblom, 2008)

<table>
<thead>
<tr>
<th>CALCULATION (with 4% rental income ground floor premises)</th>
<th>Investment cost for the collection system (SEK)</th>
<th>Operating cost (SEK/year)</th>
<th>Rental income from released surface space (SEK/year)</th>
<th>TOTAL Operating and capital cost (SEK/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual handling, containers (one reinvestment for containers at 10th year)</td>
<td>27133043</td>
<td>2814839</td>
<td>-</td>
<td>5083189</td>
</tr>
<tr>
<td>Underground waste transport system, primary and secondary network</td>
<td>44275000</td>
<td>823099</td>
<td>-2049942</td>
<td>2030990</td>
</tr>
</tbody>
</table>

SEK – Swedish Krona (Currency of Sweden)
One Swedish Krona (SEK) = 8.17 Indian Rupee.

Table 2.1- Cost per apartment of two waste collection systems for the Vastra Sjostaden project (Sweco Viak AB, 2005- Kogler, 2007)

<table>
<thead>
<tr>
<th>Preliminary calculation per apartment</th>
<th>Investment cost (EUR per apartment)</th>
<th>Operating costs (EUR per apartment per year)</th>
<th>Total costs- 6% cost of capital (EUR per apartment per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual waste handling</td>
<td>1406</td>
<td>130</td>
<td>232</td>
</tr>
<tr>
<td>Stationary vacuum system</td>
<td>2254</td>
<td>43</td>
<td>206</td>
</tr>
</tbody>
</table>

(The SEK to EUR exchange was made by kogler (2007), (1 EUR = 9.37589 SEK).

Similar analysis is proposed for Gwalior city is under progress.

6-Environmental comparison-

The benefits of the AVAC collection in terms of the environmental aspects of city living are given previously. Nevertheless, besides the improvement of the conditions of living and the aesthetics of the city there are some further issues that need to be pointed out. These are linked with the city’s environmental conditions in terms of pollutant emissions due to the traffic load generated by the transport trucks. Apart from the reduction in noise and the traffic congestion effects, there will be a considerable upgrade in the city’s air quality. For example, in the above case of the Marousi area, only one vehicle is required for the waste transport instead of three trucks used under the conventional waste collection scenario, greatly reducing the required transportation cost.
7-Conclusion-
The development of new approaches for the management of the urban waste is become a big issue for modern society.

The following are the conclusions draw by our present study:

- Utilization of subsurface space can be proved most beneficial in tackling the drawbacks of traditional waste management and collection systems.
- Surface space is released and made available for other use while on the same time, all process are taking place underground minimizing their effects in living environment.
- The establishment of permanent underground infrastructure for the collection and management of waste can provide efficient and cost effective solutions. Thus the following example already set by other utilities(e.g. water, sewerage, gas, electricity e.t.c) that have developed over time into an underground infrastructure.
- Pneumatic systems would also offer local safety and public health benefits due to reduced particulates emissions, noise emissions, accidents, disease vectors.
- Major benefit from the usage of AVAC system is minimized operating cost for the waste handling, 2 to 3 times lower than conventional collection methods.

8-Further Scope-
A detailed cost analysis for AVAC system, if applied for Gwalior city may be done.

9-References-