A REVIEW OF SOLID WASTE COLLECTION ROUTE OPTIMIZATION VIA GOOGLE EARTH AND GIS TECHNIQUE IN BIRATNAGAR METROPOLITAN CITY

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Abstract

Increasing urbanization and population growth have made solid waste management a significant problem for emerging states like Biratnagar. Environmental harm and social unrest may result from problems with solid waste management. Solid waste management includes the following steps: production, collection, transportation, treatment, recycling, and disposal. The high cost of solid waste management is mostly attributable to inefficient collection and transportation practices that may result in environmental damage. It's critical to reduce transportation and collection costs if rising economies are to implement sustainable solid waste management. For maximum effectiveness, economic savings, and environmental preservation, collection and transportation can be managed and monitored. This review article highlights the difficulties emerging nations face in managing their solid waste and stresses the need for effective collection and transportation networks in order to achieve sustainable solid waste management. The review offers insights into how collection and transportation techniques might be optimized through system analysis and operation utilizing technologies like Arc GIS and Google Earth, with an emphasis on the advantages of cost reductions and environmental preservation.

Keywords: *Solid Waste, Urbanization, Sustainable solid waste management, Transportation and collection costs, System Analysis, Arc GIS, Google Earth, operation*

1. Introduction

Waste management is becoming more crucial and challenging, especially for developing nations like Nepal, when factors like energy and transportation, labor costs, landfill selection and operation, and urban expansion are taken into account. Transportation is a significant factor in moving garbage through this process, which is expected to use two-thirds of the overall cost. In order for collection to be practical, solid trash and recyclables must first be gathered, and then they must be transported to the site where the collection truck is being emptied. This place could be a landfill dumping site, a materials processing facility, or a transfer station. The development of waste occurs in every home, apartment, commercial facility, and individual facility in addition to in the streets, parks, and even vacant places, making the collection of solid waste in an urban area challenging and complex. As a result, it is crucial to consider the following when planning a garbage collection operation: the different waste-collecting services and systems, the equipment to be used, the necessary workforce, and the collection routes. Systems for the sustainable management of solid waste in developing nations must include effective collection and transportation. Solid waste management costs are significantly influenced by ineffective collection and transportation, which raises operating costs and pollutes the environment. Because of this, route optimization is essential to maximizing the collecting and transportation process and lowering costs while preserving the environment. When deciding on the most effective solid waste collection and transportation routes, system analysis and operation can be used to take into consideration variables such as trash generation rates, population density, state-by-state routes, and collection frequency. By reducing travel time, fuel use, and vehicle wear and tear, route optimization can lower costs and greenhouse gas emissions. As a result, optimizing solid waste management processes is essential to attaining sustainable growth in poorer nations.

Route optimization is one of the systematic and strategic approach for the management of municipal solid waste where the distance is optimized by fixing the collection centers. For the management of waste of municipality, it needs much manpower and transport resources for its collection and disposal which can be improved by the Google Earth and Arc GIS. The Google Earth and ArcGIS helps to analyze and manipulate data so that the alternative can be determined and take effective decision for the route optimization in the transportation of waste in municipality so that the time and cost can be minimized. The network analysis gives output on the two criteria that are distance criteria and time criteria. On the distance criteria, it analyzes and manipulates the data of efficient travel routes, and on the time criteria, it reduces the total time required for the collection and transportation of waste.

Google Earth and Arc GIS can help in managing the large volume of municipal waste by providing better transportation and labor for waste collection and disposal. The new technologies Google Earth and GIS can make a significant contribution to waste management in society in a short amount of time. In order to establish the best course of action for route optimization in the transportation of garbage in municipalities, it is helpful to analyze and manipulate data using Google Earth and ArcGIS. This reduces both time and expense.

2. Objectives

The main objectives are:

- To compile and analyze the transport and collection information for municipal solid trash in Biratnagar metropolitan city.
- To conduct ArcGIS and Google Earth analysis and produce an efficient route for the collection of solid garbage in BMC.
- To compare the study of the collecting system's distance, fuel consumption, and time between the present and suggested optimal systems.

3. Research Methodology

3.1. Study area

Biratnagar, a metropolis in Nepal, is one of the biggest and most populous cities in the world. It serves as the capital of the Koshi Province. It is situated in the Koshi region's Morang district. BMC recently underwent building or renovation to become a metropolitan city on 2074/2/17 BS. BMC has 19 wards, totaling 76.9 km2 in size. According to CBS (2014), the city has 305,529 residents and is expanding at a pace of 2.25 per year. India forms its southern boundary with the region, Budhiganga and Gramthan VDC its northern border, Kathari and Jahda VDC its eastern border, Sunsari district its western border, and Budhiganga and Jahda VDC its western border. BMC is renowned for having a wide range of industries. On the BMC map in Figure 1, the 19 wards and their boundaries are depicted.

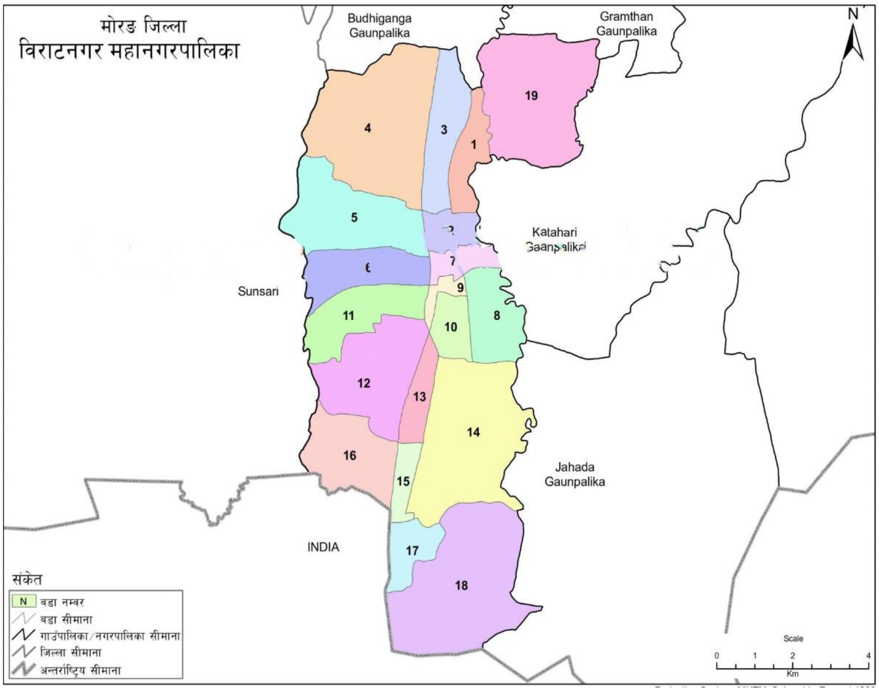

Figure 1: Map of Biratnagar Metropolitan City showing each ward

(source: http://biratnagarmun.gov.np/)

Table 1: Geo-Physical and Social Features

Name	Biratnagar Metropolitan City
Province	Koshi Province
District	Morang
Number of wards	19
Total Area	76.99 sq. km
Total Population	305529
Number of Households	47798
Population Density	3892
Longitude	26°27′15″N
Latitude	87°16′47″E
Elevation	80m

(source: http://biratnagarmun.gov.np/)

3.1.1. Climate

i. Temperature:

An analysis of the meteorological data for Biratnagar during a 30-year period (1982 to 2012) revealed that the maximum monthly temperature was 32.6^{o}C in June and the minimum temperature was 23.4^{0}C in January. The temperature is high throughout the year, with a daily range of 5-100 ^{0}C. The four distinct seasons are absent from Biratnagar, where the climate is perpetually hot and muggy.

Table 2: Monthly Temperature in Biratnagar (Unit^{0}C)

Category	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Mean maximum temperature	23.4	25.8	31.3	33.6	33.2	32.6	31.7	32.2	31.4	31.0	28.7	25.0
Mean temperature	16.2	18.1	23.2	27.0	28.1	28.8	28.5	27.9	26.1	21.6	17.4	24.3
Mean minimum temperature	9.0	10.5	15.1	20.5	23.1	25.0	25.3	25.6	24.4	21.3	14.6	9.8

ii. Precipitation:

An analysis of the meteorological data in Biratnagar over a 30-year period (1982 to 2012) showed that the average annual precipitation was 1898mm, and precipitation was high during the wet season from June to September.

Table 3: Monthly precipitation in Biratnagar

Category	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Average precipitation	10	9	18	47	144	340	543	367	313	95	8	4

3.2. Generation and composition of municipal solid waste

Biratnagar produces solid garbage from houses, businesses, institutions, hotels, and restaurants in addition to people that move there from rural areas in pursuit of employment and other possibilities. According to a recent trash composition and generation survey done for the study, the rate of garbage generation per person is 0.317 kg/person/day, and the total amount of waste produced daily is 110 tons. Biodegradable materials (62.13%), Plastic (15.20%), paper/cardboard (14.39%), glass (2.95%), textiles (1.66%), rubber/leather (1.53%), metal (0.99%), and miscellaneous rejected materials (1.11%) make up the majority of waste produced. The total garbage produced by the various sectors in BMC is shown in Figure 2.

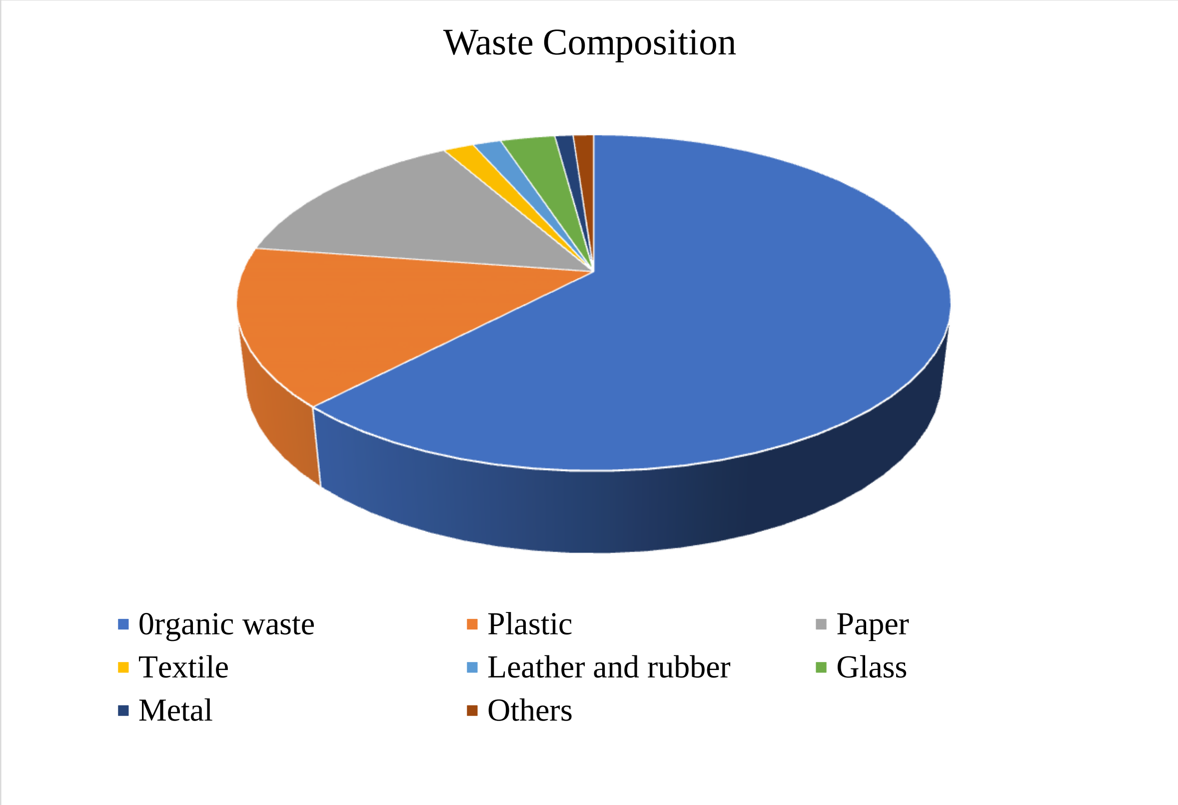

Figure 2: Waste composition of various sectors in BMC

3.3. Existing Solid Waste Collection and Transportation Practices

For waste collection and disposal, Biratnagar Metropolitan City has used the PPP approach since 2008. The garbage management system has been outsourced by the city to private companies. Currently, a contract has been signed with three private contractors to work in the north belt, south belt, and central belt of the city. The city is divided in the manner shown below:

- North belt has been managed by Nepal Fulbari Trash 3R pollution control and contains wards 1, 2, 3, 4, and 19.
- Middle belt: It has been run by Health and Peace for Environment Nepal and consists of wards 6 through 11.
- Wards 12 to 18 make up the South Belt, which has been run by Sagarmatha Multi Service Pvt. Ltd.

Biratnagar adopted collection along predetermined routes. In locations with limited roads, rickshaws are employed, while markets and areas with wide roads favor tractors. As shown in Figure 3, the survey indicates that 70% of households receive point collection, followed by door-to-door collection (14%), collection from the garbage pile along the roadside (9%), and collection from the waste container (7%).

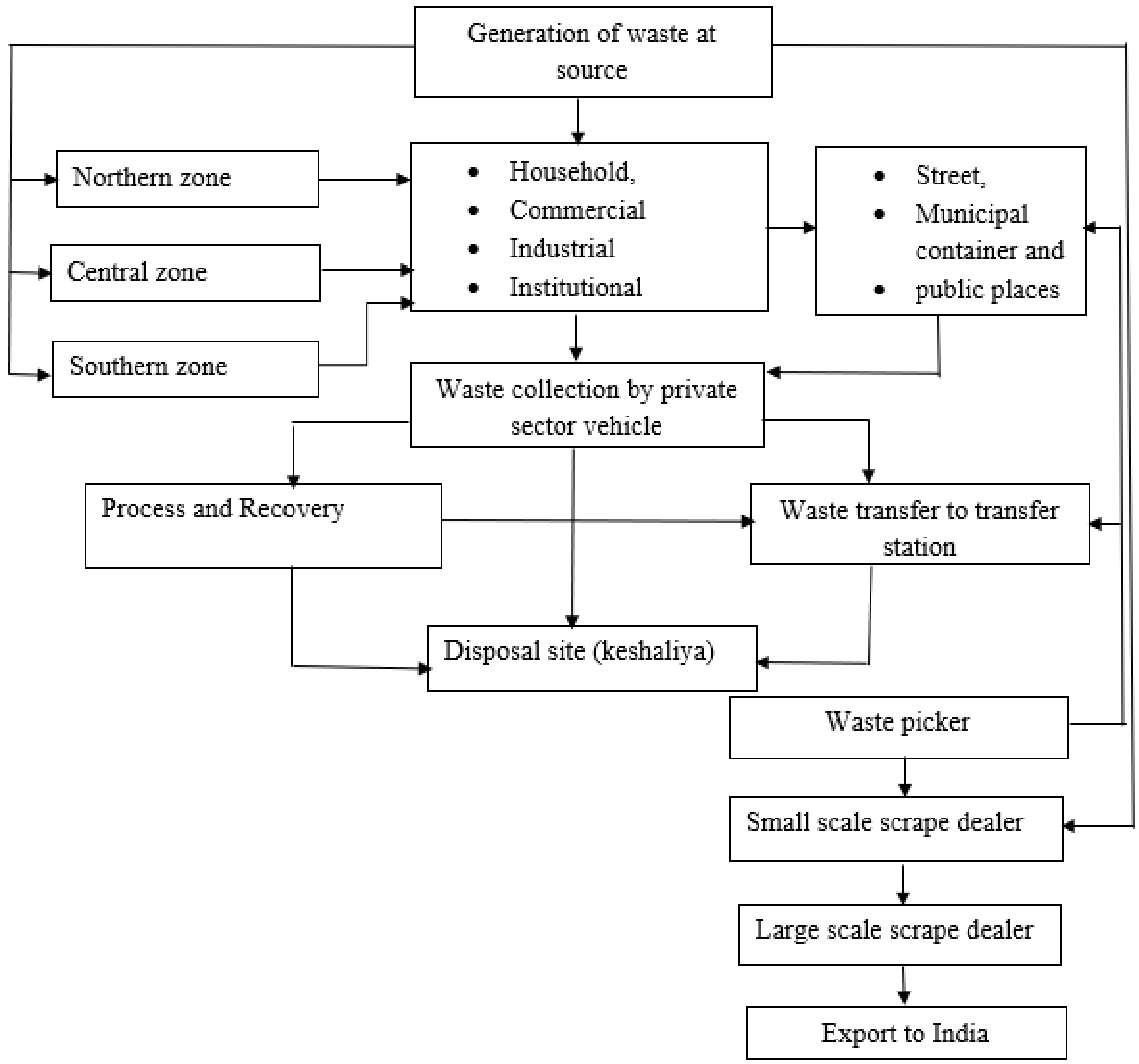

Figure 3: Solid waste management system of BMC

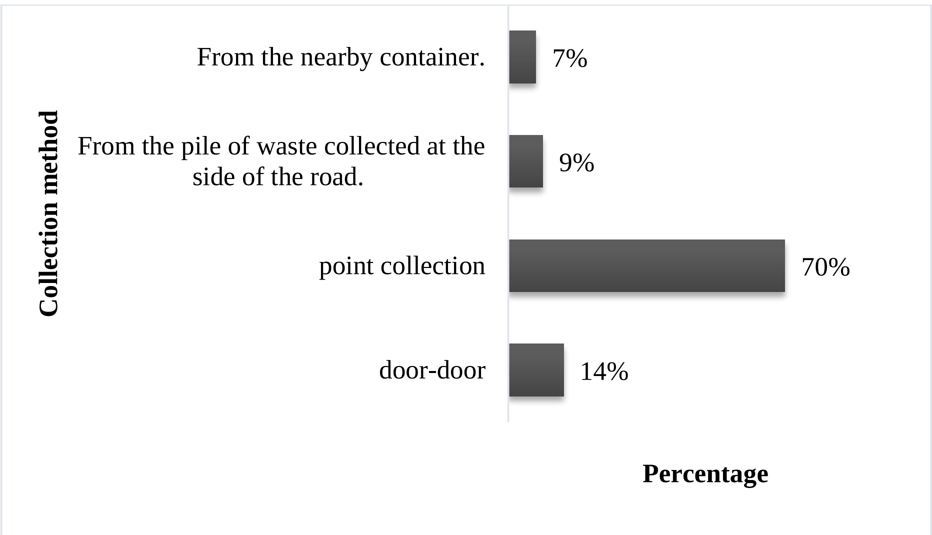

Figure 4: Waste collection method of BMC

3.4. General Methodology

For accurate and precise findings, optimizing solid waste collection routes necessitates a broad grasp of subjects like algebra and calculus, Google Earth, GIS, and computer science. Route optimization may be a novel and superior solution to reduce the expense and time for waste management in Biratnagar Metropolitan City compared to the various strategy that has previously been applied in the management of garbage. The current study, "Optimizing Solid Waste Collection Routes through Google Earth and GIS Engineering in Biratnagar Municipality," analyzes the performance of the MSW collection system using territorial data for trash identification carrying capacity per vehicle and the fuel consumption ratio of the vehicle. Additionally, depending on data analysis, mathematical algorithms will be used to compute the time and route. Route optimization will increase the efficiency of a point-to-point collection system from containers, which is currently the only method for collecting urban waste. The Google Earth image will be used to plot the current traffic base route using various layers. Arc GIS analyzes and interprets distances. After that, the optimal distance will be examined using the same methodology to arrive at the smallest gap possible. In order to confirm the transportation route and garbage collecting practices, a survey involving pertinent agencies and local residents will be conducted. Data on numerous SWM and route-related topics will be gathered from a number of pertinent organizations, including the city office and the landfill. Data on population size and growth rates, waste production rates, waste production rates per person, and waste production rates will be gathered from landfill managers and city offices. The anticipated waste density is 300 kg/m3, which is determined by averaging data from a quantitative study carried out by a former municipality and densities discovered in several disposal sites in Nepal for incompressible vehicles (Bijay et al. 2011). The trash bin site will be taken into consideration to be within a 200m radius as a strategic garbage collection source, and the routes that will be near 200m of one another will be combined into a single route for optimization. These will be referred to as the maximum distance and the collection point.

3.5. Materials

The following materials and technology will be used:

i. The following information is needed to determine the best routes for collecting solid waste:

- the study area's boundaries
- the names of the roads, their widths
- traffic volume information
- the number of storage bins and their locations
- the capacities of the bins
- the amount of time required to collect solid waste per bin
- the type of vehicle being used and its capacity
- the run routes for compactor vehicles currently in use
- the fuel consumption of the compactors

ii. Arc GIS and Google Earth.

3.5.1. Google Earth

Various data layers, including existing and optimized routes (paths), dumps (points), and containers (point), will be plotted using Google Earth Pro 7.3.3.7786 (64 bit) as an image source. The distance of the routes will be displayed using the path layer's measure tool. Plot points and path layers will be georeferenced and saved as .kml files for later analysis. For maximum visibility and clarity, images are chosen based on the last observed minimal cloud cover (no more than 20%).

Figure 5: Location of disposal site using Google Earth

3.5.2. Arc GIS

Map overlays will be created and laid out using ArcGIS 10.5 software. There are several standardized tools in ArcGIS that may be quickly applied and combined to handle various forms of geographic data (such as raster, vector, and tabular data) in order to produce data and maps. The .shp file from Arc GIS, which also contains data georeferenced using several GIS tools, has been used in place of the .kml file downloaded from Google Earth. To make data visualization and presentation easier, GIS Arc will be used to build digital maps of the Transport Units, Collection Units, and Disposal Yard.

Figure 6: Location map of three sectors in waste management

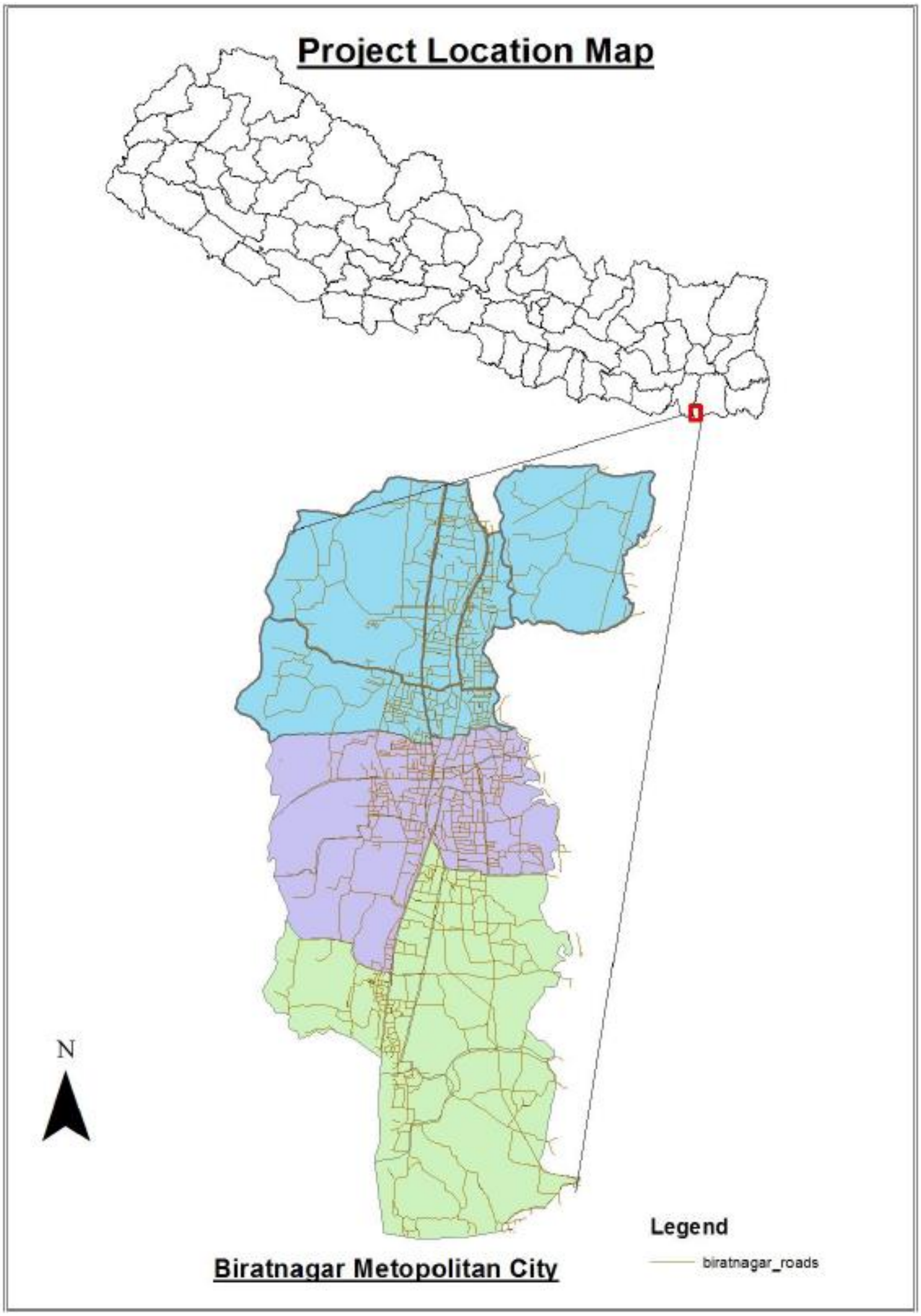

Figure 7: Road Network of Biratnagar Metropolitan City

3.6 Calculation

3.6.1 Measurement of optimized distance and time

Arc GIS projections of container layers, transport routes, and dumps are necessary for data processing. Based on the data gathered using Arc GIS, the ideal path for MSW collection will be selected. For the time requirements, the runtime of the vehicle can be found by considering the length of the road and the speed of the vehicle on each road.

3.6.2. Working flowchart for Google Earth and GIS

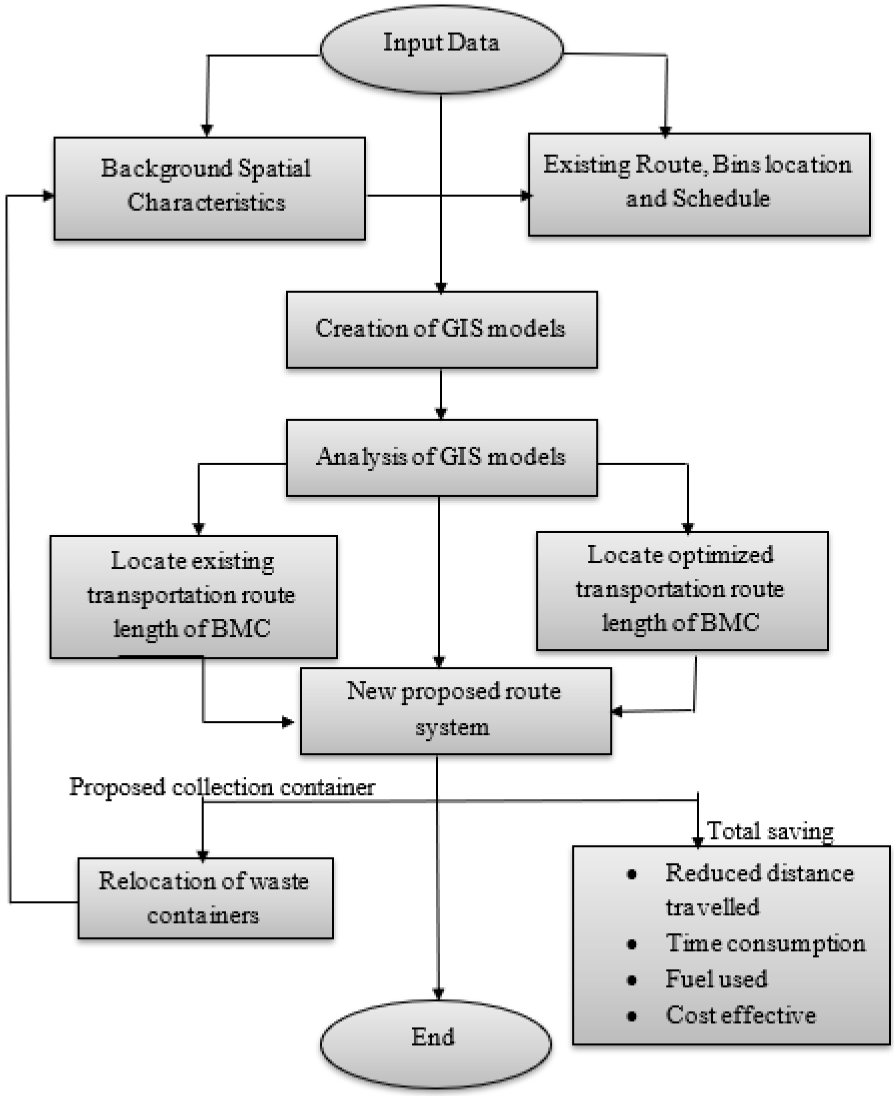

Figure 8: Google Earth and GIS working flowchart

i. Route Distance Calculation

Total Present Route Distance = Incoming Route Distance + Outgoing Route Distance

ii. Route Time Calculation

Time = Total Route Distance (in m) /Velocity of Vehicle (in m/s)

iii. Optimized Route Time Calculation

Incoming Time ($\mathbf{t}1$) = Incoming Route Distance (in m)/ Incoming Velocity (in m/s)

Outgoing Time ($t2$) = Outgoing Route Distance (in m) /Outgoing Velocity (in m/s)

Total time taken = t1+t2

iv. Cost-Effective Analysis

[Daily Route Distance Travelled (Present)/ Daily Route Distance Travelled (Estimated)] = [Yearly Cost For Fuel Consumption (present) / Yearly Cost For Fuel Consumption (Estimated)]

4. Literature Review

4.1. ArcGIS Waste Collection Route Optimization

In Turkey, landfills are a well-liked option for the ultimate disposal of municipal solid waste (MSW). Selecting a landfill site is a very challenging endeavor because it depends on many variables and laws. A methodical procedure should be created and followed to guarantee that an appropriate site is chosen. Strong public opposition frequently prevents the installation of landfills. Geographic information integration (GIS) and multi-criteria assessment (MCE) were used in this study to find potential landfill sites in Cumra County, Konya City. Because it could do a fit analysis utilizing MCE analysis, the ArcGIS 9.0 software and its extensions were employed as a GIS tool. Eight input map layers were used to determine the most acceptable landfill locations in the Cumra district. These levels included distances to municipal and local wells, irrigation canals, transport, and railroad routes, distances to historical landmarks, distances from populated areas, land use/land cover, and land slope. for constraint mapping. A final map was made to show the locations that would be best for the landfill. The chart shows that 6.8% of the research area is the most favorable, followed by 15.7% wholly suitable, 10.4% somewhat suitable, 25.8% not very suitable, and 41.3% not suitable at all. Three potential sites were found at the conclusion of the investigation. But further fieldwork is necessary before the ultimate MSW landfill site is chosen. (Nguyen-trong et al., 2017).

Over the past ten years, the volume of municipal solid garbage has consistently increased in accordance with the pace of waste generation and population growth. Due to the lack of available land, landfills are typically situated outside of urban areas. There is no set path for transportation. Overcrowding has developed in the existing garbage situation's waste collection and transportation due to a lack of facilities and resources. This article will give a model to enhance municipal solid trash collection. The optimization strategy is first created in a static environment before being incorporated into a dynamic context utilizing simulation and a multi-agent model. An analysis of the Hagiang City, Vietnam case study is provided to demonstrate the effectiveness of the suggested model. The optimized results revealed an 11.3% decrease in the cost of the MSW collection. (Nguyen-trong et al., 2017).

For the best route identification for municipal waste collection, ArcGIS Network Analyst is introduced. The suggested application includes all crucial garbage collection parameters, allowing desktop users to mimic real-world network scenarios and procedures. In this case, the simulation analyzes access scenarios to load locations in the municipality of Nagpur to collect municipal solid waste that cannot be collected by typical waste collection vehicles due to their size and other prohibited obstructions. The analyzer is employed to ascertain the relationship between dynamic aspects in the research area, such as variations in network traffic (roads are closed as a result of climatological or technological concerns, such as fallen trees, automobile accidents, etc.). It also provides the finest options. The user has complete control over the dynamic elements of the initial scenario, and by adjusting key parameters, multiple scenarios with different outcomes can be created. The optimal option is ultimately determined by a function that takes into account a number of criteria, such as the shortest distance, the road network, as well as social and environmental considerations. (Bhambulkar et al., 2011).

4.2. Positive Effects of Route Optimization

A route optimization can be used in a municipal solid waste management system to lower collection/hauling expenses, which account for 85% of total disposal costs. As a result, a significant number of economic advantages are being enhanced. Route optimization can lower overall costs by lowering the negative impact of "empty miles" in the solid waste collection and hauling process. Turkey's northeastern city of Trabzon is home to roughly 185 000 people.

The city contributes only approximately 1% of Turkey's Gross Domestic Income, according to the Census of 2000. In other words, it indicates that the average income in Trabzon City is low. By taking into account information on the road network, demography, and solid waste output, the study's goals are to optimize the route of collecting and hauling in Trabzon City. A Sony DCR-TRV145E brand video camera was used to capture the procedures in order to examine the city's solid waste hauling and collection operation. To apply the route optimization procedure, data on current spending, truck type and capacity, solid waste production, population, and GPS receiver data for each route were gathered and all the data were compared with one another. A shortest path model was used to 39 city districts in order to improve the solid waste collection and hauling procedures while aiming for the lowest possible cost. This was accomplished by using the Route View ProTM software as an optimization tool. The software includes GIS components such as production amounts of solid waste, demographic distribution, numerical paths, and container distribution. Thematic container layer includes 777 container position points for the entire city, to give you an idea. The software's optimized routes were compared to the actual routes once the routes had been completed. For time and distance, the optimization technique has a success rate of 14–65%. As a result, the overall cost of a route optimization operation for the street stationary container collection system will be reduced by 24%. (Apaydin et al., 2007).

The exponential increase in the urban population of developing nations over the past few decades and the resulting phenomena of accelerated urbanization have highlighted the need for effective waste management systems that are ecologically friendly. One of the main strategies for disposing of municipal solid waste is the sanitary landfill. Optimized siting decisions have grown increasingly important in order to ensure the least amount of harm to the various environmental sub-components and to lessen the stigma felt by those who live nearby, improving the overall sustainability of the life cycle of a landfill. This study employs a geographic information system (GIS)-based overlay analysis and multi-criteria decision analysis (MCDA) to determine the best location for a new landfill. By revising its knowledge base, the suggested system can incorporate fresh data on the landfill site selection. The siting procedure takes into account a number of variables, such as geology, water supply resources, land use, sensitive locations, air quality, and groundwater quality. According to their respective importance and ratings based on the relative amount of influence, weightings were applied to each criterion. The results of the system's testing on several websites demonstrate its usefulness in the selection procedure. (Sumathi et al., 2008).

Municipal Solid Waste (MSW) disposal in landfills is a popular option in Turkey. Landfill sitting is a very challenging operation to complete because the site selection process depends on many elements and regulations. To guarantee that the right site is picked, a methodical procedure should be created and followed. A landfill site proposal that faces strong public resistance usually fails. Through the combination of geographic information systems (GIS) and multi-criteria evaluation (MCE), suitable locations for an adequate landfill area in Cumra County of Konya City are identified in this study. In order to execute suitability analysis utilizing MCE analysis, ArcGIS 9.0 software and its extensions were utilized as the GIS tool. Eight input map layers are used in constraint mapping to identify appropriate landfill locations in the Cumra district. These input map layers include proximity to municipal and local wells and irrigational canals, distance from roads and rails, distance from archaeological sites, distance from urban areas, land use/land cover, and land slope. A final map that shows places that are suitable for the location of the landfill site was created. The chart shows that 6.8% of the research area is the most suitable, followed by 15.7% wholly suitable, 10.4% somewhat suitable, 25.8% not at all suitable, and 41.3% unfit. Three candidate sites are chosen at the conclusion of the analyses. However, additional field study is necessary before choosing the ultimate MSW landfill location. (2009) Springer Science + Business Media B.V. (Nase et al., 2010).

5. Conclusion

Solid waste collection in Biratnagar metropolitan areas is challenging since waste generation is becoming increasingly dispersed. As mentioned above two-thirds of the money spent on the collection, transportation, and disposal of solid waste is spent in this phase. This aspect is crucial since even a tiny percentage improvement in the collection process might result in a large decrease in the overall cost. In order to improve the performance of current systems and to produce data and cutting-edge methodologies to build and assess new systems for metropolitan areas, there is a growing interest in the study of solid waste collecting systems. A review of the literature demonstrates how widely used geographic information systems (GIS) are for route optimization research. GIS is a good tool for these kinds of studies because it can store, retrieve, and analyze a lot of data and produce visualization in a reasonable period of time. In its most basic form, GIS offers network-based spatial analysis, and the use of ArcGIS Network Analyst enables users to dynamically model real-world network conditions, such as turn and height restrictions, one-way streets, speed limits, and variable travel speeds based on nearby traffic. This method reduces the cost of SWM by around 50%, but it initially needs competent individuals to carry out the process of optimization and allocate the routes to the appropriate vehicles. The method can also be used by municipal authorities as a decision-support tool for effective management of the daily operations for transporting solid wastes, load balancing within vehicles, managing fuel consumption, and generating work schedules for the workers and vehicles in order to overall minimize costs. The study highlights how ISWM planning with optimization models not only lowers SWM costs but also conserves the environment (minimizes land for landfilling, reduces leachate contamination, decreases methane generation, etc.) — encouraging the growth of an industry that is both environmentally and economically sustainable.

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