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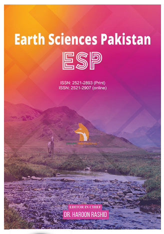

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RESEARCH ARTICLE

LAND DEMARCATION AND DESIGNING OF WASTE TRANSFER STATION USING GIS TECHNIQUE FOR LAHORE CITY, PAKISTAN

Anam Maqsood[a*], Gulfam Shoaib[b], Maryam Zafar[b]

[a] *Department of Structures & Environmental Engineering, University of Agriculture, Faisalabad, Pakistan.*
[b] *Institute of Environmental Engineering & Research, University of Engineering & Technology, Lahore, Pakistan.*
**Corresponding Author Email: anammaqsood920@gmail.com*

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ABSTRACT

Rapid population growth and high rate of urbanization make municipal solid waste management a challenging task for municipalities. Lack of sufficient infrastructural facilities worsen this challenging situation. To curb this, transfer stations, which are facilities located close to residential areas and are used to receive and hold waste temporarily until it is transported to distant landfills. It reduces waste transportation cost and provide a place for waste segregation. In Lahore open transfer station is built near river Ravi and residential areas which is creating air and land pollution. This study is carryout to select the suitable location for waste transfer station in Lahore that meets the USEPA criteria. Buffer command of Arc GIS is used for site selection. Best suitable sites selected for Lahore in this analysis are UC Sultanki and UC Chandrai where more buffers are joint during buffer analysis. Furthermore, cost estimation for the construction and operation of both waste transfer stations are done.

KEYWORDS

Waste transfer station, Buffer analysis, Arc GIS, Siting criteria, Digitization of site, Cost estimation.

1. INTRODUCTION

Population growth all over the world has led every country to manage and dispose the large volumes of municipal solid waste effectively. According to the World Bank report, the average global municipal solid waste (MSW) generation per person on daily basis is about 1.2 kg and the figure is expected to rise upto 1.5 kg by 2025. It therefore means that every state and local authority suffer the problem of effective waste disposal due to the generation of too much waste. To overcome this situation different countries and regions use different methods for disposal of waste (Damghani, 2008). In developing countries due to the low budget for waste disposal open dumpsites are common, which increases the risk of pollution, animal hazard on that area, road accident and health diseases. It produces vertebrates and other disease-causing microorganisms which are hazardous to human health. Due to this it is difficult for humans to live near waste collecting area. Unsystematic waste management in developing countries is the main issue (Bosompem, 2015).

Over the years every country stepped on its urbanization which led many developments around waste disposal sites. These waste disposal sites are linked directly with the environmental nuisance. Due to their impacts, the population therefore opposes these waste disposal sites. Such landfills should be located at a distance from human settlements and source of waste generation. This ultimately will increase the cost of waste hauling to the landfill sites. To solve this problem waste transfer stations are made (Zurbrugg, 2002). A waste transfer station is a facility where municipal solid waste (MSW) is released and held for a while and refilled into the bigger long-distance truck to landfill or other treatment facilities. A transfer station is a facility with a selected reception area where waste collection vehicles release their waste. The waste is often compressed, the loaded into larger vehicles for long haul shipment to a final disposal site typically a landfill, waste to energy plant, or a composting facility. No long-term storage of waste happens at a transfer station, waste is rapidly merging and loaded into a larger and moved off-site typically in a matter of an hour the siting, planning and action of a transfer station, if not properly done, can cause problems for local breathing closer. Transfer station also provide waste sorting and recycling facilities (Eshet, 2007; EPA, 2002).

The dominant measure used to select a transfer station site has generally been also cheap transport expenditures since it is cost-effective to haul great size of waste over the long distance in large trucks in smaller ones. Where the distance from the waste collection area to the waste treatment facility is large, a transfer station may be used to bulk up the waste for more efficient transport larger trucks. A transfer station is an prospect to monitor waste prior to discarding (Bovea, 2007). Why transfer station area valuable, because minor or average size societies may not generate sufficient waste to support a disposal facility. Second, if the distance to the disposal plant is more than 28 km then cost of minor collection trucks may be unnecessarily high. Third the site of a single discarding plant in a remote location to serve numerous societies will remove environmental effect from the housing area (Gil and Kellerman, 1993).

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United States Environmental Protection Agency (US EPA) describes the feasibility of community transfer station as being dependent on the design variable such as capacity require for recovery of material from waste before haulage, types of collection vehicle that use the facility, types of transfer vehicles that can be accommodate at the disposal facilities, and topography and access of this site. There are different types of the transfer station on the basis of capacity. Small transfer stations have capacity less than 100 ton/day, medium transfer stations have capacity ranging between 100 to 500 tons/day, while large transfer stations have capacity greater than 500 tons/day. On the basis of operation, the transfer stations can be categorized as direct dump with no floor storage and direct storage with floor storage (Herbert, 2001).

2. Problem Statement

Population is increasing very fast in every country and creating many problems of solid waste specially. In Pakistan population increased 43% from population of 1998 that is 137 million. Lahore is the 2^{nd} biggest city according to population of Pakistan. Its population increases from 6 million in 1998 to 11.12 million in 2017.As growing population increases solid waste which creates many problems like air pollution due to the chemical reaction if there are some toxic materials and also land pollution due to seepage of leachate. To avoid these problems generated due to waste we forced our attentions to manage solid waste (SW) (Eshat, 2007). Currently municipal solid waste is collected by two companies i.e., OZPAK and Albayrak. These companies are collecting waste from 273 Union Councils, providing door to door waste collection services. Lahore is divided into two zones. Ferozpur Road is the dividing line for the two (02) zones. Albayrak collect waste from zone 1 and OZPAK collect from zone 2.

Albayrak transport waste directly to lakhodeir while OZPAK Company collect waste and transport it to waste transfer station which is located near River Ravi and then transport to lakhodeir landfill site (Batool and Ch, 2009). Transfer station should not be located near the water bodies, residencies and coastal lines. It should be 1000m away from urban canters and 500m away from river and lakes, as waste transfer station is considered as point of pollution also. The transfer station that is working near River Ravi in Lahore is not properly designed. It is near to River and residential area that is against recommendation of USEPA. Waste is collected by small vehicles and transfer to this waste transfer station (TS) which is open to atmosphere, creating odour problems. Another problem in Pakistan is poor awareness regarding waste segregation at source. So it is best approach to have waste segregation plant to manage waste most efficiently.

According to USEPA waste transfer station consider as a point source of pollution because it has impacts like noise, dust and odour problems so it is sited with specific design criteria. It should not be located near residence, water bodies or cost line and natural habitats (EPA, 2002). Due to rapid population and waste generation in Lahore city there is need to reduce waste so that landfill site life can be increases and we can move towards sustainability. For this purpose, waste segregation is very important so that waste can be recycled or diverted from the landfill site. Due to lack of knowledge and aware in people mixed waste is disposed into collection bins. To segregate this waste there is need to have a facility which provide waste segregation before sending to a landfill site. The aim of this study is to first select the most suitable waste transfer station site which follow all the selection criteria of EPA using multi-criteria analysis and Geographic Information System (GIS). The selected site can be used as a waste segregation plant by adding some area for this. In this study layout of transfer station which also contain the waste segregation facility is provided. Direct and indirect collection cost comparison is also an objective to analyse the difference.

3. Materials and Methods

Methodology adopted in this study is explained step wise as follows:

3.1 Study Area

3.1.1 Location

Lahore city is the capital of the province of Punjab, Pakistan. It is located 31.55^{o} latitude and 74.34^{o} longitude in the eastern side of the province. It is at an elevation of 224 meters above the sea level. It lies 811 miles (1,305 km) northeast of Karachi within the higher Indus plain on the Ravi River, which is a tributary of the Indus. The total area of Lahore is approximately 1772 km^2 which is a huge area and still continuously in extension phase. The area of Lahore is still expanding due to increase in population (Zaman, 2012). The Lahore is divided into 9 towns as shown in Figure 1.

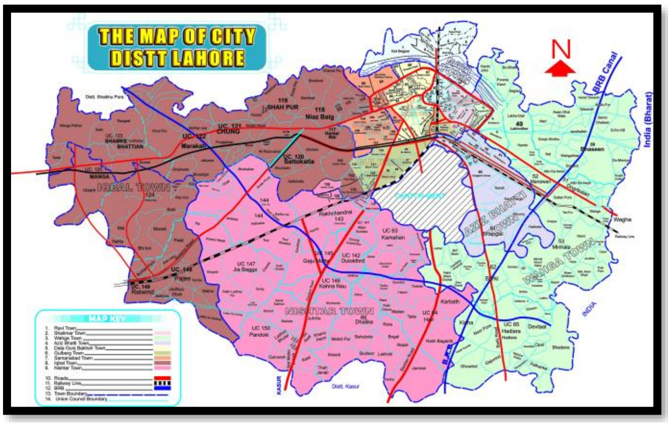

Figure 1: Map of Lahore Area showing different town of the city (eProperty, 2011)

3.1.2 Population Characteristics and demography of the study area

For the designing of any municipal facility population is a most important factor. Due to rapid industrialization huge change will appear in the population growth which will directly affect the solid waste production. Population and solid waste production are closely linked to each other. Therefore, the study and analysis of population growth and distribution within urban development is that the basic step for the design of any facility similar to this nature (Shirazi and Kazmi, 2014). Lahore is one of the most populous city in Punjab province and considered as 2^{nd} largest city of Pakistan. In 1998 the growth rate of Lahore was 3.22 % which then increased to 4.22% in 2017. According to Census 1998, the total population of Lahore was **63 lac** which raised to **1 crore** as per census 2017 (Bosompem, 2015; Zurbrugg, 2002). The growth in population is due to the large industrialization and more commercial activities in Lahore than other cities (Statictics, P.B.O. Population Census, 2017).

3.1.3 Software support for data collection and analytical techniques

In this study different software were used for various functions. The software facilitated to perform work in less time with more accuracy. Table 1 contains the software name and the purpose of their use.

Table 1: Software and their purpose.

	Software	Purpose
1	Arc GIS 10.0	For Data processing and analysis
2	Google Earth	For marking collection points
3	DNRGPS	To convert kml file to shape file
4	UMD	To download the detail maps
5	Excel	For the design of transfer station

To achieve the objective of the study the following activities have been performed:

- The information and literature available on transfer station have been collected and reviewed.
- Used GIS for the selection of suitable sites for TS in Lahore.
- Designed of TS on selected sites.
- Cost analysis of waste collection with and without TS.
- Estimate the revenue generated from waste.

The steps involve in methodology for siting and design of transfer station for study area in Lahore city has been described in Fig. 2.

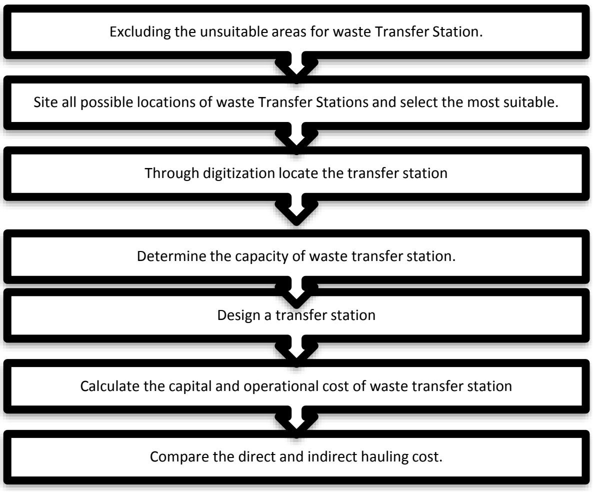

Figure 2: Flow chart of research plan

3.2 GIS Analysis

GIS tool was used for analysis, modelling and decision making. Figure 3 has demonstrated the conceptual diagram which shows the steps involved in the selection of potential site for transfer station.

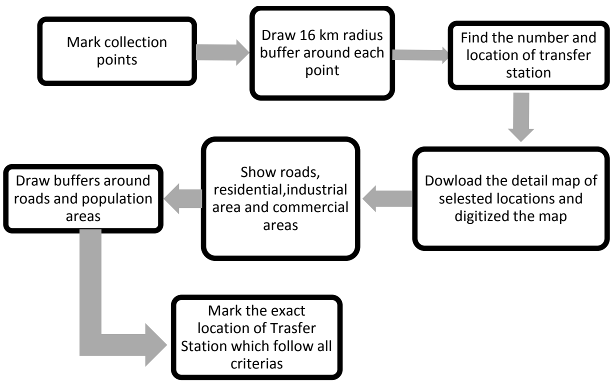

Figure 3: Conceptual diagram of working of GIS

3.3 Determining Transfer Station size and capacity:

Physical design of transfer station include size and capacity. Capacity depend upon the amount of waste. According to amount of waste generated and the number of years for which the facility was designed the capacity of transfer station was calculated. To calculate the size of transfer station was used

$$A = BA + PA \tag{1}$$

Where,

A is Area in m^2, BA is Building Area, PA is Parking area

Building area and parking area depend upon number of factors firstly all the factors was calculated. The procedure of finding these factors are discussed below in detail. The factors are:

- Amount of waste generated in the service area.
- Design life of transfer station
- Capacity and number of vehicles used at transfer station

Waste segregation facility capacity

3.4 Waste generated amount

To find the amount of waste generation, the initial step is to calculate the population present in the service area. Geometric mean method is used for future population projection.

Following equations are used,

$$\boldsymbol{Pf} = \boldsymbol{Pi} \times (\mathbf{1} + \boldsymbol{X})^{\boldsymbol{n}} \tag{2}$$

$$W = P \times r \tag{3}$$

Where,

Pf is Future population, Pi is initial population, X is annual population growth rate, n is number of years after which population is required, W is amount of waste generated is in kg/day, P is population in persons,

r is generation rate in kg per capita per day

Area required for tipping floor is calculated using amount of waste generated. (EPA, 2002)

$$TA = 4000 + (W \times 20) \tag{4}$$

Where,

TA is tipping floor area in ft^2 , W is weight of waste in tons

The number of semitrailer and trucks is obtained by using capacity of semitrailers and waste amount. Capacity of semitrailers ranges from 20-60 tons. Appropriate capacity of semitrailer is selected

$$S = \frac{W}{C} \tag{5}$$

Where,

S is number of semitrailer, C is capacity of collection vehicle in tons

3.4.1 *Design of Transfer Station*

Design of transfer station involved determination of area acquired by each facility in a transfer station. Total area is estimated by taking sum of area require for each facilities i.e. scale, house, machines area, service area, office area and storage area. In this research manual separation using conveyer belt is selected. Glass, paper, cardboard, plastic and tetra pack is sorted manually and magnetic separator is selected for metal separation. For the compaction of segregated waste stationary compactor is used. Area of conveyer belt, magnetic separator and stationary compactor is calculated using dimensions of each. Some percentage of conveyer belt area is added to include the person area. For segregated recyclable waste 3 days storage time is selected and the storage area is calculated for each waste.

$$V = \frac{Ww}{\rho} \tag{6}$$

$$A = \frac{V}{H} \tag{7}$$

Where,

V is volume in m^3, W_w is weight of waste in tons, ρ is density in tons/m^3, H is height in m, A is area in m^2

Total area of Transfer Station building is the summation of different areas.

$$BA = TP + MA + SA + STA + OA \tag{8}$$

Where,

BA is building Area, TP is area of tipping floor, MA is area of machines, SA is service area, STA is Storage area, OA is Office area

Parking area is obtained using area of vehicles used.

$$PA = n1 \times (L \times Wv) + Sa \tag{9}$$

Where,

n1 is number of vehicles, L is length of vehicle in m, Wv is width of vehicle in m, Sa is Scale area

3.4.2 Capital, operational and transport cost

Capital cost of transfer station include following costs equipment cost, Vehicle cost, Land cost and construction cost of building and parking. Land cost and construction cost is calculated by using Equation 10 and Equation 11. 1 m^2 area cost was obtained from literature. (Visit, 2019)

$$Lc = Ci \times TSa \quad (10)$$

$$Cc = Ca \times A \quad (11)$$

Where,

Lc is land cost is in PKR, Ci is cost of 1 m^2 area, TSa is total area of TS in m^2, Cc is construction cost is in PKR, Ca is construction cost of 1 m2 area Operating cost of transfer station include power of each machine, labour wages, energy used by office, energy usage of front end loader and maintenance cost of machines Power of each machine was provided by the manufacturer. Operating cost of machine is calculated by using Equation 12.

$$Oc = P \times Oh \times Cu \quad (12)$$

Where,

Oc is operating cost in PKR/day, P is power in kW, Oh is operating hour, Cu is unit cost Labour wages are calculated by using Equation 13

$$Lc = Lw \times hr \times Np \quad (13)$$

Where,

Lw is labour wages are in PKR/hr, Np is number of persons, Lc is labour cost is in PKR/day, hr is number of hours Factor of safety is also added in the parking area to include the area of collection vehicles. Equation 14 (Techobangalous, 2018) was used to calculate the power requirement for conveyer belt.

$$HP = M\,\frac{(0.48+0.00302Li)}{10} \quad (14)$$

Where,

M is amount of waste (tons/day), HP is horsepower to convey waste, Li is Conveyer length (ft) Number of persons needed for segregation of each waste was calculated by using the segregation capacity of a person per hour provided in literature. 1% of total cost of machines was calculated as maintenance cost of machine. By adding all total operating cost was calculated. Transportation cost include total distance covered by vehicle, number of Vehicles, diesel cost and operating cost of vehicle. For the estimation of transport cost distance covered by one vehicle is calculated first.

$$d = 2 \times dik \times N \quad (15)$$

Where,

d is distance covered is in km/day, N is number of trips, dik is One way distance to the landfill in km Diesel consumption of collection vehicle ranges from **29L/100 km** to **35L/100 km** and **45L/100 km** to **52/100 km** for transport vehicle. Total fuel cost increased to 20% to include maintenance cost.(Komilis, 2008) From the above ranges one value was selected and transport cost is calculated.

$$Tc = d \times (Fc + Mc) \quad (16)$$

Where,

Tc is Transport cost in PKR/day, Mc is Maintenance cost in PKR/km, Fc is Fuel cost in PKR/km

3.5 Direct and indirect hauling cost

Direct hauling cost involve transport cost of collection vehicle to transport waste from source to landfill site. It was calculated by using Equation 16 shown above. Indirect hauling cost is the summation of:

- Operating cost of transfer station
- Transport cost of collection vehicle to transport waste from source to transfer station
- Transport cost to transport remaining waste from transfer station to landfill site
- And transport cost to transport biodegradable waste from transfer station to composting plant.

The next step was to calculate the revenue generated from composting and from selling recyclable waste. The biodegradable waste was sent to composting plant to form compost. Revenue was generated by selling compost. Revenue of compost was by using Equation 17. Per ton revenue was taken from Lahore waste management company.

$$Rc = Bw \times Ri \quad (17)$$

Where,

Bw is Biodegradable waste in tons/day, Rc is Revenue from composting is in PKR/day, Ri is Per ton revenue. Per ton revenue generated from recyclables waste is determine by selling the recyclables. Equation 18 was used to calculate total revenue.

$$R = PC \times Ci + Mw \times Ci + Tp \times Ci + G \times Ci + Pi \times Ci \quad (18)$$

Where,

R is Revenue in PKR/day, PC is Paper and cardboard amount, Ci is per ton cost, Mw is Metal waste amount, Tp is Tetra pack amount, G is Glass amount, Pi is Plastic amount Revenue cost is subtracted from indirect cost then the obtained cost is hauling cost of waste using transfer station.

4. Results and Discussion

Figure 4 has shown the selected UCs which are suitable for the construction of waste transfer station. We draw 16 km buffer around each point (UC) and each radius buffer is shown with different colour. After buffer analysis chandrai (UC 241) and sultanki (UC 264) are selected as transfer stations because maximum buffer intersect with their buffers.

Figure 4: Selected UCs of Lahore

Figure 5 and 6 are the digitized map in which yellow colour shows 100m buffer around the road to select location near road. And other different colour of triangle show the industrial, colony and urban centre etc. which are unsuitable area for the construction of transfer station. According to above situation red placement mark is our suggested location for TS. Which is most suitable area.

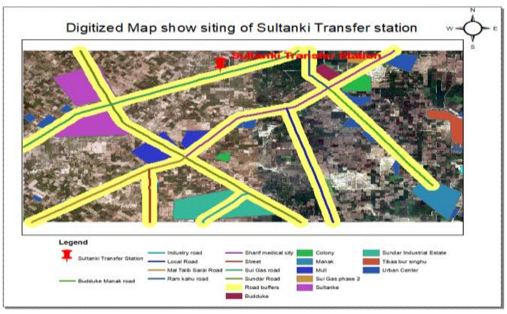

Figure 5: Digitize map for Sultanki TS

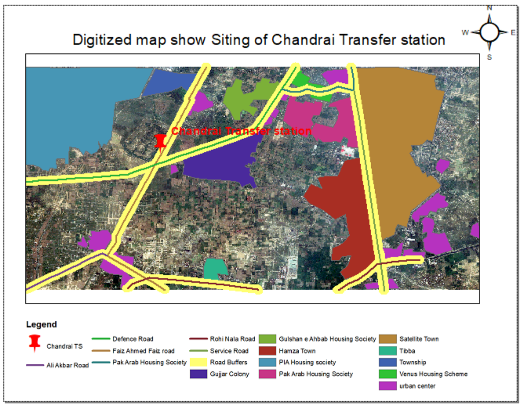

Figure 6: Digitize map of Chandrai TS

Figure 7 has shown the suggested or porposed layout for transfer station. It clearly depicts that waste will enter in transfer station through small vehicle. Vehicles will unload the waste into the tipping floor from where loader load it to conveyer belt where we can separate the plastic waste, metal waste, glass and paper card board manually. And the remaining waste provided suitable storage sent into composting plant though which we will generate the revenue.

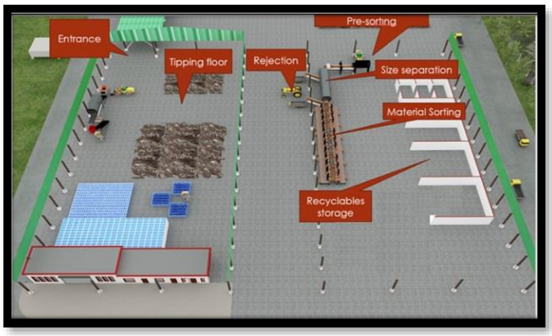

Figure 7: Proposed Layout of transfer station

4.1 Chandrai Transfer station

The area required for all processes are shown in Table 2 .The total area calculated is 5869.7 m².

Table 2: Area of each structure at Chandrai TS	
Name	**Area (m²)**
Tipping floor	3993.15
Machine area	175.28
Storage area for Plastic	78.6
Storage area for Paper and Cardboard	95
Storage area for Metal	5.3
Storage area for Glass	15.4
Storage area for Tetra pak	37
Total building area	4799.3
Parking Area	1070.3
Total area of transfer station	**5869.7**

4.2 Requirement of Equipment and vehicles

These are the equipment and vehicles required at Chandrai TS.

Table 3: Number of vehicles and equipment	
Name	**Number**
Transport Vehicles	7
Magnetic separator	1
Scale for weight	1
Stationary compactor	1

4.3 Sultanki Transfer Station

The area required for all processes are shown in Table 4. The total area calculated is 5869.7 m².

Table 4: Area Area of each structure at Sultanki TS	
Name	**Area (m²)**
Tipping floor	2645.6
Machine area	111.5
Storage area for Plastic	49.3
Storage area for Paper and Cardboard	59.7
Storage area for Metal	3.4
Storage area for Glass	9.7
Storage area for Tetra pak	23.3
Total building area	3167.28
Parking Area	1020.96
Total area of transfer station	4188.24

4.4 Requirement of Equipment and vehicles

Equipment and vehicles required at Sultanki TS are shown in Table 5.

Table 5: Number of vehicles and equipment	
Name	**Number**
Vehicles	8
Magnetic separator	1
Scale for weight	1
Stationary compactor	1

4.5 Cost analysis

The total capital cost for transfer stations was calculated. The capital cost comprised of equipment and vehicle capital cost, land cost and construction cost. The estimated capital cost of chandrai TS was approximately Rs. 1450 million shown in Table 6 and approximately Rs. 170 million for Sultanki TS shown in Table 6.

Table 6: Capital cost of Chandrai TS	
Name	**Cost (PKR)**
Equipment and vehicle capital cost	22,764,473
Land cost	1334184622
Construction cost	101544828
Total Capital cost	1,458,493,923

Table 7: Capital cost of Sultanki TS	
Name	**Cost (PKR)**
Equipment vehicle capital cost	23,853,848
Land cost	82796136
Construction cost	67284719.5
Total Capital cost	173,934,704

4.6 Cost Comparative Analysis

When there is no transfer station then cost of waste collection was approx. which is known as direct hauling cost. And when we built a transfer station and done waste segregation there then cost is 44 thousand approx. Which is known as indirect hauling cost. Through this we can see that cost reduction is 7 lac. In this cost analysis we only include the transportation cost and operational cost. The total revenue generated from the Chandrai TS is 140,000 Rs approx. which is subtracted from the indirect hauling cost. This revenue is gained from the recyclable and biodegradable able waste. Figure 8 is the graphical representation of results obtained after cost estimation of chandrai TS. It also shows the cost reduction if indirect hauling was done.

Table 8: Operating cost And Revenue from Chandrai TS			
Name	Cost (PKR/day)	Name	Revenue (PKR/day)
Operating cost	76929.00363	From Recyclables	866897
Transportation cost	1445049.74	From Biodegradable while composting	610397.92
Indirect disposal cost	44683.75	Total revenue	**1477294.93**
Direct disposal cost	835314.64		
Cost reduction	**790630.89**		

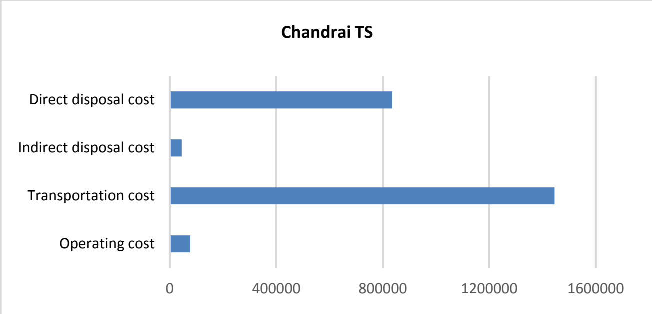

Figure 8: Cost analysis of Chandrai TS

Table 9 shows that in case of sultanki TS approximately all hauling cost recover from revenue. In addition, profit of Rs. **885,158.80** also gained. This shows that construction of Sultanki TS is more beneficial.

Table 9: Operating cost And Revenue from Sultanki TS

Name	Cost (PKR/day)	Name	Revenue (PKR/day)
Operating cost	65329.57524	From Recyclables	2038482
Transportation cost	1471273.29	From Biodegradable while composting	383279.68
Indirect disposal cost	0	Total revenue	2421761.68
Direct disposal cost	844616.08	Profit	**885158.80**
Cost reduction	**844616.08**		

Figure 9 is also the graphical representation of cost estimated for Sultanki TS

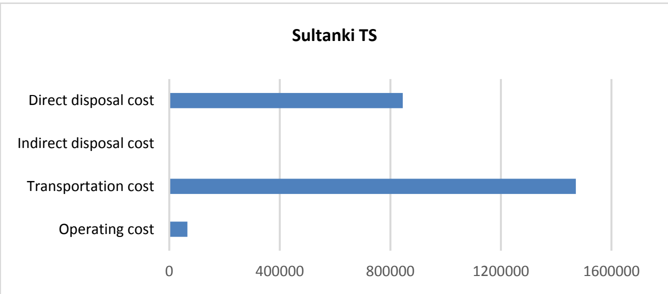

Figure 9: Cost analysis of Sultanki TS

5. Conclusion

This paper has presented the basic elements of a conceptual level design of a transfer station, From the selection of transfer mode to the application. For Lahore direct hauling cost is not feasible for 55 selected UCs. Then for those there should be 2 transfer station superposed. One is chandrai transfer station and second is sultanki transfer station. Chandrai transfer station has capacity of 1950 ton / day. And other hand sultanki has capacity 1250 ton/day. Direct and storage type TS should be provided where waste will be segregated easily, Plastic waste, metal waste, and glass and paper card board should be separated manually. And the remaining waste sent to composting plant. From the selling of recyclable waste and biodegradable waste revenue will be generated which will help to recover our capital cost of TS. Indirect hauling using proposed type of TS is economical than direction hauling as it recovers almost 90% of cost. Our selected sites for TS are located near industrial site which will allow recycling of segregated and recyclable items by industries. Solid waste volume that going to landfill site will less which increases the life of landfill site (Lakhodeir). As the need for transfer stations increases, the adoption of adequate design methods becomes even more important. Future research in this area can focus on determining the distribution of Inter vehicle arrival and vehicle service times at various types and sizes of transfer station, with the objective of developing simulation or graphical methods or rules-of-thumb that are generally applicable to transfer station design.

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