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Eco Efficiency Optimization of Municipal Solid Waste Management

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Abstract: ***Municipal solid wastes, commonly referred to as trash or garbage, are the solid wastes generated from human activities. A number of these wastes are extremely toxic and infectious. The uncontrolled and unscientific way of dumping such wastes have raised the number of incidents of hazards to human health. One among the important aspects which gains more impact on sustainability of the environment is management of municipal solid waste. A case study of Juhu (MCGM) has been selected for effective and efficient management of municipal solid waste. The main objective of the research is to seek out an optimal route for transporting the rubbish from dumper bins and from temporary transfer stations to the ultimate dumping yard. The research work has been administered in two stages, namely data collection within the first stage and data analysis for optimization within the second stage. For locating the optimal transportation route, VRPTW model is employed in the GIS and GA environments. The proposed study is concentrated on finding the optimal route in transporting the MSW from dumper bins and temporary transfer stations to the dump-yard. MCGM must operate 90 such vehicles in 6 trips. . When time window is employed for vehicle routing, resources like labours and vehicles can be effectively managed and utilized. Due to the time window, it is easier for the highest-level officials to manage both labour and transportation vehicles.***

Keywords: Municipal solid waste, Geographic Information System, Vehicle Routing Problem, Collection and Transportation of MSW.

I. INTRODUCTION

Solid waste is the term to describe non liquid waste materials arising from domestic, trade, commercial, agricultural, and industrial activities and from public services. In Indian cities it's a mixture of varied heterogeneous waste materials. It is commonly known as garbage, refuse, rubbish, or trash.

Its main sources are residential premises, business establishments, and street sweepings. It is a mixture of vegetable and organic matter, recyclable materials. Solid Waste Management (SWM) is a civic problem, and it has to evolve optimally and continuously to serve the future generation. Solid waste if unchecked not only be a health hazard but will impart multidimensional threats, which include session's detrimental, environmental, social, and economic impacts. Solid waste management in developing countries is a complex issue as the types of waste generated vary widely because of the varying localities with diverse populations. In the present study, Municipal Solid Waste Management (MSWM) for Juhu Brihanmumbai Municipal Corporation (MCGM) has been chosen as a case study for efficient management of Municipal Solid Waste (MSW). The standard practice of a municipality or an organization of handling the solid waste is collecting the waste and disposing it intrinsically within the dumping yard. MCGM is additionally disposing the municipal waste intrinsically during a dump yard at Deonar, 18 km far away from the centre of the town. The MSW in MCGM may be a commingled waste mass. The amount of solid waste generated under Indian conditions varies from 0.3kg/capita/day to 0.6 kg/capita/day

Pursuing research on this trend an in-depth survey was administered to collect data regarding the population, street location details, quantity of garbage generated, sort of collection, the traffic details, location of bins, location of temporary transfer stations etc. for the 72 wards covering an area of 60 sq.km. With the collected data ward maps for all the 72 wards were prepared.

II. NEED FOR RESEACRCH

1) To develop a base map with a database of Juhu MCGM since maps and other spatial data become part of the work routine in municipal services.
2) Integration of data from various levels of jurisdiction (city, zone, range, and health ward level)
3) Assimilating Voluminous Information for analysis
4) No comprehensive and cohesive system to handle a great deal of data

III.OBJECTIVE OF RESEARCH

The objective of the research is to optimize the municipal solid waste collection and transportation route of MCGM by examining the prevailing solid waste management practices with reference to capacity, location, and environmental protection and public health issues.

The optimization of collection and transportation of MSWM leads to the utmost utilization of the infrastructure facilities, resources, collection coverage and minimization of fuel consumption or in other words the minimum transportation cost of all to reinforce the general efficiency of the proposed system.

IV.LITERATURE REVIEW

The literature concerning the subsequent areas were reviewed and presented during this chapter.

The review areas include:

1) Municipal Solid Waste Management
2) Vehicle Routing Problem
3) GIS applications in municipal services, transportation
4) GA applications in transportation to seek out optimal routes.

Optimization models and related methods are widely applied to different issues in solid waste management, including optimization of collection routes (Ramachandra et al 2003), suitable location of waste bins, site selection of waste disposal (Syed Mahmood Anwar 2005), site selection of transfer stations (Ramachandra et al 2003, Clarke et al 2005), and selection of networks of treatment, transport, and disposal activities for hazardous waste. Optimal routing is received as a micro level study of macro routing, in such a way that the waste is going to be collected within a selected time on minimum time-period concept. The corresponding micro routing for locations in each zone is left because it is, considering the experience of collection workers.

The Municipal Solid Waste Management (MSWM) system in India is gaining more importance mainly due to increasing urban population and public awareness towards cleanliness. There's a good difference within the waste composition and therefore the techno-socio-economic condition, in comparison with the conditions within the developed countries. This necessitates the event of appropriate technology for municipal solid waste management in India. There is also a requirement for a country-specific national policy, and a legal and revenue structure for MSWM (M. Akhtar et al).

Efficient routing and en-routing of solid waste collection vehicles can decrease the prices by reducing the labour expended on waste collection. Routing procedures usually consist of two separate components: Micro routing and Macro routing (T. E. Kanchanabhan et al 2010)

Macro routing, also mentioned as route balancing, consists of dividing the entire collection area into routes sized in order that they represent one day's collection for one crew. The dimensions of every route depend on the number of wastes collected per stop, distance between stops, loading time, and traffic conditions.

Micro routing can define the precise route that the gathering vehicle should follow. The tactic selected for micro routing must be simple enough to use for route balancing when system changes occur or to reply to differences due to the season in waste generation rates. To enhance the present solid waste management services, it is essential to explore the varied constraints or issues like community participation, human resource development, promoting GIS-GPS (Global Positioning System) systems to get reliable data on waste and legal mandates.

In India, however, thanks to the shortage of awareness and co-operation from citizens, the community bins often have an outsized quantity of waste littered around with only a meagre quantity deposited inside. Thanks to unsanitary conditions, the nearby residents object to the situation of bins near their premises, thus necessitating their location at public places that are often not the best sites. An approach to assess the satisfaction level with reference to the performance of the solid waste system has been formulated then tested through a case study. This may provide important feedback to the management on the effectiveness of the prevailing system and identify areas where restructuring is required (W. Naninja 2013).

GIS is an efficient tool for several application areas like site selection and finding optimal route, in solid waste management, urban transportation, water system, and irrigation engineering. In solid waste management, the GIS is employed for locating collection bins, selecting alternative places for dumpsites, and for optimal routing of the gathering and transportation vehicles. For choosing suitable sites for bin location or dumpsite, overlay analysis is employed. O. Apaydin, et al (2004), in his personal website published the use of GIS for choosing suitable locations for waste bins.

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V. STUDY AREA

In the present study, MSWM for MCGM was chosen as a case study for efficient management of MSW. Juhu is an upmarket neighbourhood of Mumbai. It is most famous for the sprawling Juhu Beach. It is surrounded by the Arabian Sea to the west, Versova to the north, Santa Cruz, and Vile Parle to the east and Khar to the south. Juhu is among the most affluent areas of the city and home to many Bollywood celebrities. The MCGM area is divided into 7 zones, which in turn is divided into 227 wards for functional convenience by MCGM. MCGM for Juhu is disposing of the MSW of 650 tons for 72 wards daily in the dump yard at Deonar 18 km far away from the middle of the town

A. Profile of JUHU

The city is located at 19.10° N latitude and 72.83° E longitudes. The city extends to an area of 60 sq. kms and as per the 2001 census the population is 20 lakhs. Juhu Beach is located on the shores of the Arabian Sea.

B. Climate

Juhu enjoys a uniform climate throughout the year. In summers the maximum temperature reaches 35 °C and the minimum temperature is 25 °C. The weather is pleasant in winter. Monsoons prevail from mid-June to September, when it rains quite heavily.

VI. STATISTICAL ANALYSIS OF MEASURED QUANTITY OF WASTE

In developing SWM systems, it's often necessary to work out the statistical characteristics of the observed solid waste generation rates. For example, for several large industrial activities it might be impractical to provide container capacity to handle the most important conceivable quantity of solid wastes to be generated during a given day. The container capacity to be provided must support a statistical analysis of the generation rates and therefore the characteristics of the gathering system

Per capita waste generation per day = Total Garbage / Population

As per the sector study the entire resident population arrived as 648434. With this 20% for floating population got to be added to urge the total population.

Total Population = Resident population + Floating population

= 648434 + 129687

= 778121

Total garbage = 262960 kg.

Per capita waste generation per day = 262960 / 778121= 0.40kg/capita/day. Correlation analysis between the particular garbage generated and therefore the population was administered which is giving the Pearson's correlation coefficient as 0.89. Meaning there's a correlation between the particular garbage generated and population.

With this information and supporting the results of random sampling and therefore the data provided by MCGM the waste generation rate for MCGM has arrived as 0.35 kg/capita/day.

The salient details of the prevailing SW quantification as per the info collected from MCGM and from this study are as detailed in Table 1

Table 1: Salient features of Solid Waste

SR NO	DESCRIPTION	DETAILS
1	Per capita waste generated (kg/day)	0.35
2	Waste Generated per day (MT)	450
3	Waste collected per day (MT)	375
4	Biodegradable waste (% of total weight)	70%
5	Non – Biodegradable waste (% of total weight)	30%

VII. METHEDOLOGY

The data regarding the physical and chemical characteristics, quantity of garbage generated and picked up, mode of transport utilized for collection, frequency of collection, capacity of bins and therefore the location of bins, type of road, road network and traffic of the road are collected by conducting field surveys. Ward map for every ward is ready using the collected data and the road network and bin locations are georeferenced using Global Positioning System (GPS).

The National Environmental Engineering Research Institute (NEERI) has made a comprehensive study of the SWM in different cities in India during 1978 to 1992. Consistent with this study the quantity of waste generated in India ranges between 0.2 to 0.6 kg/capita/day. As per the manual on SWM the per capita waste generation for cities having population between 1 and a couple of million is 0.27 kg/capita/day. With this information and supporting the results of sampling and therefore the data provided by MCGM the waste generation rate is assumed as 0.40 kg/capita/day.

To suit MSW (M&H) Rules, 2000, immediate steps should be taken as per the provisions of the principles, 2000. The MC has the responsibility to enforce these, Rules. Under the principles MSWM functions are to be undertaken like collection, segregation, storage, transport, process, and disposal of MSW.

The most functions of those rules include:

1) Prohibit littering on the street.
2) Organize house-to-house waste collection and notify the public about the schedule and the methodology of collection.
3) Conduct awareness programs to disseminate the information to the public and hold regular meetings with the resident welfare groups and NGOs.
4) Devise ways to collect waste from unsanitary and difficult areas such as slums, hotels, restaurants, office complexes and commercial areas.
5) Build adequate storage facilities considering the population density to prevent overflowing of trash cans.
6) Color-code waste bins to promote segregation of waste at source green for biodegradable, white for recyclable wastes and black for other wastes.
7) The wastes are to be transported only in closed vans to avoid spilling of waste.

Disposal of the collected wastes by adopting any of the prescribed methods such as vermi-composting, anaerobic digestion, incineration, Pelletization, etc., and landfill is to be adopted for inert waste.

A. Geographical data System (GIS)

GIS is arising as a replacement wave of data Technology and as it is a comparatively new area, this study utilized ArcGIS, one among the GIS tools for locating the optimized route for the gathering and transportation of MSW of MCGM. Geographical analysis usually involves quite one geographical dataset and requires the analyst to proceed through a series of steps to succeed in the answer. There are three common sorts of geographical analysis available in ArcGIS namely, proximity analysis, overlay analysis, and network analysis. GIS technology uses the buffering to work out the proximity between features and is used for locating the space between features. An overlay analysis might be done to mix soil and vegetation layers to calculate the world of a particular vegetation type on a selected sort of soil. The network analysis examines how linear features are connected and how easily resources can flow through them. This study is routing the transportation vehicle hence network analysis is chosen for the analysis of optimum routes. The flow chart of GIS is shown in Fig. ARCGIS developed by ESRI is the most generally preferred location-based analysis software. The maps given by the corporation aren't to the scale. GPS of accuracy lm was wont to get the track log of the study area. Google earth map is employed to urge the whole MCGM road network. For regional accuracy the GPS track log was compared with the Google earth map for the removal of dangling and any crossover within the road network. The accuracy of the Google earth map is additionally lm considered. There's no actual road network dataset available with the MCGM.

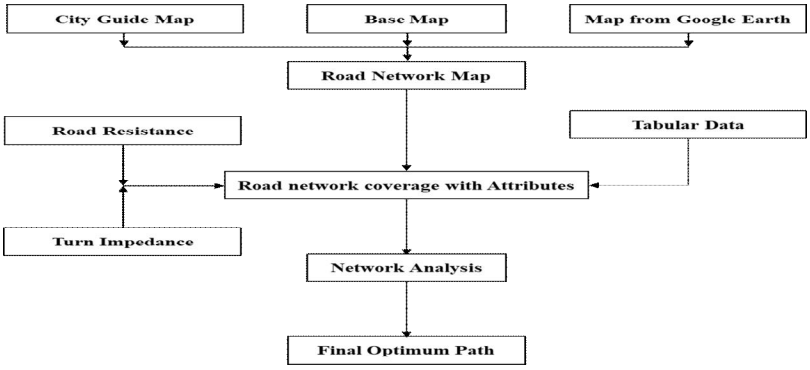

Figure: Flow diagram of GIS

B. Genetic Algorithem

This research introduces the appliance of GAs as an efficient tool for optimization of VRP in MSW management. Within the present work the GA concepts are introduced for a case study of MSW transportation routes. Here the ward numbers 13, 27 and 47 of Juhu (MCGM) are considered as a pilot study area. The gathering of garbage is categorized as primary collection and secondary collection. Both primary and secondary collection of garbage is administered in most of the wards. Within the pilot study area, the rubbish is collected in two alternative ways as secondary collection. There are temporary storage bins called dumper bins of capacity 1.5t are placed within the main roads which are having 2 lanes and within the minor/other roads/streets and lanes the garbage is collected as door-to-door collection and therefore the same is stored temporarily on the most roadsides as heaps called temporary transfer station. The heap of garbage is cleared by auto/tractor/lorry/refuse collector and is transported to the ultimate dumping sites/transfer station. The study area has mixed sort of buildings namely residential, commercial, public and educational institutions.

VIII. RESULTS AND DISCUSSION

This chapter is meant to look at the findings and discuss the results of GIS and GA in optimal routing of the gathering and transportation of the MSW within the pilot study area of MCGM. The results obtained by GIS and GA are analyzed to support the value estimates. The optimized routes obtained using GIS and GA in terms of cost estimates are compared with the prevailing system of transportation. The map of MCGM was digitized for creating the transport topology. The transport topology is analyzed for any dangling, self-intersect or overlap and the same are removed or rectified. From the transport topology, the network topology is made and therefore the same is planarized for analysis. The data regarding the number of garbage generated within the 3 wards namely, ward nos. 13, 27, and 47. The number of garbage is distributed along the network dataset consistent with the bin location. The network dataset was created with the details of MCGM road network, bin location, and therefore the temporary transfer station. The attribute data regarding the number of garbage generated, the population data, quantity of garbage, the sort of road and lane, the traffic volume were prepared with the network dataset. Using the network analyst tool within the ArcGIS, the vehicle routing problem is chosen for analysis. The layer property of VRP contains general layers, source, analysis settings, advanced settings, and network locations. Within the general tab the layer name, description of the layer, and scale range are properties of the layer VRP-BINS which is made for the analysis of bin routing. Similarly, the load locations, time window, turn impedance, road restrictions, etc. got as layer properties. The maximum capacity of TTS collection vehicles and dumper placer vehicles and the time window are given as inputs. The network dataset was created with the road network data, bin location, and therefore the temporary transfer station. Also the attribute data regarding the quantity of garbage generated, the population data, and therefore the sort of garbage collecting vehicle with their capacity were related and joined with that layer.

Table: Results of GIS and GA for collection of bins

Sr. No.	Route Name	Total Cost in (Rs.)			% Deviation from Existing System	
		Existing System	GA	GIS	GA	GIS
1	a1	3015	1599	3150	46.96	-4.48
2	a2	2160	2477	2875	-14.67	-1.39
3	b1	2820	2607	2190	7.55	0.53
4	b2	2910	2900	2805	0.34	1.55
5	c1	2880	2217	2865	23.02	1.56
6	c2	2430	1842	2835	24.20	1.85
7	d1	3000	2268	2385	24.40	5.00
8	d2	2880	1866	2805	35.21	2.60
9	d3	2250	2612	2220	-16.09	1.33
10	e1	2985	2698	2940	9.61	1.51
11	e2	3090	2147	3030	30.52	1.94
12	f1	2805	2482	2760	11.52	1.60
13	f2	2985	2205	2940	26.13	1.51
14	f3	2295	2324	2250	-1.26	1.96

The performance of GIS and GA as compared with the existing system and the performance analysis is as listed below:

1) As far as the TTS total cost is concerned, the percentage deviation is more for GA compared with GIS from the existing system.
2) The percentage deviation of GA varies from 4% to 18% for TTS and it is on the negative side which means the values of GA are higher compared with the existing system.
3) The percentage deviation of GIS varies from 2% to 13% for TTS. For tipper lorry, the total cost is more in GIS compared with the existing system whereas for the BRC and tractor, the results obtained are considerably reduced for the optimized routes.
4) The percentage deviation for GIS varies from 0.53% to 4.5% from the existing system. Except for the routes al and a2, the total transportation cost for bins is less compared with the existing system of transportation.
5) In the case of GIS results, the cost reduction for one route comes around 1.5% on an average, from the existing system. If the entire corporation area is considered, for each time window, 75 routes need to be traversed by a dumper placer vehicle which will be landed up with a significant amount of cost saving in the optimized route.

Also, the total transportation cost comparison of GIS and GA with the existing system is graphically represented as shown in Fig and respectively for bins and TTS.

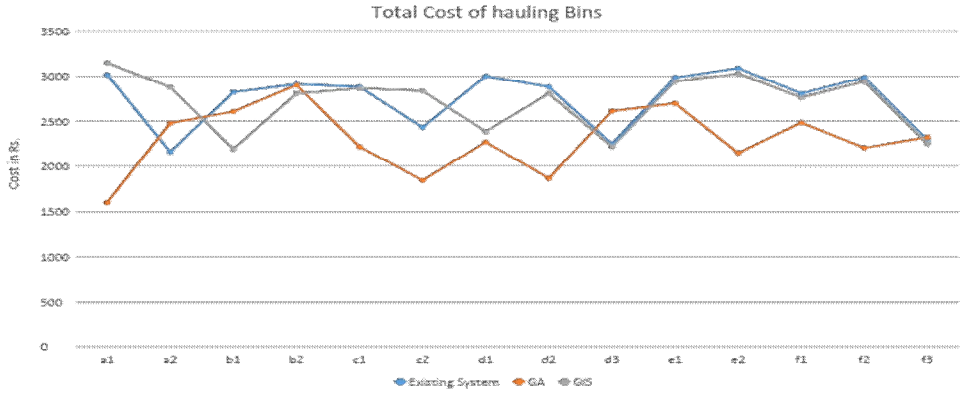

Figure A: Total transportation costs of GIS, GA and existing system for bin

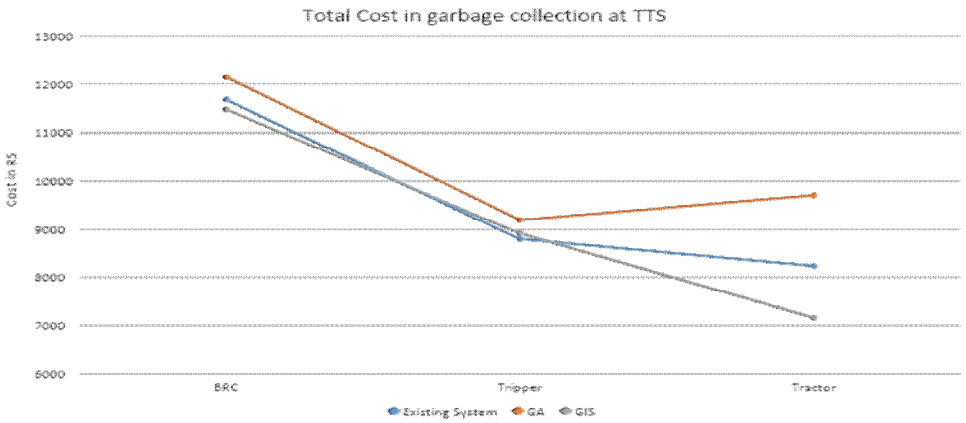

Figure B: Total transportation costs of GIS, GA and existing system for TTS

From Fig A and Fig B the optimal cost arrived using GA is slightly higher for TTS as compared with GIS whereas in the case of bin the optimal cost arrived is lower than GIS. For routes the optimum cost arrived in GIS is approximately 50% higher which may be due to the theoretical incorporation of the parameters in the genetic algorithm. GA is based on a theoretical approach. That is why the deviation is on the higher side and it sometimes converges at local optima instead of global optima. In the GIS analysis the short-term changes can be handled by the user immediately & interactively by placing barriers using the tools provided on the interface. Only medium to long term changes need to be affected as changes in the attributes. Hence the proposed model using GIS will help the MCGM at all times whatever may be the changes. On the other hand, in the proposed GA the coding part needs to be changed.

To achieve the reduction in vehicle maintenance expenditure and improved traffic conditions in urban areas, time window concept is introduced. The time window of a particular ward is selected based on the traffic conditions of that area. For example, ward 13 is a mixed area of educational institutions like SVKM's institute of international studies, SNDT law School and Govt. offices like PWD, Income tax, BSNL head office. From the traffic volume study, during 10.00am-2.00pm the traffic is considerably less compared with other timings. So, a time window of 9.30am-12.00pm is selected for that ward which will reduce the waiting time due to traffic congestion and hence the vehicle can maintain steady speed, reducing the maintenance expenditure.

IX. CONCLUSION

The conclusions drawn from the study are as follows:

1) GIS results are visualized and much useful for the corporation to implement, easy to know even by the bottom most labor.
2) Now-a-days, Geographical data systems may be a very essential part of day-to-day operations in any corporation. It is important to utilize and maintain the info efficiently. Success of corporations on MSWM not only depends on the allocated funds to manage but also on the choices which solution or tool supports the choices. Spatial data is better manageable.
3) The results of VRPTW are obvious in routing the transportation vehicle efficiently. Also, the resources like labor and vehicles are often properly scheduled and effectively managed.
4) The concept of your time window shows that the monitoring of labor and vehicles by the highest officials from a central place is easily possible.
5) GIS has given the chance not only to seek out the optimum route but also to optimize the first collection distance from the dumper bins and also from TTS.
6) With the assistance of GIS, it becomes easy to match between alternatives. Thus, the routes and site of bins which were through GIS analysis became more reliable.
7) For the choice makers' purpose, GIS is often best utilized with minimum changes within the input file derived from a comparison of GIS and GA .
8) The solutions of the proposed GA as compared with the existing system reveal that the GA generates better solutions.
9) A multivariate analysis of the input helps finding the accuracy and dependability of the info handled.
10) An entire inventory of the items related to SWM and a correct transportation management and spatial planning are often done using the assistance of GIS analysis based on various generated feature clauses about the MSWM issues for implementing and managing the system at field level.

The resulting VRPTW output features a great impact on the MSWM. The advantage of the VRPTW model is that it is an operationally usable model which will be applied to any corporation area of a developing country with a minimum number of changes within the input file.

Accordingly, the degradable wastes are going to be used for preparation of manure and the non-degradable wastes are going to be disposed of scientifically, which may be best achieved if the gathering and transportation vehicles are routed during a scheduled manner. There's an urgent need to protect the bottom water pollution in the vicinity. The proposed VRPTW model provides an effort to improve the prevailing MSWM and will provide support and respect in the process of converting the dumpsite into landfill site.

X. SCOPE FOR FUTURE STUDIES

1) The present study opens a variety of avenues for further work. The proposed VRPTW model in the GIS and GA environment uses only static data. To improve the performance and to possess updates then and there, VRPTW dynamic modelling is often tried.
2) The VRPTW model works on either GIS or GA platforms. As an extension work, GA are often utilized as a tool for setting the time window in VRP and therefore the same are often integrated with GIS.
3) Another area of further study is developing web-based applications for MSWM which can support the workflow of the organization and streamline all components associated with MSWM.
4) The VRPTW model in GA environment can further be extended for stochastic and reliability considerations in scheduling, optimal resource allocation, and scheduling supported finite vehicle capacity.
5) The application of the GA tool, VRPTW model proposed during this research, is often extended using the opposite meta — heuristic techniques like Ant Colony Optimization, Simulated Annealing, Particle Swarm Optimization, Neural Networks, and also symbolic logic.

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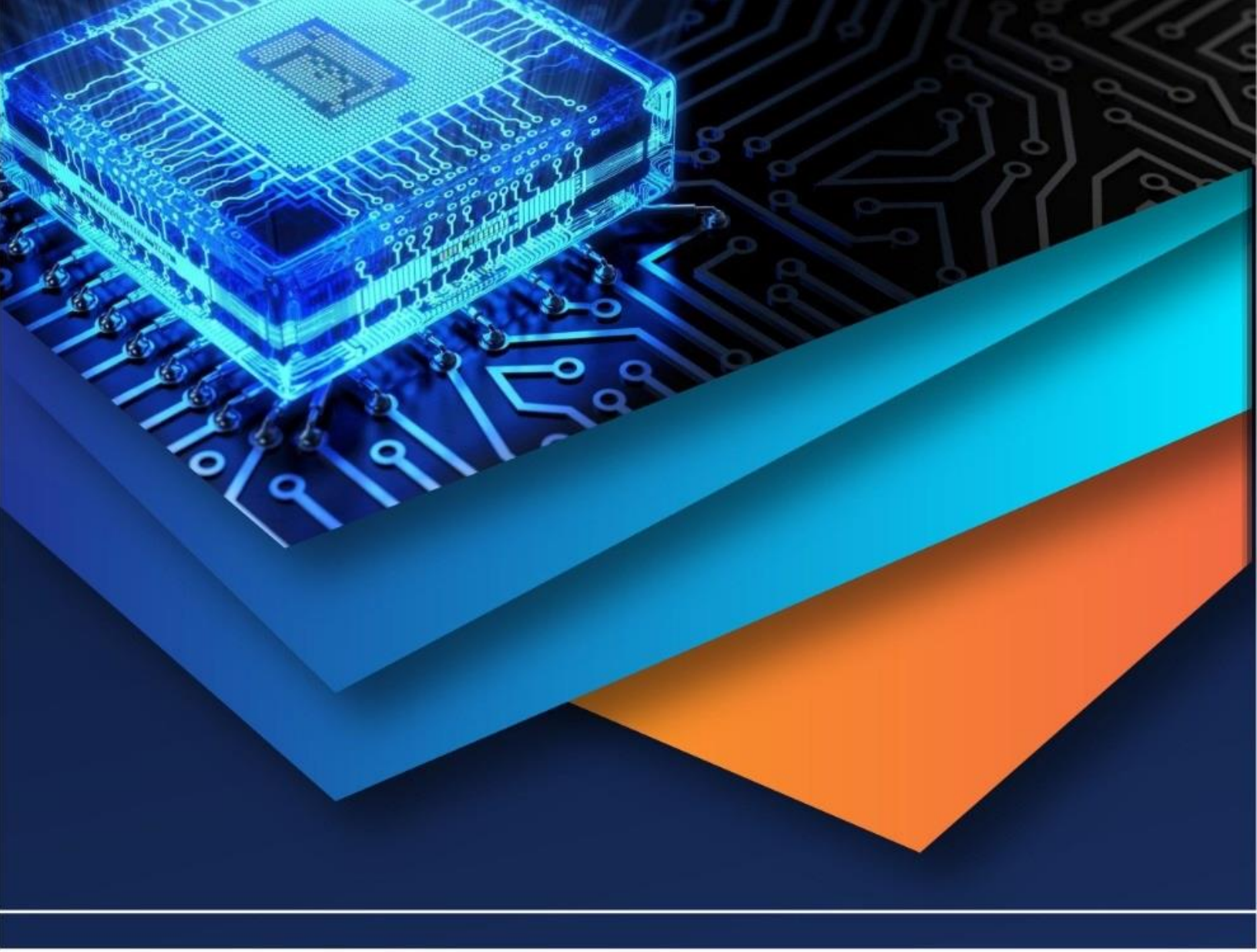

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