

## Resource Planning For a Single Landfill Site Selection Model Based on Greedy Strategy: A Case Study

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### Abstract

Landfilling, which has emerged as the most common method for disposal of solid waste and selection of appropriate landfill for solid waste management, is a crucial aspect in urban planning. It is compulsory to consider the various criteria, such as environmental, economic, and social criteria, in order to get the best search outcomes that can minimise the adverse effects of the surrounding population. As widely known, the process of selecting new landfills is divided into two important phases, which are: 1) the determination of potential candidate locations through an initial screening, and 2) suitability assessment based on several criteria. Previously, issues related to landfill site selection have been successfully solved by using Geographic Information System (GIS) and Multiple Criteria Decision-Making (MCDM) techniques, either individually or as an integrated approach. With that, this research aims to assist the authorities in planning a single landfill site selection by utilising all the available resources, which translates being cost-effective. Therefore, the Nearest Greedy (NG) technique had been employed to assess all five potential candidate locations by considering several related constraints. Next, the solutions were ranked based on the total distance travelled by vehicles in completing the overall waste collection process. The proposed approach was tested on a real dataset of the waste collection problem in a district located within the Northern Region of Peninsular Malaysia, which consisted of 146 residential areas and involving up to 18749 unit premises. After that, the solution obtained was compared with the present operating landfill facility, in which Candidate 4 appeared as the best alternative with a 6.74% reduction of total distance travelled, in comparison to the present operating landfill method. As such, the proposed solution may aid the local authorities and serve as a guideline in identifying suitable locations for waste disposal based on availability resources, which can discard unnecessary expenditure, such as fuel consumption.

**Keywords:** Landfill site selection; Greedy technique; Resources planning; Case study.



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### 1. Introduction

Landfills are defined as the facilities used for disposal of residual wastes Tchobanoglous *et al.* (1993) and they have been declared as the oldest, the most convenient, and the cheapest disposal method Al-Ruzouq *et al.* (2018) in comparison to other approaches, as widely applied across many nations worldwide, including Malaysia. The landfill refers to a place to dispose of non-reusable waste materials that are difficult to discard. Despite of the various initiatives projected by the government to develop new technologies in the attempt to reduce the amount of waste, massive volumes of waste materials are generated from both the residential and the commercial sectors. Thus, efforts to decide the best landfill are a critical issue in the urban planning process as it has a huge impact on economic, ecological, and environmental health of the area. The main purpose of the landfill site selection process is to locate the best location that could diminish the dangers to the environment and public health Kahraman *et al.* (2018); Uyan (2014).

A good landfill site selection is determined by several important steps, and subsequently, if implemented in the manner specified, adverse long-term effects could be avoided Ball (2005). Generally, the landfill site selection process is comprised of two main steps, which are: 1) identification of possible candidate sites through preliminary screening, as well as 2) suitability assessment based on environmental impact assessment, engineering design, and cost comparison Chang *et al.* (2008); Charnpratheep *et al.* (1997).

Determining a suitable location for landfill among potential alternative locations is categorised as an Multiple Criteria Decision-Making (MCDM) issue as it involves a substantial number of criteria, such as distance to surface water resources Kahraman *et al.* (2018); Rahmat *et al.* (2017); Bahrani *et al.* (2016), land use (Kahraman *et al.* (2018)); Rahmat *et al.* (2017); Liu *et al.* (2018), residential areas Al-Ruzouq *et al.* (2018); Kahraman *et al.* (2018);

Liu *et al.* (2018); Santhosh and Sivakumar (2018), road access Al-Ruzouq *et al.* (2018); Kahraman *et al.* (2018); Rahmat *et al.* (2017); Majumdar *et al.* (2017) airport Al-Ruzouq *et al.* (2018); Santhosh and Sivakumar (2018); Ding *et al.* (2018), agricultural areas Santhosh and Sivakumar (2018); Ding *et al.* (2018), and historical sites Bahrani *et al.* (2016).

Although prior studies have used a variety of criteria, such as the criteria above, in connection with landfill site selection, these studies have neglected to examine the planning of resource utilisation in selecting a new landfill site, which may interfere at the implementation phase. In managing wastes, resources refer to workers, vehicles, fuel, money or anything else that assist the transportation of wastes from a house to the disposal facilities. In order to carry out all the tasks related to waste collection, the resources assigned to those tasks must be made avail. Nevertheless, prior to assigning those resources, their availability has to be ascertained. Resource availability refers to information regarding the resources that are required, as well as their availability and conditions. This is because; some resources, such as drivers and vehicles, have to be arranged in advance.

To further depict the scenario, for instance, a list of candidate landfill sites that meets all environmental impact assessments procedure and requirements is drawn. Next, those sites must be further evaluated to determine the top ranking. The best site is usually determined based on the secondary criteria, such as area width, soil depth, wind direction, and visibility from residential areas Bahrani *et al.* (2016). In fact, the evaluation criteria seem to differ for each study. Therefore, the ranking of candidate landfill sites may turn into a controversial issue due to the varying perspectives held by varied people Ball (2005). The above scenario conjured a thought to evaluate these candidate sites based on the availability of resources that may reveal the problems faced by the local authorities. In such situations, the candidate sites need to be evaluated based on several additional requirements, such as total distance covered by the collection vehicle for each candidate site. If the farthest landfill site is selected, then more maintenance cost should be allocated due to the long distance covered by the collection vehicles, and vice versa. Hence, this criterion appears to be significant, whereby the local authorities can make plans in terms of the number of drivers and vehicles required before an area is selected. Moreover, various techniques have been utilised in past studies to solve issues related to landfill site selection, for example, Geographic Information System (GIS), MCDM, hybrid techniques, and fuzzy-based approaches.

Thereby, the main objective of this paper is to develop a single model for solving a real case of landfill site selection problem with consideration of resource requirements. The rest paper is arranged in the following manner. Section 2 presents a review on solution techniques that have been used previously in solving landfill site selection problems. Next, Section 3 describes the real dataset of waste collection problem and the technique employed as a solution to the problem, while the retrieved computational outcomes are deliberated in Section 4. Lastly, some final remarks on conclusion and several recommendations for future work are offered in Section 5.

## 2. Review on Solution Techniques in Solving Landfill Site Selection Problems

In solving issues related to selection of landfill sites, various techniques have been considered and successfully employed, involving GIS, MCDM, hybrid techniques, and fuzzy approaches. For instance, Erkut and Moran (1991) developed a landfill siting procedure based on the Analytical Hierarchy Process (AHP) technique to locate municipal landfill facilities in the City Of Edmonton, Alberta, Canada. Meanwhile, a mixed integer programming model with a raster-based GIS was used by Kao and Lin (1996) to locate optimal facilities by considering site compactness. Besides, the first combination of GIS and AHP for landfill site selection was suggested by Siddiqui *et al.* (1996) in Cleveland County, Oklahoma. Charnpratheep *et al.* (1997) focused on the first phase of the landfill site selection process in Thailand by integrating the techniques of fuzzy set theory with AHP into raster-based GIS.

Meanwhile, Dikshit *et al.* (2000) identified potential landfill areas for preliminary site screening in the Nilgiri block of Balasore district in Orissa, India, by using the GIS technique. Sener B. *et al.* (2006) employed two different MCDA methods; simple additive weighting (SAW) and AHP, which were then embedded into a GIS to locate an appropriate landfill site in Ankara vicinity located at Turkey. As a result, they discovered that SAW had two assumptions of linearity and additivity that had been very difficult to apply in real-world situations, whereas the solution derived from AHP suggested more conservative outcomes. Wang *et al.* (2009) presented a landfill site selection problem in Beijing by employing GIS technologies and AHP after considering several environmental and economic factors, and at the same time, suggesting an optimal and backup location for reference in the future.

Nas *et al.* (2010) applied a combination of GIS and multi-criteria evaluation (MCE) analysis to identify a suitable location for landfill siting in Cumra County of Konya City, Turkey. Additionally, Sener S. *et al.* (2010) determined an appropriate landfill site for the Lake Beysehir catchment area using a combination of AHP and GIS. Gorsevski *et al.* (2012) described a GIS-based MCDM approach to evaluate the appropriateness of landfill site selection in Macedonia. The fuzzy membership functions integrated with AHP and ordered weighted average (OWA) techniques had been utilised to better explain the decision-making process. Nazari *et al.* (2012) proposed a methodology for evaluation and identification of potential locations for MSW landfill based on Chang's fuzzy AHP approach, hence discovering that that approach is the most suitable method to rank alternative sites. Isalou *et al.* (2013) on the other hand, integrated fuzzy logic with analytic network process (F-ANP) to determine an appropriate location for sanitary landfill in Kahak Town, Iran and discovered that this integrated technique gave better outcomes, in comparison to other individual methods, such as AHP, fuzzy approach, and ANP. Uyan (2014) identified a suitable location for landfill siting in Konya metropolitan, Turkey by using the GIS and AHP methods.

Beskese *et al.* (2015) utilised decision-making tools, such as fuzzy AHP and fuzzy technique for order preference by similarity to generate an ideal solution (fuzzy TOPSIS) to tackle landfill site selection problem, which reflects the fast growth rate of Istanbul urbanisation. Bahrani *et al.* (2016) screened several potential locations in the

city of Shabestar, Iran for municipal landfill construction, as well as to identify the most suitable location by applying a combination of GIS, fuzzy functions, AHP, and weighted linear combination (WLC). Next, [Majumdar et al. \(2017\)](#) employed an AHP method to select a sanitary landfill site for Kolkata Municipal area and revealed that the proposed method is an effective tool for landfill identification amongst developing nations. An integration of GIS, AHP, and SAW methods was employed by [Rahmat et al. \(2017\)](#) for landfill site selection in Behbahan County at Iran. Other techniques used for solving landfill site selection can be referred to an extensive review article published by [Mat et al. \(2017a\)](#). In addition, several recent studies pertaining to landfill site selection are portrayed in Table 1.

**Table-1.** Recent Studies Pertaining to Landfill Site Selection

References	Descriptions
(Al-Ruzouq et al., 2018)	A combination of fuzzy membership and AHP in GIS environment was used for landfill siting in Sharjah city, United Arab Emirates
(Ding et al., 2018)	Presented a selection of Construction and Demolition (C&D) waste landfill sites in Shenzhen, China using GIS and AHP methods. The solution may serve as guidance for site location decisions in the future.
(Kahraman et al., 2018)	Included information axiom into a trapezoidal intuitionistic fuzzy set to overcome doubts among experts in deciding the best location for landfill siting in Istanbul Metropolitan Municipality.
(Liu et al., 2018)	Proposed a new hybrid modified MADM model via DEMATEL-based ANP to estimate the influential factors and via a hybrid modified VIKOR method to improve and to select the location for food waste composting facilities.
(Santhosh and Sivakumar, 2018)	Presented a landfill site selection process in Bengaluru city, India using integrated AHP with GIS after considering groundwater vulnerability contamination assessment. The assessment was solved by using the DRASTIC method.

By realising the importance of considering appropriate resources to local authorities in planning a new landfill site selection, this study proposes a single landfill site selection model by examining the planning of resource utilisation in selecting a new landfill site so as to illustrate a real-life applications scenario. In practice, many reasons may influence the decision to choose only one location, even if options are offered to choose a few (perhaps more than one) to be new facilities. This is because; some decisions must be made urgently regardless of limited available resources. For instance, a single depot is available with a set of customers and five potential locations to be located as disposal facility. Of these locations, only one has to be selected with a minimum number of total distances to complete the waste collection process and the solution is considered as the best option. In precise, this study investigated a single landfill site selection problem that could minimise waste collection operating cost. With that, a well-known constructive heuristic algorithm called ‘greedy techniques’ was adopted from [Mat et al. \(2017b\)](#) to construct several initial solutions for waste collection, in which later on, the proposed solution was applied to evaluate the suitability of potential candidate landfill site. Some studies that have successfully solved the actual cases associated with waste collection problem using greedy techniques can be found in [Mat et al. \(2017b\)](#).

### 3. Materials and Methods

This section presents the real dataset of waste collection and the greedy technique utilised in this study.

#### 3.1. Real Dataset of Waste Collection Problem

This paper explored a real dataset of the waste collection problem in a district located in Kedah, Malaysia. The dataset was used to test the proposed single landfill site selection model by taking into account several resource constraints. A model of waste collection vehicle routing problem with time windows (WC-VRPTW) is presented to mirror a real scenario that occurs in waste management planning. The problem highlighted in this study is considered as a node routing problem mainly because the demands (i.e., waste) and the locations of the customers are represented by nodes of the road network. The problem consisted of 146 residential areas (referred as nodes) that involved up to 18749 units of premises. The characteristics of the dataset are displayed in Figure 1.

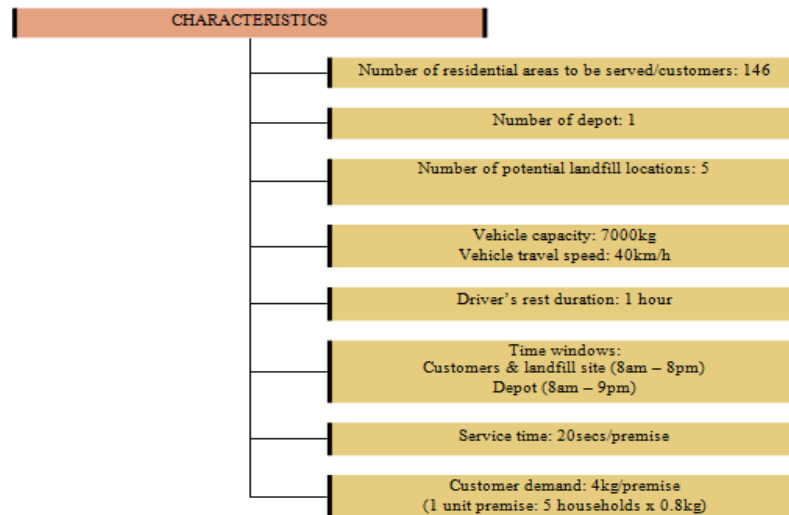
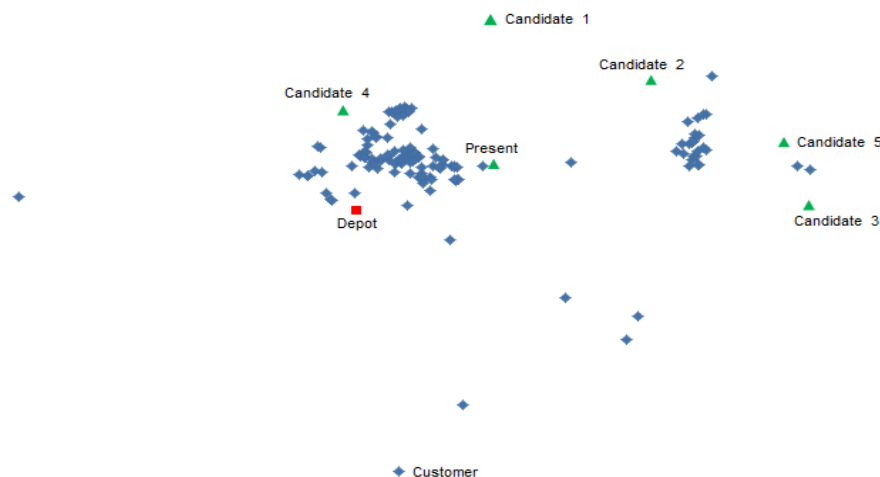
**Figure-1.** Characteristics of a Real Waste Collection Dataset

Figure 1 presents the characteristics of a real life waste collection problem, which consisted of 146 residential areas, one depot, one present operating landfill (for comparison purpose), and five candidate landfill locations. In this research, the candidate landfill locations were determined based on assumption. Google Earth was used manually to identify the locations of free land areas (unused or agricultural land), which is located further from residential areas. In fact, some guidelines have to be adhered in determining the permissible distance between the located landfill sites and the residential areas, as stipulated in the law. For instance, a minimum buffer zone of 1000m was considered by [Al-Ruzouq et al. \(2018\)](#) and [Uyan \(2014\)](#), while [Wang et al. \(2009\)](#) considered a buffer zone greater than 2000m to be more suitable for landfill siting. A minimum buffer zone of 3000m was considered in this research. However, as mentioned before, this is merely an assumption, whereby field work determination is recommended to obtain more reliable locations. Furthermore, the vehicle capacity to serve the customers is limited to 7000kg. Besides, the lunch break allocated for the driver is one hour. The time window for depot is between 8am and 9pm, whereas the time window for customers and landfill site is between 8am and 8pm. The service time for each premise/house is 20 seconds and the amount of waste per house is estimated at 4kg. Furthermore, 40km/h is the speed limit of the vehicle. The distribution of customers, candidate landfill sites, and the single depot is illustrated in Figure 2.

**Figure-2.** The Distribution of Customers, Candidate Landfill Sites, and Single Depot

### 3.2. Greedy Technique for a Single Landfill Site Selection Model

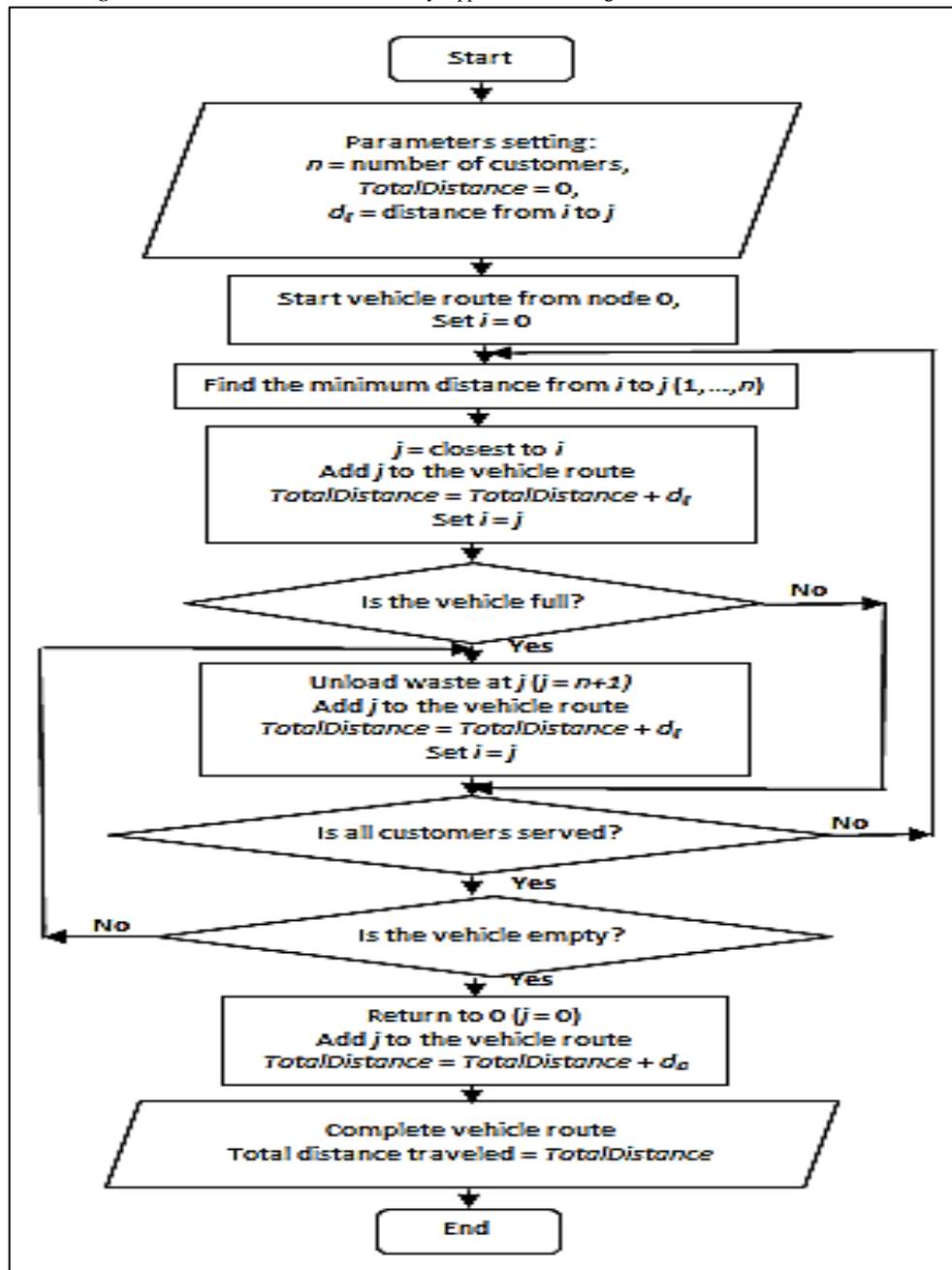
This study is a continuation of the work published by [Mat et al. \(2016\)](#), where the particular study proposed a framework of landfill site selection by weighing in resource requirement. Therefore, this study enhanced the issue by introducing a single landfill site selection model based on the availability of resources. For that purpose, the Nearest Greedy (NG) technique had been adopted from the work carried out by [Mat et al. \(2017b\)](#) to generate initial solutions for a real dataset waste collection problem. Fundamentally, in solving the problem related to waste collection, the NG technique selected the nearest customer from the current node to be served based on several constraints linked to depot, customer, landfill site, vehicle capacity, and operational, as depicted in Table 2.

**Table-2.** Constraints Related to Waste Collection Problem

Constraints	Descriptions
For depot/customer/landfill site:	<ul style="list-style-type: none"> <li>• Total number of customer to be served</li> <li>• Total number of depot</li> <li>• Total number of landfill sites</li> <li>• Time windows</li> <li>• Demand (amount of waste to be collected from customers)</li> <li>• Service time</li> </ul>
For vehicle:	<ul style="list-style-type: none"> <li>• Maximum number of customers served per day</li> <li>• Capacity of vehicle (maximum weight allowed for vehicle)</li> <li>• Driver's lunch break</li> <li>• Speed (maximum speed allowed for vehicle to carry waste)</li> </ul>
For operational:	<ul style="list-style-type: none"> <li>• Each vehicle must start and end at the depot</li> <li>• Each customer needs to be served exactly once</li> <li>• The amount of waste collected from customers cannot exceed the allocated load for a vehicle</li> <li>• The vehicle must be emptied if the capacity is full before continuing servicing customers or before returning to the depot upon completion of collection.</li> </ul>

In this research, the NG technique was adopted to construct vehicle routes in order to solve waste collection problem. A new set of initial solutions was constructed based on the number of candidate landfill site. For example, six landfill sites (five potential and one present operating landfill) were identified, thus indicating six initial solutions for comparison at the end of the analysis. The total number of stops for each landfill site was calculated as  $(n + \text{one depot} + \text{one landfill site})$ , where  $n$  refers to total customers served. Each node was defined based on ID, which are 0 for depot  $\{1, \dots, n\}$ ,  $n$  for customers, and  $\{n+1\}$  for landfill site. A new vehicle route was constructed from node 0. Then, the nearest customer from node 0 was identified by using the NG technique. During this process, the distance between 0 and  $n$  customers had been compared. The selected node with the lowest distance was added to the present vehicle route, while the remaining customers that are yet to be served were updated. The vehicle capacity was determined soon after each customer was served. If the vehicle was fully loaded with waste, they would need to dispose the collected waste into the landfill site  $\{n+1\}$ . The process continued until all customers had been served. Before returning to node 0, the vehicle load would have to be emptied at the landfill site. As such, the algorithm calculated the total travel distance by the vehicle and the total time required by the drivers to complete the waste collection process. Finally, the algorithm was terminated. The total travel distance for each candidate landfill site was ranked in ascending order. The candidate landfill site with the lowest distance emerges as the best optimal solution. The flowchart of the nearest greedy approach in solving the waste collection problem is demonstrated in Figure 3.



**Figure-3.** Flowchart of the Nearest Greedy Approach in Solving the Waste Collection Problem

#### 4. Results and Discussions

In this paper, the proposed algorithms that solved WC-VRPTW were run on a Pentium® Dual-Core CPU T4300 @ 2.10GHz with 3.00 GB memory using C++ language. Table 2 presents the comparison of the computational outcomes between the present operating landfill site and the other five potential landfill sites. The solutions were compared in terms of total travel distance, total travel time, and the number of drivers required completing the waste collection process for landfill site selection planning. In addition, the ranking of the potential landfill is presented in the last column of Table 3.

**Table-3.** Computational Outcomes using the NG Technique

Landfill	Total travel distance (km)	Total travel time (secs)	Number of drivers required	Computational time (secs)	% improvement in distance over present landfill	Ranking based on total travel distance
Present	702.963	52416.1	11	0.188	-	-
1	1004.16	74874.8	11	0.195	-42.85	4
2	953.734	71114.7	11	0.187	-35.67	2
3	973.978	72624.2	11	0.177	-38.55	3
4	<b>655.562</b>	<b>48881.7</b>	<b>11</b>	<b>0.157</b>	<b>6.74</b>	<b>1</b>
5	1011.05	75388.8	11	0.291	-43.83	5

The computational results tabulated in Table 3 show the resources required to provide service to 18,749 units of premises based on six different landfill sites. In view of the analysis for the proposed solution, candidate landfill 4 appeared as the best alternative, in comparison to other candidate sites, whereby the total distance travelled by all drivers was 655.562km (a decrease by 6.74%, as compared to the present landfill site). Besides, the time taken to complete all the vehicle routes was about 13 hours and 58 minutes. Nevertheless, the local authorities would need to hire the same number of drivers (eleven) for all landfills to complete the waste collection process. As a conclusion, if the local authorities decide to choose a minimum distance covered by all vehicles to complete the whole waste collection process, candidate landfill 4 seems to be the best choice as it resulted in the lowest travel distance, hence signifying lower fuel consumption.

## 5. Conclusion

To date, disposing solid waste via landfilling is the most common method widely used across the globe, which suggests the selection of a suitable landfill for solid waste management as a crucial aspect in urban planning. Various criteria from the light of environmental, economic, and social need to be considered so as to obtain the best search results, which can reduce the adverse side effects upon the surrounding communities. Previously, landfill site selection problems have been successfully addressed by using GIS and MCDM techniques, either individually or amalgamated with each other. This research, hence, aims to help those in the waste management arena to plan new landfill site selection by considering all the available resources, which is cost-effective. As such, the NG technique was employed to evaluate all potential locations by considering several related constraints. Next, the solutions were ranked based on the total distance travelled by the vehicles after completing the whole waste collection process. The proposed approach was tested on a real dataset of the waste collection problem in a district located in Kedah, Malaysia. The computational outcomes exhibited that resources, such as drivers and distance of travel, affected the landfill site selection process. Generally, it is summed up here that if the authorities decide to establish a landfill far from the society, they would need to bear higher operating costs, such as maintenance costs and fuel for the purpose of waste collection. In the near future, the authors would like to make comparison between single and multiple landfill site selection based on resource requirements in the attempt to derive at a more viable solution.

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