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Transportation of Solid Waste Based on Location-Allocation Method: A case study in RUET Campus Area

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Abstract

The main focus of this paper lies on solving solid waste problem which has been produced within campus area and also to formulate a mathematical model for solid waste transportation of Rajshahi University of Engineering & Technology. In the campus different waste sources scatter throughout the area in heterogeneous way that increase waste collection and transportation cost in the waste management system. The objective is to identify the sources and distribution centers for garbage transportation using location allocation algorithm. Therefore this model is mainly used for the beautification and enrichment of the institutional programs of campus area and also ensures optimal distance for collecting and transportation of solid waste.

Keywords: *Solid waste transportation, Location of distribution centers, Location-allocation problem.*

1. Introduction

Solid waste collection is an issue that every community has to deal with and many citizens operate a day to day basis without giving it much thought. Waste is completely unavoidable in any and every human activity. The population growth, rapid economic development and urbanization have led to an increase in the generation of solid waste. Waste generation from the public has been increasing over the last few decades, and although public awareness are improving, the rate of waste generation is still extremely high [3][8]. For this only when waste collection is disrupted do we see how important it is. In this perspective, solid waste management with proper collection and transportation techniques facilitates the waste managers to extract the required resources for recovery. In the past, garbage was dealt with much difficulty. Prior to door to door pickup, residents would take their own wastes to the dump. However the way the waste is collected, handled, stored, and disposed-off will determine the quality of the surrounding environment to be either clean, pleasant, healthy, and sustainable or filthy, disgusting, harmful, and wasteful.

The main focus of the paper is on the collection, transfer and transportation of solid waste from any waste generation sources (households, campus infrastructures) to the processing disposal destinations [2][4][5]. Location-allocation modelling is the method of optimizing the location of centers or facilities. This modeling system has been widely used for the facility location planning in both public and private sectors. Despite it being a significant factor in the successful achievement of solid waste, the location allocation problem of sitting storage depots have not been much studied. Optimization of the collection bin and storage bin location-allocation problems in solid waste management can be advantageous with respect to bin access to every individual person of municipality, reduction in the numbers of open dumping yards, and as an effort toward sustainable and green world.

This paper discusses possible collection methods for solid waste management in RUET campus and presents methods for optimal collection and transportation of waste. The optimal waste collection and transportation routes derived from the analysis will result reduction in travel distance along the routine collection road network followed. This study proposes possible transfer station locations based on various design factors like open land availability, ease of access from all the source to dustbin locations, transfer means by environmental factors [6][7]. This paper will discuss about the previous works over solid waste management and their collection methods, methodology of this model, model formulation, application and conclusions

2. Literature review

In 2017 two authors published a novel which proposed a model for Solid waste generation and characterization in the University of Lagos for a sustainable waste management. In this paper they have discussed about the waste collection method and the procedure of recycling it. This was done by using ASTM method [7].
Another author in 2017 have also researched on waste collection and transportation optimization. In that paper they have used location allocation method and have found the coordinates using Arc-GIS. But they have researched over Vellor city. They have proposed a waste collection and transportation model.[6]
In 2015 a novel was published Optimization of municipal solid waste collection and transportation routes where he used Integer Programming model. The survey was done over Kolkata city. Optimization of municipal solid waste (MSW) collection and transportation through source separation becomes one of the major concerns in the MSW management system design, due to the fact that the existing MSW management systems suffer by the high collection and transportation cost. Generally, in a city different waste sources scatter throughout the city in heterogeneous way that increase waste collection and transportation cost in the waste management system. Therefore, a shortest waste collection and transportation strategy can effectively reduce waste collection and transportation cost [2].
Another writer in 2015 published a paper where he discussed about Solid Waste Recycling Plant in Sakarya University Campus. The system approach is: waste management should involve waste formation, collecting, processing and removal as well as energy, protection of environment, protection of sources, increase of productivity, and employment as a whole. A system approach of waste management should deal with the removal of the waste from the human environment and furthermore protect and improve human health. In this project, we aim to dispose Sakarya University's waste by establishing a recycling plant making waste re-usable.
In 2017 Kagan [8].

3. Methodology

Let the location of the set of n known sources be given by (x_{Di},y_{Di}) (i= 1, 2, , n) their coordinates in a Cartesian coordinate system. Similarly let the coordinates of the m destinations that are to be determined be given by (x_j , y_j) (j= 1, 2, , m). If it is assumed that there are no destination capacity restrictions and the unit shipping costs are independent of destination output. However assuming in the definition of the objective function, φ (the cost of supplying n sources to m destinations). This is expressed by the use of a multiplier α_{ij} , which is 0 or 1, depending upon whether the ith source is not or is supplied to the jth destination. Accordingly,

$$\varphi= \sum_{j=1}^{j=m} \sum_{i=1}^{i=n} \alpha_{ij} \psi \,(x_{Di}, y_{Di}, x_j, y_j) \tag{1}$$

$\psi\,(x_{Di},y_{Di}, x_j , y_j)$ = Cost function for supplying the ith source to the jth destination.

In order to find the set of (x_j , y_j) that will minimize φ, differentiating (1) with respect to x_j and y_j and solve the equations resulting from setting the derivatives equal to zero. Thus

$$\partial\varphi \,/\, \partial\, x_j = 0\ , \qquad \partial\varphi \,/\, \partial y_j = 0 \tag{2}$$

Therefore have

$$\sum_{j=1}^{j=m} \alpha_{ij}\ [\psi\ (x_{Di}, y_{Di}, x_j, y_j) \,/\, \partial\, x_j\ ] = 0 \tag{3}$$

$$\sum_{j=1}^{j=m} \alpha_{ij}\ [\psi\ (x_{Di}, y_{Di}, x_j, y_j) \,/\, \partial y_j\ ] = 0$$

It is desired to minimize euclidean distance between sources and destinations, under the assumption that cost is proportional to distance. For that case

$$\psi\,(x_{Di}, y_{Di}, x_j, y_j) = w_{ij}[(x_{Di} - x_j)^2 + (y_{Di} - y_j)^2] \tag{5}$$

Where w_{ij} is a weighting factor resting to multiplicity of supply trips or service calls and effectively increases relative distance, we therefore have

$$\varphi= \sum_{j=1}^{j=m} \sum_{i=1}^{i=n} \alpha_{ij}\, w_{ij}[(x_{Di} - x_j)^2 + (y_{Di} - y_j)^2]^{\frac{1}{2}} \tag{6}$$

Let, $$D_{ij} = [(x_{Di} - x_j)^2 + (y_{Di} - y_j)^2]^{\frac{1}{2}}$$

Differentiating to find the minimum yields then the external equations become

$$\sum_{i=1}^{i=n} [\ \alpha_{ij}\, w_{ij}(x_{Di} - x_j\,) /\ D_{ij}] = 0 \tag{7}$$

$$\sum_{i=1}^{i=n}[\alpha_{ij}\, w_{ij}\ (\ y_{Di} - y_j\ )\ /\ D_{ij}\ ] = 0$$

These equations are solves iteratively. Let the superscript indicate the iteration parameter. The iteration equations for x_j and y_j are simply

$$x_j^{\ k+1} = \sum_{i=1}^{i=n} (\alpha_{ij}\, w_{ij} x_{Di} / {D_{ij}}^k) \,/\, \sum_{i=1}^{i=n} (\alpha_{ij}\, w_{ij} / {D_{ij}}^k) \tag{8}$$

$$y_j^{\ k+1} = \sum_{i=1}^{i=n} (\alpha_{ij}\, w_{ij} y_{Di} / {D_{ij}}^k) \,/\, \sum_{i=1}^{i=n} (\alpha_{ij}\, w_{ij} / {D_{ij}}^k)$$

A set of convenient starting values that always yields a convergent algorithm is simply the weighted mean coordinates

$$x_j^{\ 0} = \sum_{i=1}^{i=n} \alpha_{ij}\, w_{ij} x_{Di} \,/\, \sum_{i=1}^{i=n} \alpha_{ij} \qquad (9)$$
$$y_j^{\ 0} = \sum_{i=1}^{i=n} \alpha_{ij}\, w_{ij} y_{Di} \,/\, \sum_{i=1}^{i=n} \alpha_{ij}$$

By the following method one can find the location of a destination. However, for large numbers of destinations (>10) the method is not computationally attractive. In addition, these equations are valid only if, costs are proportional to distance. The above technique is exact and feasible[1].
By using this method a systematic approach was followed to obtain exact and feasible solution.
The following manner is:
Step 1: Identification of the number of sources.
Step 2: Determination of the location of each source.
Step 3: Using this method determination of the location of each destination.
Step 4: Choosing approximately with the ease of access.

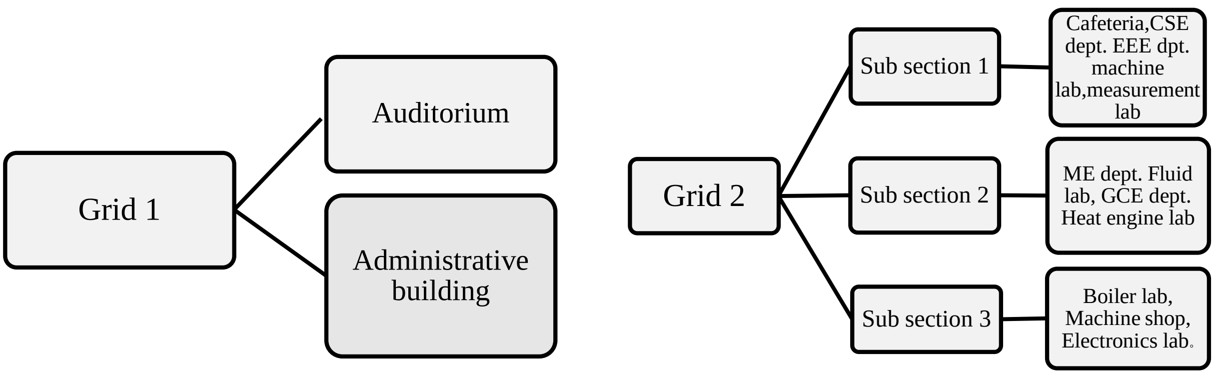
4. Applications

The numerical solution of minimization problems of the sufficient dustbin allocation in the RUET campus the following steps are included.

Step 1: Identification of the number of sources
For allocating sufficient dustbin and providing proper dumping system in the campus, a path is considered from source to destination model where infrastructures were assumed as sources and dustbin location as destination. Sufficient number of sources has been selected to carry out the solid waste in total campus area. Sources are divided into grids basing over the use of infrastructures by the students and authority.

Step 2: Identification of the location of sources
At first the location of sources was identified using the Master Plan of RUET. Under the sources administrative building, all of the departments, sessional building, students' hall, teacher's quarters, staff house, guest hall, and grocery shop are included etc. The location of the sources has been selected precisely keeping the cost in mind.

Step 3: Determination of the location of destinations
The application of the equation (9) of the technique described above, a numerical solution was found. The following table shows the optimal combination of the sources that will minimize distance from these sources and the locations of the destinations using this technique. The map shows the university infrastructures location. The map that was used is in alphabet lettering. For the ease of calculation the alphabetical lettering has been converted into numerical numbers. A→1; B→2; C→3; D→4; E→5;F→6; G→7; H→8; I→9; J→10; K→11: L→12; M→13; N→14: O→15; P→16.
Here the whole campus area was divided into different grids. Under the grids the allocated sources are:



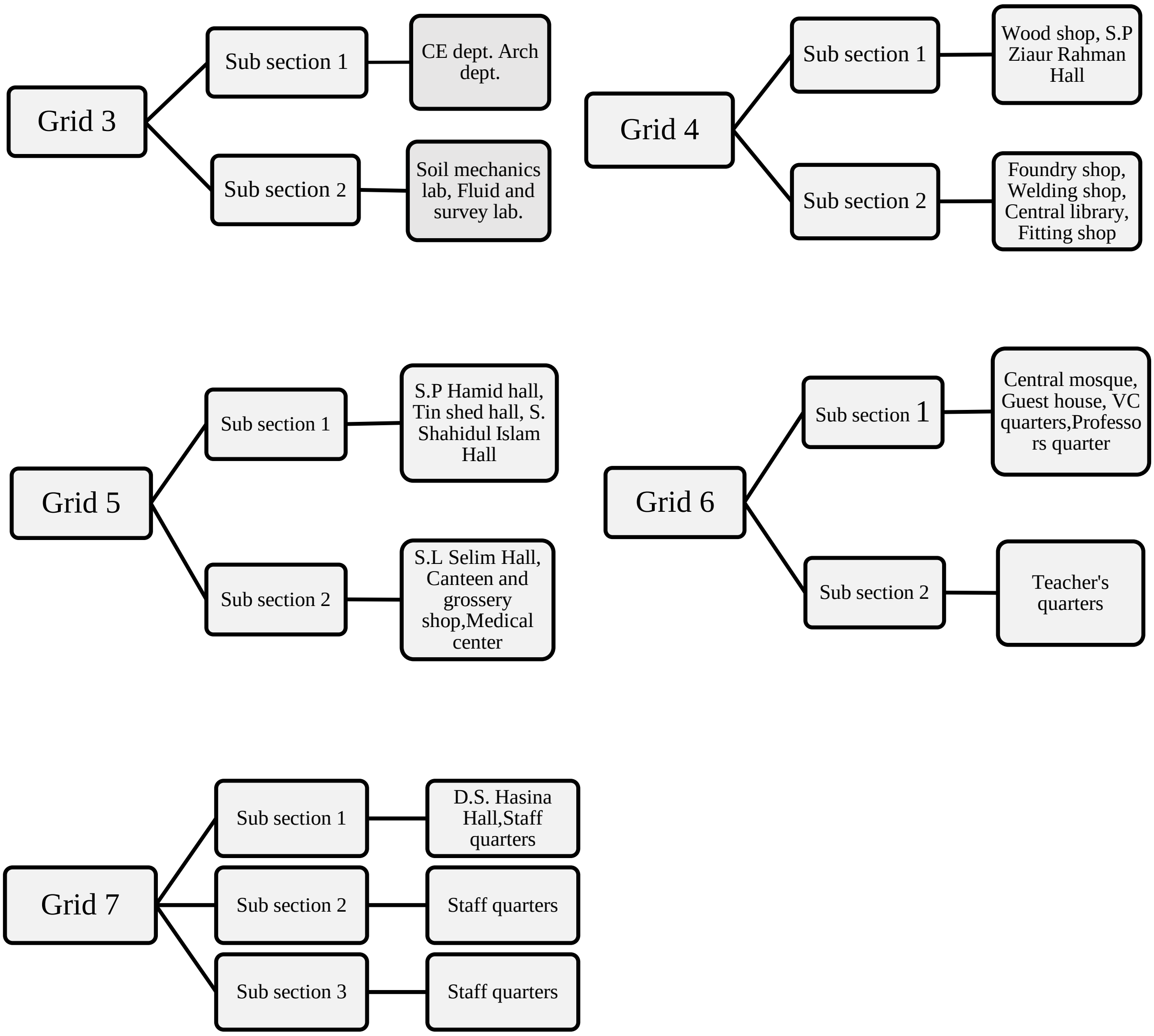


Fig. 1. Grid and sub sections.

Table 1. Determination of destinations (Dustbin)

Grid No. 1						
Sub-section 1	**1**	**2**	**3**	**4**	**5**	**6**
Sources Co-ordinates	Auditorium (11, 4)	Administrative building (5,5)				
Destination Co-ordinate	(8, 4.5)					
Grid No. 2						
Sub-section1	**1**	**2**	**3**	**4**	**5**	**6**
Sources Co-ordinates	Cafeteria (12,2)	CSE dept. (13, 6)	EEE dept. (12, 8)	Machine lab (12, 9)	Measurement lab (12, 10)	
Destination Co-ordinate	(12.2, 7)					

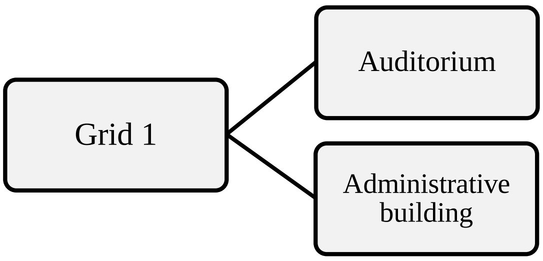
Sub-section 2	1	2	3	4	5	6
Sources Co-ordinates	ME dept. (9, 6)	Fluid lab (9, 8)	GCE dept. (9, 9)	Heat Engine lab (9, 10)		
Destination Co-ordinates	(9, 8.25)					
Sub-section 3	**1**	**2**	**3**	**4**	**5**	**6**
Sources Co-ordinates	Boiler lab (9, 11)	Machine shop (10, 13)	Electro-nics lab (12, 11)			
Destination Co-ordinate	(10.33, 11.66)					

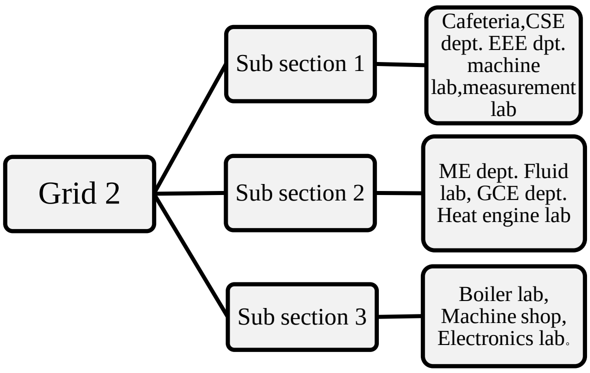
The appeal of using the sources set at a base from which the destination's coordinates have been generated in the following manner. Using the same manner the co-ordinates of seven grids have found out. Among the divided grids only two of which is shown in the map. Intuitively it seems that the larger the problem, the more likely it is that the approximate method will be correct.

Step 4: Approximate allocations

While installing the dustbin according to location table it might face some difficulties as the optimal combination of sources that were used, were also assumed. For this some while it may have to shift the dustbin location to the nearby and feasible location from the identified inappropriate coordinates.

After identifying the optimal combination of the sources that will minimize the distance between these sources and the destinations using this technique the dustbin will be installed. Here's an example is shown. The map shows the university infrastructures locations in grid 1 and 2.The whole campus's dustbin location is pointed in same manner. The distribution of dustbin shows here (in red circular dot).





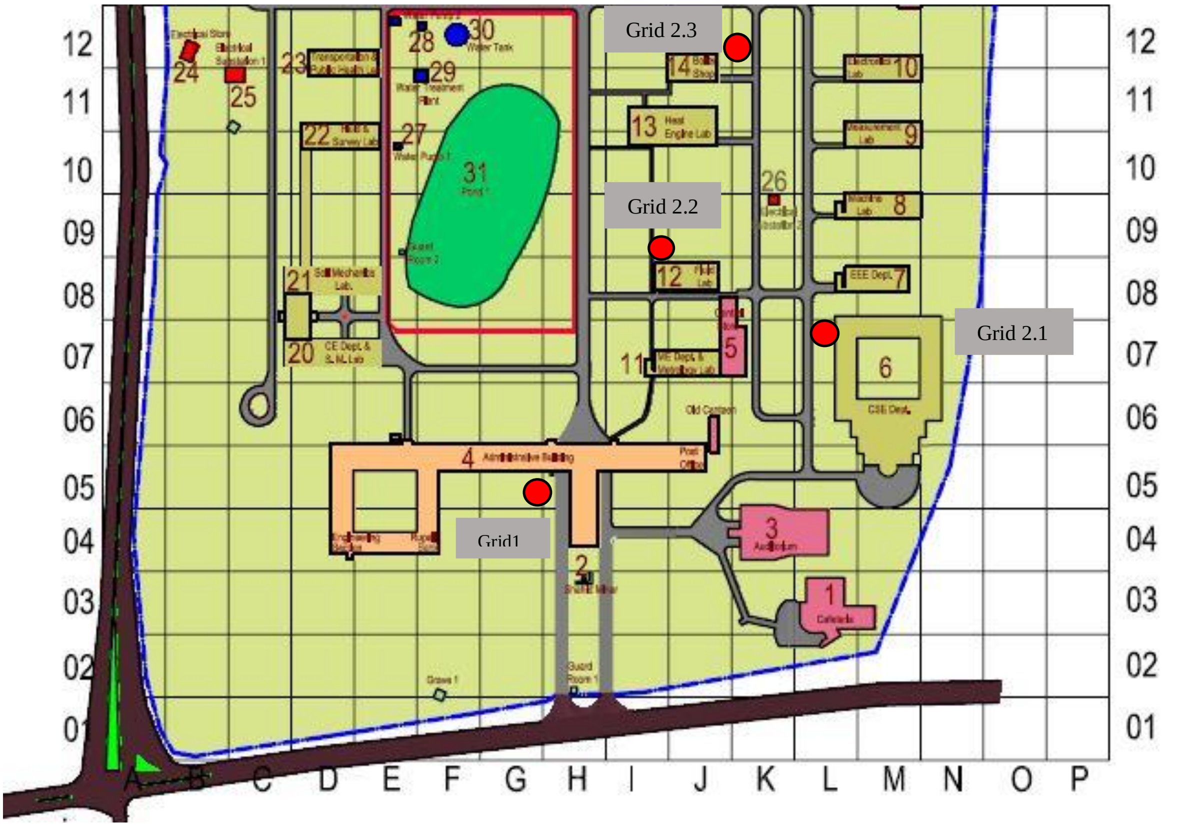


Fig.2. Locations of dustbins in GRID 1 and 2.

5. Conclusions

The approximate method of this paper and modifications proposed are all predicted on the basis of the Master plan of RUET. The appeal of using the sources set as a base from which to generate the location of destinations will sharply fulfill the objective of the goal of beautification and proper management of RUET. This method is more reliable than the most of other methods. The results shows the waste collection point through optimum path which is cost effective. Though this algorithm has tried to fulfill all the possible ways to make the campus greenly, it has some future scopes based on this model. Recycling the waste can add accelerate the beautification process and using ARC-GIS can point out the locations more precisely

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