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Sewage Generation and Treatment Status for the City of Delhi, its Past, Present and Future Scenario- A Statistical Analysis

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Abstract: Delhi, the capital of India located in northern India, has a population of over 13.9 million at present and It has grown by more than 300% since 1971 and expected to increase 23 million by 2021 at a growth rate to 26.4% and expected population by the year 2050 is projected to be 72 million at a growth rate of 44% .The decadal water requirement and wastewater generation as projected in the master plan of Delhi development authority would be in order of 6674, 5340 MLD in 2011, 8365, 6692 MLD in 2021 and 19728, 17750 MLD in 2050. Delhi alone produces nearly 600MGD of sewage on daily basis and the installed capacity of wastewater treatment plants has the capacity to treat only 512.4 MGD, out of which nearly 58% of total sewage i.e. 3296 MLD approx. of the sewage generated is dumped into river Yamuna directly or indirectly. Central pollution control board reported that the cumulative assessment of all the parameters of water quality as mentioned by the CPHEEO indicates that Yamuna is not conforming to the desired level and more or less resemble a drain, also on the basis of the information collected on the inspection of Yamuna it is reported that the river does not have fresh water. There are 30 Sewage treatment plants but they are in non-functional and underutilized condition to the extent of 37%, only 63%of the sewage treatment plant is operational at present. This paper presents the study done on the water demand, wastewater generation and treatment status of the national capital of India.

Keywords: Delhi, Yamuna, Water demand, Wastewater treatment plants, Population projection

I. INTRODUCTION

India is a country with rich and varied heritage with enormous cultural beliefs. The civilization is proved to be originated at the bank of river. The past civilization such Harappa, has the historical proof that the civilizations were blossomed at the site of the river. The past scenario of the river water quality varies drastically as per the present scenario. The rapid urbanization, industrialization has led to a plethora of environmental problems offsetting the benefits of modernization and development. Water, food and energy securities are emerging as increasingly important and vital issues for India and the world. Current and future fresh water demand could be met by enhancing water use efficiency and demand management. Thus, wastewater/low quality water is emerging as potential source for demand management after essential treatment. An estimated 38354 million litres per day (MLD) sewage is generated in major cities of India, but the sewage treatment capacity is only of 11786 MLD. Similarly, only 60% of industrial waste water, mostly large scale industries, is treated. Performance of state owned sewage treatment plants, for treating municipal waste water, and common effluent treatment plants, for treating effluent from small scale industries, is also not complying with prescribed standards. As per CPHEEO estimates about 70-80% of total water supplied for domestic use gets generated as wastewater. The per capita wastewater generation by the class-I cities and class-II towns, representing 72% of urban population in India, has been estimated to be around 98 lpcd while that from the National Capital Territory-Delhi alone (discharging 3,663 MLD of wastewaters, 61% of which is treated) is over 220 lpcd (CPCB, 1999).

In Delhi around 3296 MLD (Million Liters per day) of sewage is dumped in the River. Delhi generates approximately 600 million gallons per day (MGD) of sewage, while it has an installed capacity to treat only 512.4 MGD of waste. Nearly 58 per cent of the total sewage generated by the city is dumped in the Yamuna, emptied into the river by 22 drains between Wazirabad Barrage and Okhla Barrage (Kumar et.al. 2012). The Yamuna is tapped for drinking water supply to Delhi. In the dry season generally, no water

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is allowed to flow beyond Wazirabad barrage, as the available water is not adequate to fulfill the demand of water supply of Delhi. Whatever water flows in the downstream of Wazirabad barrage is the untreated or partially treated domestic and industrial wastewater. After 22 Km downstream of Wazirabad barrage there is another barrage, Okhla barrage, through which Yamuna water is diverted into Agra Canal for irrigation. No water is allowed to flow through barrage during dry season. Whatever water flows in the river beyond Okhla barrage is contributed through domestic and industrial wastewater generated from East Delhi, Noida and Sahibabad and joins the river through Shahdara drain (CPCB 2007). One wonders what authorities have allowed 100% water extraction from a river, and in return sewage water is thrown back to keep the stream flowing. Around 3000 million liters of sewage is released in to the Yamuna each day (Bhaskar et.al. 2013).

Table 1.1 Under-utilized STPs in Delhi (Delhi Government 2010, 13)

S.NO	Location	No of STPs	Installed Capacity (MGD)	Sewage actually Treated (MGD)	Capacity Utilization (percent)
1	Okhla	5	170	113.07	66.51
2	Rithala	2	80	43.01	53.76
3	Koshopur	3	72	23.01	32
4	Rohini	1	15	0.73	08
5	Yamuna Nagar	2	20	11.53	4.87
6	Narela	1	10	1.20	57.65
7	Pappankalam	1	20	13.45	12.00
8	Ghitorini	1	5	Nil	67.25
	Total	16	492	206.09	52.57%

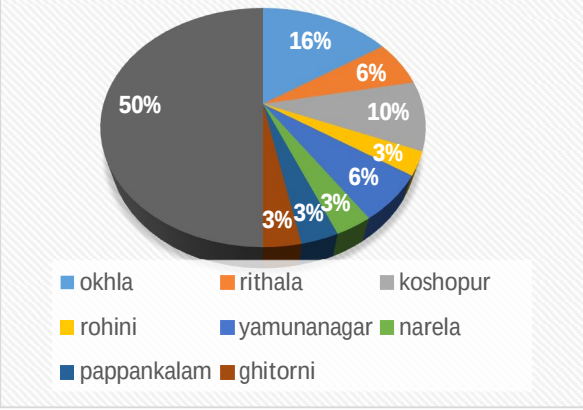


Fig1.1 under-utilized treatment plants in Delhi

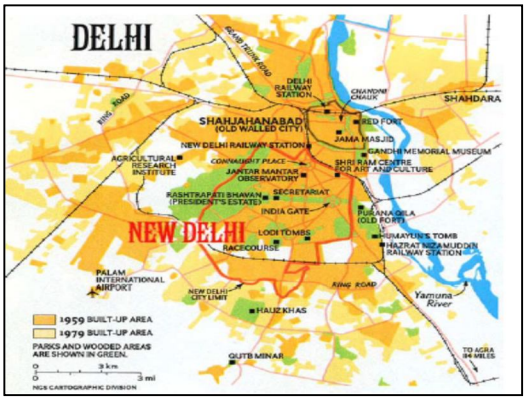


Fig1.2 Map of Delhi

Geographical location: Delhi is located in northern India between the latitudes of 280-24'-17'' and 2

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280 -53'-00'' north and longitudes of 760 -50'-24'' and 770 -20'-37'' East. It has an area of 1483 sq. kms.
with a maximum length of 51.90 kms and greatest width of 48.48kms.it shares borders with the states of Uttar Pradesh and Haryana. The blue color in the map shows the stretch of river Yamuna which is the main source of water supply in Delhi.

II. MATERIAL AND METHODS

A. *Method for projection of population*

The method of projection of the population forecasting involved mathematical method viz.

1) Arithmetic Increase method
2) Geometric increase method
3) Incremental increase method
4) Decreasing rate method
5) Logistic curve method,

The population of Delhi is known for the year 1901, 1911, 1921, 1931, 1941, 1951, 1961, 1971, 1981, 1991, 2001, 2011 and the population is projected for the year 2021, 2031, 2041, and 2051 respectively. The population is calculated by various methods and compared against the available growth rate and it is found that the geometrical increase method is most suitable for projection of the present population.

B. *Geometric increase method:*

Assuming the growth rate (r) to be constant and thus the increase in the population is compounded over the existing population every decade. This method is also known as Uniform increase method, though the population of Delhi has decadal variation in its growth rate but the calculated value is acceptable as compared to other forecasting methods.

P_1 = population after one decade, r = percentage growth in population

$P_1 = P_0 + (r/100).\ P_0$

P_2 = population after 2 decades

$P_2 = P_1 + (r/100).\ P_1$ or $P_1\ (1+r/100)$ or $P_0\ (1+r/100)^2$

The population is collected from the NSSO, Govt. of India for the preceding years i.e. from 1901 to 2011, and the available population is compounded for the succeeding decades i.e. from 2021 to 2051 by geometrical increase method.

To calculate increment in population: Subtract the population of previous year from the current

To calculate growth rate: The geometrical increase rate of growth(r) is calculated as:-

Growth= increment / previous decade population.

The geometric mean is calculated as: - $g.m = (r_1 * r_2 * r_3 \ldots\ldots * r_n)^{1/n}$

To project population for future decades:

For the projection of the population for future decades the given formula is used

$= P_n*(1+g.m)^n$

Where,

P_n= population of last decade which is available.

g.m= geometric mean

C. *Water Demand*

The water demand is proportional to the population, greater the population higher will be the water demand. It is also dependent on various other factors such as lifestyle of the individual, type and nature of the intake, size of the city, metering system etc. Based on the norms of 60 Gallon Per Capita per Day (GPCD) as per the Central Public Health and Environmental Engineering organization (CPHEEO), Ministry of Urban Development, Government of India norms. The total requirement of water in March in 2011 was found to be 1020 MGD. The water demand is calculated by multiplying the population with the per capita demand. The various types of water demand, which a city may have, may be broken down into various classes such as domestic demands, Industrial demands, Institutional demands, Public use demands, Fire, loss and theft demands. The amount of domestic water consumption per person shall vary according to the living conditions of the consumers.

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Average rate of draft in litres per day per service= V/365 * 1/ No of services

Per capita demand (q) = total yearly water requirement of the city in litres (V)/ 365 *population

Where V is total annual volume in litres or million litres

As per IS:1172-1993 the minimum domestic consumption of a town or city with full flushed system should be taken as 200l/h/d; although it can be reduced to 135l/h/d for economically weaker section and LIG colonies depending upon the prevailing condition. The Delhi development authority has taken a figure of 274 lpcd or 60 GPCD.

Table 2.1 Breakout of water demand; Delhi Jal Board

S.No	Details	Requirement of water
1	Domestic	172 LPCD
2	Industrial, commercial and community requirement	47 LPCD
3	Fire protection based on 1% of the total demand	3 LPCD
4	Floating population and special uses like hotel and embassies	52 LPCD
	Total	274 LPCD (60 GPCD)

The water demand is calculated by multiplying the water demand by the projected population. The requirement of water may keep varying decade to decade as it depends on various factors as mentioned above. A proper water supply plan has to be adopted to meet the required deficit. The master plan of Delhi-2021 prepared by Delhi development authority proposed water requirement with the norm of 80GPCD, out of which 50 GPCD is for domestic purpose and 30 GPCD is for non-domestic purpose. With the current tier of 60 GPCD the water demand for the current year 2017 is 1140 MGD (DJB). Though the projection of water demand in this paper is done by assuming the average daily demand of 80GPCD.

D. Wastewater generation

it is reported that 80-90 % of water turns into wastewater. Hence the calculated water demand is converted into wastewater by taking the percentage into consideration as mentioned by CPHEEO. The wastewater generation is projected for the financial year 2050 which is based on the quantity of water needed. Wastewater indicates the liquid waste originating from the domestic uses of water. It includes sullage, discharge from toilets, urinals, wastewater generated from commercial establishments, institutions, industrial establishments and also the groundwater and storm water that may enter into the sewers. Its decomposition produces large quantities of malodorous gases, and it contains numerous pathogenic or disease producing bacteria, along with high concentration of organic matter and suspended solids (M.M Ghangrekar et.al)

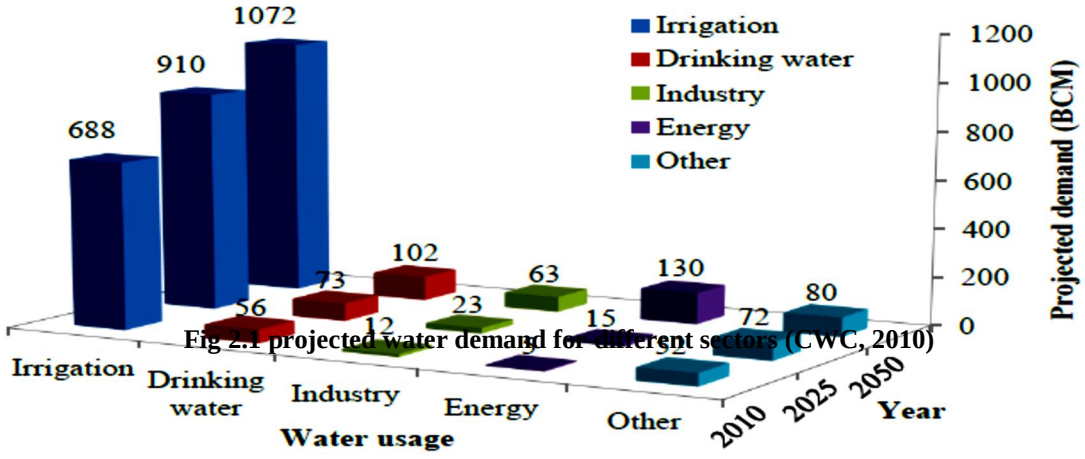


Fig 2.1 projected water demand for different sectors (CWC, 2010)

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III. RESULT AND DISCUSSION

A. *Projection of population*

Population estimates for the future decades and the increase in growth rate of the population is calculated by geometrical increase method. The population for the year 1950-2011 is known and therefore its value is used to calculate the future population.

Table 3.1 Projected populations of Delhi Region

Year	Population	Increment	Geometrical increase Rate of Growth
1951	1744500		
1961	2659990	915490	0.52
1971	4066400	1406410	0.53
1981	6220973	2154573	0.53
1991	9421311	3200338	0.51
2001	13851503	4430192	0.47
2011	16753235	2901732	0.21
2021	24141412	7388177	0.44
2031	34787774	10646362	0.44
2041	50129183	15341409	0.44
2051	72236152	22106969	0.44

The growth rate is calculated accordingly. It is to be noted that the growth rate for the year 2021-2051 is found to be constant as the population increase rate calculated by geometrical increase method is found to be linear, though the growth rate may vary in future but its accurate prediction is not possible

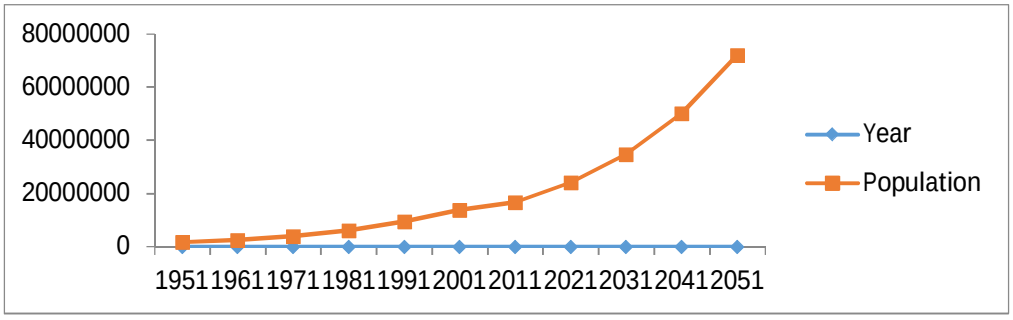


Fig 3.1 Graph showing the variation of past, present and future population

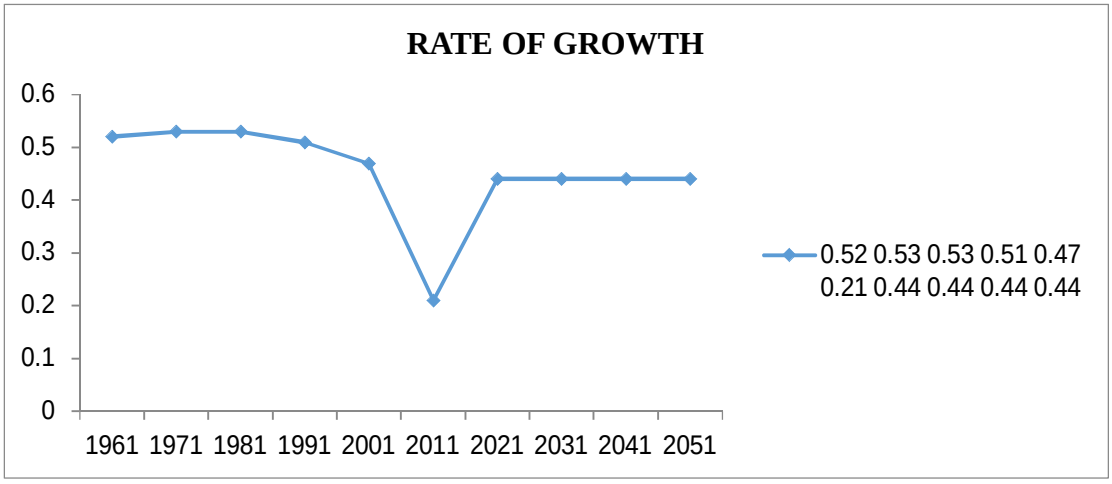


Fig 3.2 Variation of the growth rates

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The population of Delhi for the succeeding decades is increasing exponentially as the population in the year 1951 was only 17 million which is increased by 167 million which is nearly 300% of the past population, and by the year 2021 and it is mathematically projected that the population of Delhi may rise up to 7.2 billion approximately. The decadal growth rate is also found to be varying in accordance to the population increase**.** From the given fig 3.2 it is clear that the rate of population growth is decreasing gradually for year 2011 and is becoming constant for the coming decades however the population keeps on increasing.

B. Projection of water demand

Year	Population	Water demand (MLD)
2001	13851503	2070
2002	14523033	2178
2003	14952311	2235
2004	15386022	2685
2005	15831221	3763
2006	16291123	4090
2011	16753235	5181
2021	24141412	6272
2031	34787774	9531
2041	50129183	13735
2051	72236152	19792

DJB is the agency of the Govt. of NCT of Delhi responsible for procurement, treatment, transportation and distribution of water in the MCD areas. It also supplies bulk water to the NDMC,
and Delhi Cantonment Board. Water requirements for an estimated population of 16.5 million in
2021 is 6272 MLD as projected, though DJB is equipped to produce 735 MGD of water from 11 Water Treatment Plants (WTPs) and ground water abstraction from 446 tube wells & ranney well.

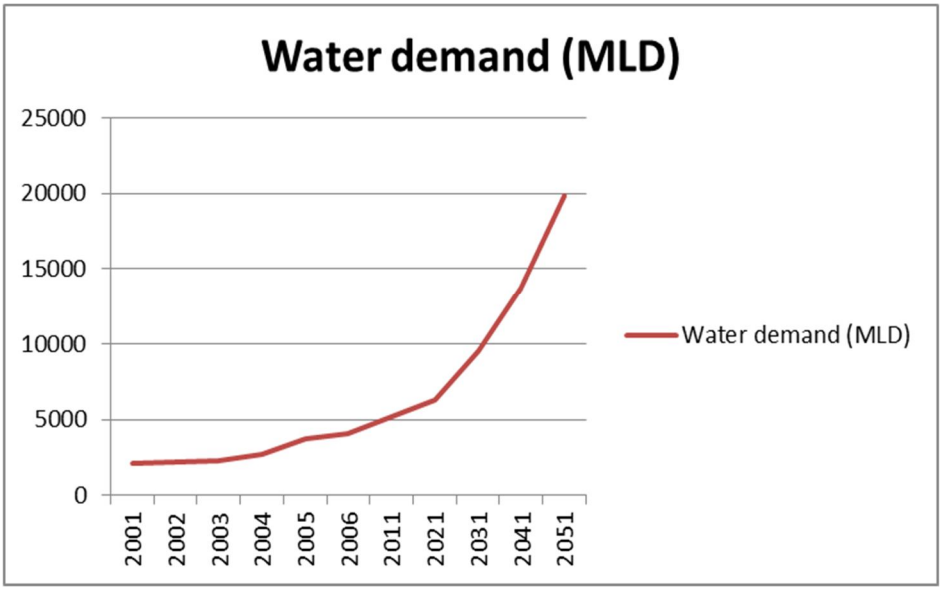


Fig 3.3 Projection of water demand

The per capita availability of water is one of the highest among urban areas. In spite of this, water is supplied for only a few hours in the day. Moreover, norms of supply to different zones vary, and areas at the end of the distribution system receive little water. About 20 per cent of the city's population is not covered by piped water supply. In the absence of piped water supply from DJB, there has been extensive abstraction of ground water (JNNURM, 2006).

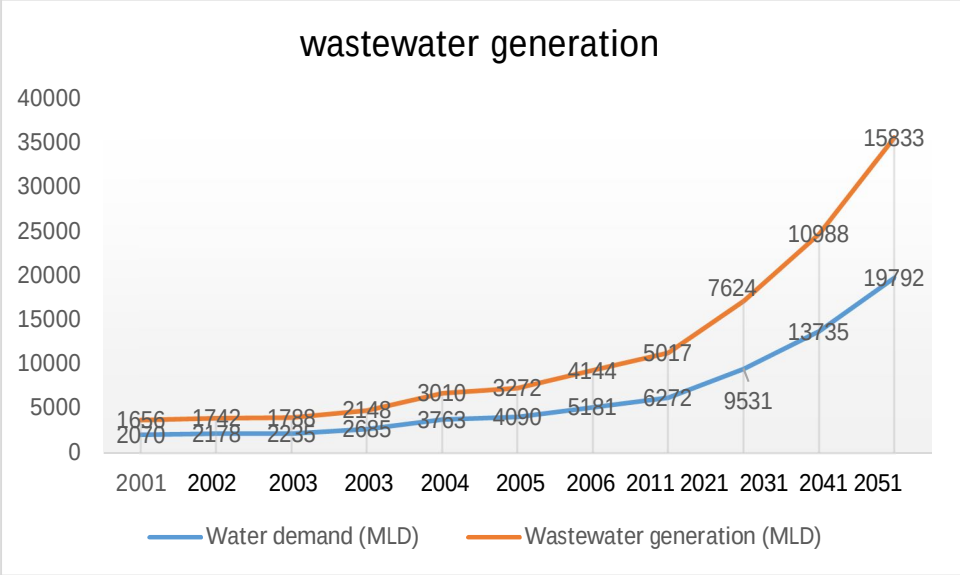
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C. Projection of wastewater generation

Year	Water demand (MLD)	Wastewater generation (MLD)
2001	2070	1656
2002	2178	1742
2003	2235	1788
2004	2685	2148
2005	3763	3010
2006	4090	3272
2011	5181	4144
2021	6272	5017
2031	9531	7624
2041	13735	10988
2051	19792	15833

Nearly 80% of water turns out as wastewater as stated by CPHEEO. The water utilization for the given years is projected in terms of wastewater. The value of water demand is known for the year 2021 as it is mentioned in the master plan of Delhi, also it is projected for the succeeding years by various mathematical method. The value of wastewater generation is therefore calculated by taking the 80% of the given value of the water demand.



IV. CONCLUSION

The water use for the city of Delhi is continuously increasing year by year due to continuous increase in the population and also due to undefined settlements like JJ Clusters. The water demand has to be fulfilled by limited means of the water supply system. The wastewater generation and treatment is further a great concern as nearly 58% of the wastewater treatment is functional and rest part of the wastewater is either dumped directly in the natural body or by partial treatment. The wastewater generation is continuously increasing as the water demand keeps increasing. Various water conservation methods has to be adopted for reducing water shortage. REUSE, and REDUCE of water has to be adopted for reducing the over exploitation of the available natural water resources.

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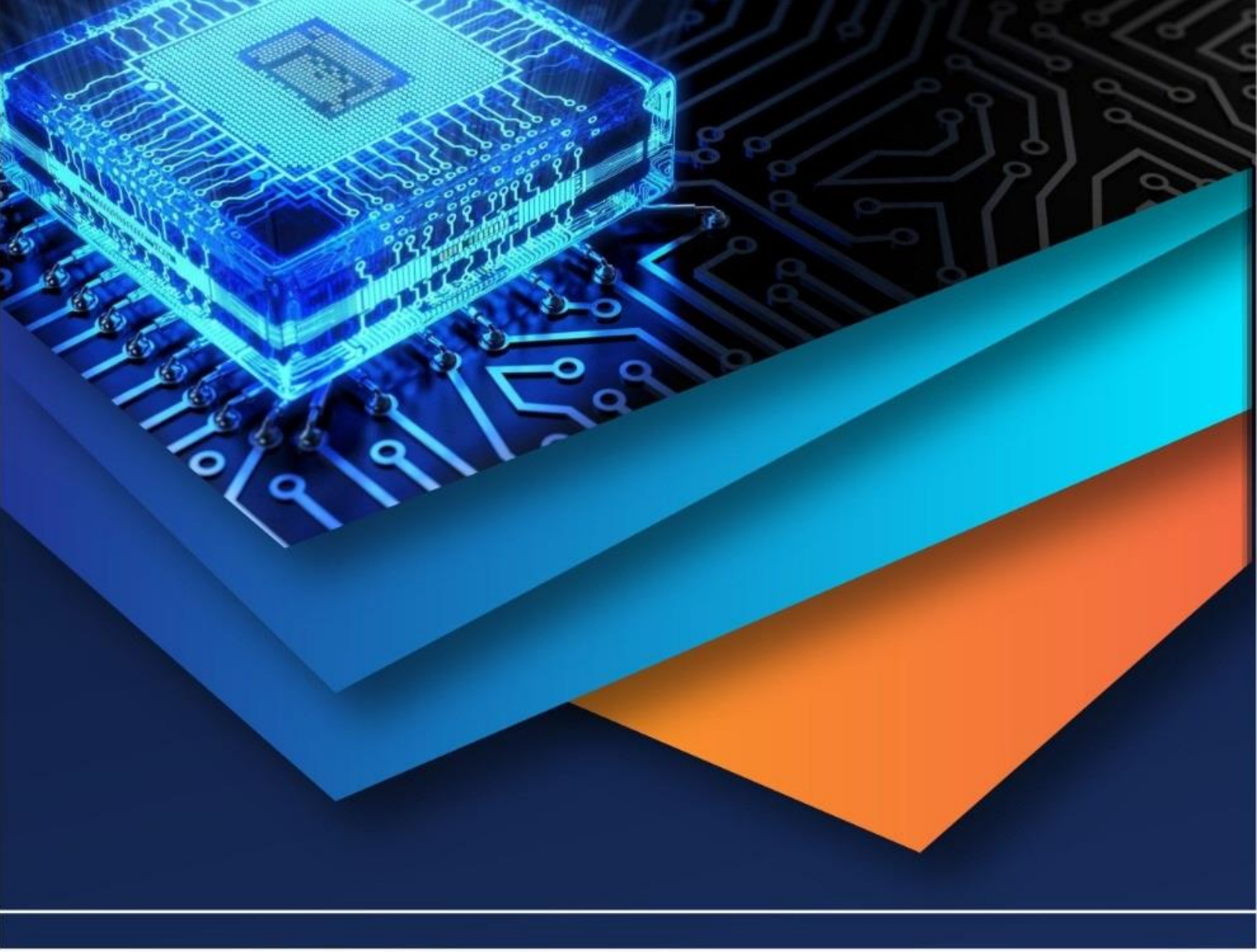
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