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Technical Analysis of Water Distribution System and Techno-economic Analysis of Distributed water: A Case Study of Rajkot City

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Abstract: ***Water is one of the most important stuffs on earth. Existence of our mother earth is not possible without water. Water is required for domestic, irrigational, industrial, institutional, and recreational and many other purposes. General methods of assessment of water in our country are water taxes and billing by water meters. As the governments in general are either reluctant or incapable to raise tariff and improve revenue from water supply, so one of the solution is permitting private participation in the section. In India, the water tariff is highly promoted- water supply sector projects are principally financed through budgetary allocations and state government guaranteed debts. The water distribution for any purposes is operated and maintained by government in our country that may be privatized based on conditional contract. The water supply system should be privatized partly or fully in favor of users for optimization and increasing efficiency of system and to decrease the operational cost of system. While the legal right to supply water may be controlled by the private sector, these rights must be closely proscribed and supervised by public sectors or government.***
Keywords: Water distribution system, revenue modal, water assessment, water meter, privatization

I. INTRODUCTION

After the air we breathe, water is the most imperative substance to human survival, growth and progress. Not only human but all living hoods are dependent upon water for their very survival. Earth will not exist without water, if there is no water there would be no life. “Water, not unlike religion and ideology, has the power to move millions of people. Since the very birth of human civilization, people have moved to settle close to water. People move when there is too little of it; people move when there is too much of it. People move on it. People write and sing and dance and dream about it. People fight over it. And everybody, everywhere and every day, needs it.” (Mikhail Gorbachev, Civilization Magazine, Oct. /Nov.2000.). (Draper, 2008) Water is essential for domestic, agricultural, industrial, institutional, commercial, recreational and many other purposes. While for domestic or residential use water is requisite for drinking, cooking, bathing, flushing, washing of clothes, washing of vehicles, washing of utensils, washing of houses. So for any city or community a well planed and designed water distribution system is required. To collect charges for this utility water assessment system also should be made available. Public have mentality that water is god gifted and it is basic need, so it should be available at minimum cost with sufficient quantity and quality, some people does not pay tax or theft water by fake connections. But to maintain quality and quantity requirements government bodies such as Municipal Corporation have to burden charges for treatment, storage and supply of water hence all the charges become encumbered to government. So a perfect water distribution system must have a well planned and technically sound water assessment system. For this purpose if privatization of water distribution system either partly or fully should be adopted. And this private body should be in favor of public. This study includes analysis of a system and requirement of privatization with suggestion.

A. Necessity for Study

This study is necessary for easy, systematic and technical way for assessment of water, for speedy resolution of complaints and grievances, for timely collection of the monthly fee to produce monthly revenue, to reduce water theft.

B. Study Area

Rajkot city is selected for this work. It is the fourth largest city of Gujarat located in center of Suarashtra region. City is spread on both banks of Aji River which cuts through the city. Rajkot city is spread across on area of 129 km^2. Population of Rajkot city is 1.78

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million. Following fig1 shows map of Rajkot city with Rajkot Municipal Corporation boundary and fig 2 shows wardwise map of the city.

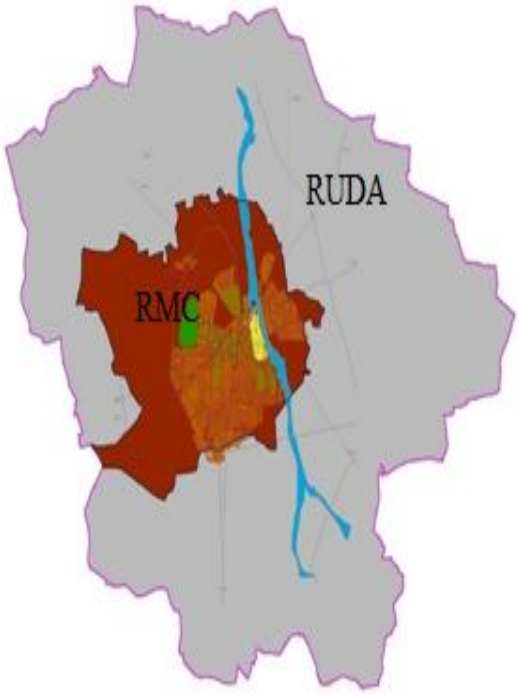

Figure 1 RMC Boundary of City

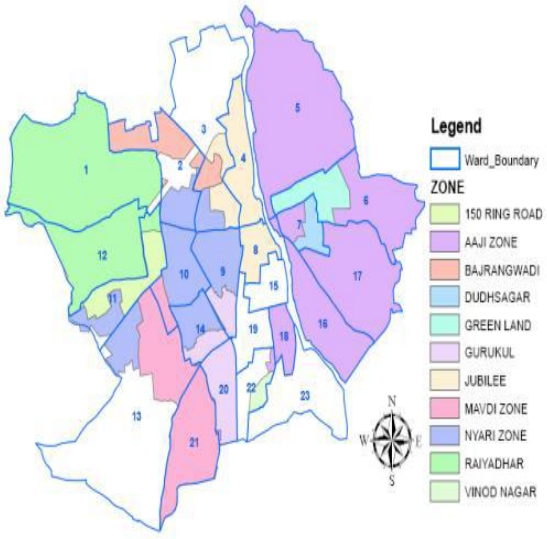

Figure 2 Ward Wise Map of City

II. METHODOLOGY

The water supply distribution network starts from water source and ends at the property level individual connections. There are two types of consumer water supply connections as domestic and non domestic in RMC. Rajkot has been in the water scarce region, so RMC does not encourage water supply connections to large industrial units. RMC have considered all the institutional connections as non domestic connections and based on size of connection monthly water tariff is charged. As per availability of source RMC supply

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water daily for 20 minutes. Rate of supply is 110 LPCD to 125 LPCD and present total city water supply is 255.49 MLD. Details about storage reservoir in Rajkot city is given in Table 1. There are 23 ground storage reservoirs and 19 elevated reservoirs.

Sr No.	Head Work	G.S.R. Capacity (ML)	E.S.R. Capacity (ML)
1	Raiyadhar	20.00	3.00
2	Nyari 1	18.60	2.30
3	Mavadi	8.00	2.50
4	150 Feet Ring Road	2.50	1.25
5	Bajarangvadi	5.00	0.50
6	Sojitranagar	3.00	1.40
7	Nyari 2 Ghanteshvar	4.00	-
8	Ribda	24.50	-
9	Gurukul	5.45	4.74
10	Jubelee	6.00	5.40
11	Lalbahadur	4.00	1.35
12	Aji	35.60	-
13	Dudhasagar	7.00	1.00
14	Marketing Yard	0.80	0.20
15	Kothariya	1.50	0.20
16	Greenland	10.00	3.00
17	Vinodnagar	10.00	3.00
18	Chandreshnagar	6.25	2.50
19	Popatpara	8.00	2.00
20	Nyara	4.00	-
21	Ishwaria	3.00	-
22	Aji 1	10.00	1.00
23	Bedi	20.00	3.00
	Total	217.15	38.34
Storage Capacity of City		255.49	

Table 1 Details of Storage Capacity of Rajkot City

Real time bulk water audit project for Rajkot Municipal Corporation is installed, tested and commission by Mechatronics System Privet Limited. This system is established for the first time in Gujarat. It is to provide portable water in the city and for purification there are various filter plants in city, they are listed in table 2.

In all these filter plants to calculate inflow and outflow of water electromagnetic flow meters are connected. Under SCADA system all storage tank is provided with chlorine analyzer and ultra sonic level sensor. In this system; there are 35 electromagnetic bore type flow meter, 52 level sensors, 27 chlorine analyzer and 31 Remote Terminal Unit/ Data Collection Platforms (RTU/DCP).

The whole system of is integrated and linked by V. H. F. to one main computer server, so from one site all data like water quantity and quality can be collected.

Android application named RMC Project is used by all officers of water works in this application current data of every 20 minutes of each water treatment plant and ESR, GSR stations like water level, water flow, water quantity, chlorine, etc are shown. Application also includes details of dam sites and pumping stations. There is a website also available as http://www.rmcscadaww.com/PageLogin.aspx, it shows all the updated data of entire system.

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Filter Plant	Capacity (MLD)
Aji 1 Filter Plant	105
Ribada Filter Plant	50
Nyari 1 Filter Plant	32
Raiyadhar Filter Plant	50
Ghanteshawar Filter Plant	13

Table 2 Water Filter Plants in Rajkot City

Monthly total water supplied in year 2016 and average water supplied are shown in table3.

Sr. No.	Month	Days	Total Water Supplied (ML)	Average Daily Supply (MLD)
1	January	31	8269.43	266.76
2	February	29	7792.04	268.69
3	March	31	8354.73	269.51
4	April	30	7943.30	264.78
5	May	31	8212.52	264.92
6	June	30	7752.89	258.43
7	July	31	8164.21	263.36
8	August	31	8224.13	265.29
9	September	30	8262.39	268.36
10	October	31	8335.50	268.89
11	November	30	8201.59	273.49
12	December	31	8502.43	274.27
Total Supply of Year (ML)			98,015.16	
Total Average Daily Supply (MLD)			268.53	

Table 3 Monthly Water Supplied in 2016

RMC water works branch manage the system. Any system can not administer without proper monetary management. RMC water works branch manage cost of treatment of water, storage of water and distribution through pipe network. This total cost includes expenditures on for water works department salary of branch, contingency expenditures, telephone charges; for pipeline distribution network expenses on maintenance of hole network, valve operating costs, govt water charges, any new work for water supply, civil works for water supply; filter plan includes costs of salary for all staff members, plant repairing cost, cost of electricity, cost of chemicals; and other charges such as water supply emergency sch. expenditure, nyari 2 emergency cost, nyari 1 operation and maintenance cost, and other. All this expenditures for year 2016 is shown in following table 3 as remaining grant register. From table 4 the total expenditure done by RMC for water supply work of city is 582948116.00 Rs.

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Sr. No.	Budget Name	Account Name	Grant Amount	Amount Used	Rem Grant
1	Water Works Branch Salary	Water Works Branch Salary	123000000	94353573	28646427
2	Contingency Exp.	Contingency	200000	115964	84036
3	Telephone Exp.	Telephone	200000	148559	51441
4	Maintenance Exp.	Pipeline maintenance	65000000	52427523	12572477
5	Valve Operating Exp.	Valve Operating Exp.	29500000	18076076	11423924
6	Govt. Water Charges	Govt. Water Charges	250000000	1508116	248491884
7	New Works for Water Supply	Pipelines	40000000	24916000	15084000
8	Civil Works for Water Supply	Valve Chamber	40000000	32597825	7402175
9	Filter Plant Salary	Filter Plant Salary	29500000	22518960	6981040
10	Filter Plant Repairing	Filter Plant Repairing	75000000	49627004	25372996
11	Filter Plant Elec.	Electricity	240000000	150816051	89183949
12	Chemicals Pur. Exp.	Chemical Usage	13500000	10224051	3275949
13	Water Supply Emergency Sch. Exp.	Water Supply Maintenance	3600000	3018234	581766
14	Nyari-2 Emergen	Water Supply	4200000	3136226	1063774

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	cy.	Maintenance			
15	Nyari-1 Operation and Maintenance	Water Supply Maintenance	3500000	1665342	1834658
17	Water Supply by Tanker	Water Distribution Exp.	10000000	5405011	4594989
18	Works Under JNNURM Mission 1	Works Under JNNURM Mission 1	112800000	90988691	21811309
19	WW Branch Store AD.	WW Branch Store AD.	50000000	21404910	28595090
		Total	1090000000	582948116	507051884

Table 4 Remaining Grant Register of Year 2016

While property tax branch collect from public as water tax and revenue generate for water supply is sum of water tax and interest on water charges; for year 2016 they are Rs. 328088877 and 37150457 respectively so total revenue is Rs. 365239334.
In this research by using simple mathematics and from all these data general revenue modal which shows profit or loss is generated for year 2016. Further analysis of current water distribution system and what changes are to be adopted if water meter system would be adopted is discussed and then based on several parameters whether privatization of Rajkot city is necessary or not is analyzed, and if privatization is in need then "how?" is considered.

III. ANALYSIS AND RESULT

A. Revenue Modal

From above mentioned details of total expense by water works branch is Rs. 582948116.00 and revenue for water supply is Rs. 365239334.00. Hence gape of revenue is Rs. 217708782.00 this amount should be granted by government. Following table 5 shows total revenue for water supply for year 2016.

Sr. No.	Type of Amount	Amount (Rs)	Percentage (%)
1.	Total Operational Cost	582948116.00	100
2.	Total Revenue	365239334.00	62.65
3.	Total Gape of Revenue	217708782.00	37.35

Table 5 Total Revenue

Thus to reduce grant by government there should be an assessment system such that it make public to reduce water wastage, some

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cross checking that aware officers directly if any leakage and/or water theft and generate revenue. If electromagnetic water meters would be made available and installed at each and every water connections and they are integrated as same manner that is available for water filter plants under SCADA by GPS devices then draw backs would be minimized and system will be ideal. This smart water meter system can be defined as "a communication channel that permits the utility, at a minimum, to obtain meter reads on demand, to ascertain whether water has recently been flowing through the meter and onto the premises, and to issue commands to the meter to perform specific tasks such as disconnecting or restricting flow".

Here revenue modals are suggested based on this revenue gap for biggest mass of connection. The biggest mass of connection is residential connection; for ease of work here one connection per 6 persons is considered. Two types of modals are suggested first for water tax system and another for water meter system.

From table 3; total water distributed in year 2016 is 98015.16 ML and daily average water supplied is 268.53 MLD and population of city is 1.78 million so average water supplied per capita is 150.75 litters per day. As per municipal norms there are 1 connection is provided for 6 person therefore average water supplied per connection is 904.5 litters per day and average water supplied per month is 27135 litter; for ease taken as 27 kilo litter

1) *Revenue modal for water Tax System:* If the current water assessment system is to be continued then the gape of revenue may be minimized by increasing water tax. So following calculation shows water tax would be

a) Present total Revenue gap is Rs 217708782 per year and population of city is 1.78 million so debit per capita is Rs122.3

b) Hence Revenue gap per connection (6 person) is to be Rs 733.8 per year

So tax should be increased by Rs 733.8 hence to reduce this revenue gap tax should be Rs 1533.8 per connection.

2) *Revenue modal for water meter system*

a) As per present tax collection Mathematical form for water meter charges is shown below.

b) Revenue collection by RMC is Rs 365239334 per year

c) Average water supplied per capita per day is 150.75 litter

d) Average water supplied per connection per day is 904.56 litter

e) Average water supplied per connection per month is 27136.8 litter ≈ 27 kilo litter

f) Present water tax is Rs 800 per connection per year

g) So per month water tax is Rs 66.67 per connection

As per above data water meter charges may be considered based on the year 2016 as following table 6 by try and error method

Sr. No.	Quantity of Water Used(KL)	Rate per Month per KL (Rs)
1	0 to 5	1
2	6 to 10	1.5
3	11 to 15	2.0
4	16 to 20	2.5
5	21 to 25	4.0
6	Above 25	6.0

Table 6 Rate of Water Meter

Cross check for above modal

Use of water per connection per month

= 150.75 × 6 × 30 = 27135 litter ≈ 27 KL

Water bill as per above rate

= 5 × 1 + 5 × 1.5 + 5 × 2 + 5 × 2.5 + 5 × 4 + 2 × 6 = 67 Rs ≈ 66.66 Rs

Hence ok.

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For yearly provision of water bill rates of water are as per following table 7.

Sr. No.	Quantity of Water Used(KL)	Rate per Month per KL (Rs)
1	0 to 60	12
2	61 to 120	18
3	121 to 180	24
4	180 to 240	30
5	241 to 300	48
6	Above 300	72

Table 7 Rate of water meter

2) As per expenditures by RMC: Mathematical form for water meter charges is shown below.

a) Total expenditures in water supply by RMC during year 2016 is Rs 583948116

b) Present water tax is Rs 800 per connection per year

c) Present total Revenue gap is Rs 217708782 per year and population of city is 1.78 million so debit per capita is Rs122.30

d) Hence Revenue gap per connection (6 person) is to be Rs 733.8 per year

e) Total expenditure per connection is Rs 1533.8 per year

f) So monthly expenditure by RMC per connection is Rs. 127.80 per month

As per above data water meter charges may be considered based on the year 2016 as following table 8 by try and error method

Sr. No.	Quantity of Water Used(KL)	Rate per Month per KL (Rs)
1	0 to 5	1.5
2	6 to 10	2.5
3	11 to 15	3.5
4	16 to 20	6.0
5	21 to 25	8.0
6	Above 25	10.00

Table 8 Rate of water meter

Cross check for above modal

$= 150.75 \times 6 \times 30 = 27135$ litter ≈ 27 KL

Water bill as per above rate

$= 5 \times 1.5 + 5 \times 2.5 + 5 \times 3.5 + 5 \times 6 + 5 \times 8$

$+ 2 \times 10 = 127.5$ Rs ≈ 127.8 Rs

Hence ok.

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For yearly provision of water meter bill rates are as per following table 9

Sr. No.	Quantity of Water Used(KL)	Rate per Month per KL (Rs)
1	0 to 60	18
2	61 to 120	30
3	121 to 180	42
4	180 to 240	72
5	241 to 300	96
6	Above 300	120

Table 9 Rate of water meter

B. Privatization

Privatization is process of transferring a scheme, project, service or system from the public sector to private sector. Privatization is a trend in many parts of both developed and developing countries. Sometimes government sector are not more efficient and objective so to bring more efficiency and objectivity to that sector privatization may be considered.

Countries and governments, especially in developing countries, are experiencing increasing pressure from their citizens, civil society organizations and media to provide accessible and affordable services; this issue arises due to rapid economic growth, growing urban population, increasing rural-urban migration, and all around social and economic development have compounded the pressure on the existing infrastructure, and increased the demand-supply gap.

While the gap is rising, government budgetary resources are increasingly constrained in financing this deficit. The governments do not allow making the required investments in upgrading or rehabilitating the existing infrastructure or creating new ones by reason of rising cost of maintaining and operating existing assets, inability to increase revenue and cut costs and waste and rising constraints on budgets and borrowing so PPP is one of the solutions.

Private sectors works on basis of various conditions such as investment level, ownership control, risk sharing, technical collaboration, duration of the project, financing mode, tax treatment, management of cash flow etc, based on various terms and conditions of various Public Private Partnership models are as per following

1) BOT - Build Operate Transfer
2) BOO - Build Operate Own
3) BOLT - Build Operate Lease Transfer
4) BOOT - Build Operate Own Transfer
5) DBFOT - Design Build Finance Operate Transfer
6) ROT - Rehabilitate Operate Transfer

For RMC water works branch a BOO PPP model can be suggested. RMC is currently working with a technically sound water treatment and distribution system but for assessment it has no any sound system if there any technically sound system for assessment of water used by end users then entire system will be tends to completely perfect system.

In this; contract should be such that authority of all sources of water would remains with government, private company is chosen based on tenders for the assessment system. The suggestion for assessment system is given here.

7) As similar to water distribution system, all water flow meters would be connected to GPS devices and a central data base would be provided. So door to door billing collection will be avoided and time to time water used by public could be monitored. Also facility of paying bill online to be made available.
8) Another facility would be provided such that it also checks quality of water that is purified by RMC for satisfaction.
9) There would be also an alarming massage system such that if user use more than some pre-decided value i.e. at every use of 10 kilo litters of water a massage should be conveyed to aware consumer to reduce water usage.

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10) Also a helpline center would be made available to solve any problem in meter and any other query by consumers.

C. Advantages of this assessment system

1) Water wastage is tends to eliminate
2) It is a clear system as who use less will pay less and who use more will pay more
3) By help of massage system public would be aware to reduce water use
4) Quick query solution is available
5) Quality is checked twice once by RMC and then by private sector so satisfactory
6) Long term cost beneficial, economic and revenue generating system; deals with ultimate goal of water saving

D. Disadvantage of this assessment system

1) Initial investment is high
2) People having private bore hole do not agree with this system

IV. CONCLUSION

Revenue gap of year 2016 is Rs. 217708782 which is burden on government. It can be reduced by either increasing tax or by providing water meter system as per expenses done by RMC water works branch as per table 8 for monthly bill or as per table 9 for yearly bill. Privatization as per suggestions given is beneficial for RMC but it should be done that authority of sources would remains with government and private sector manage supply of water and collection of bills.

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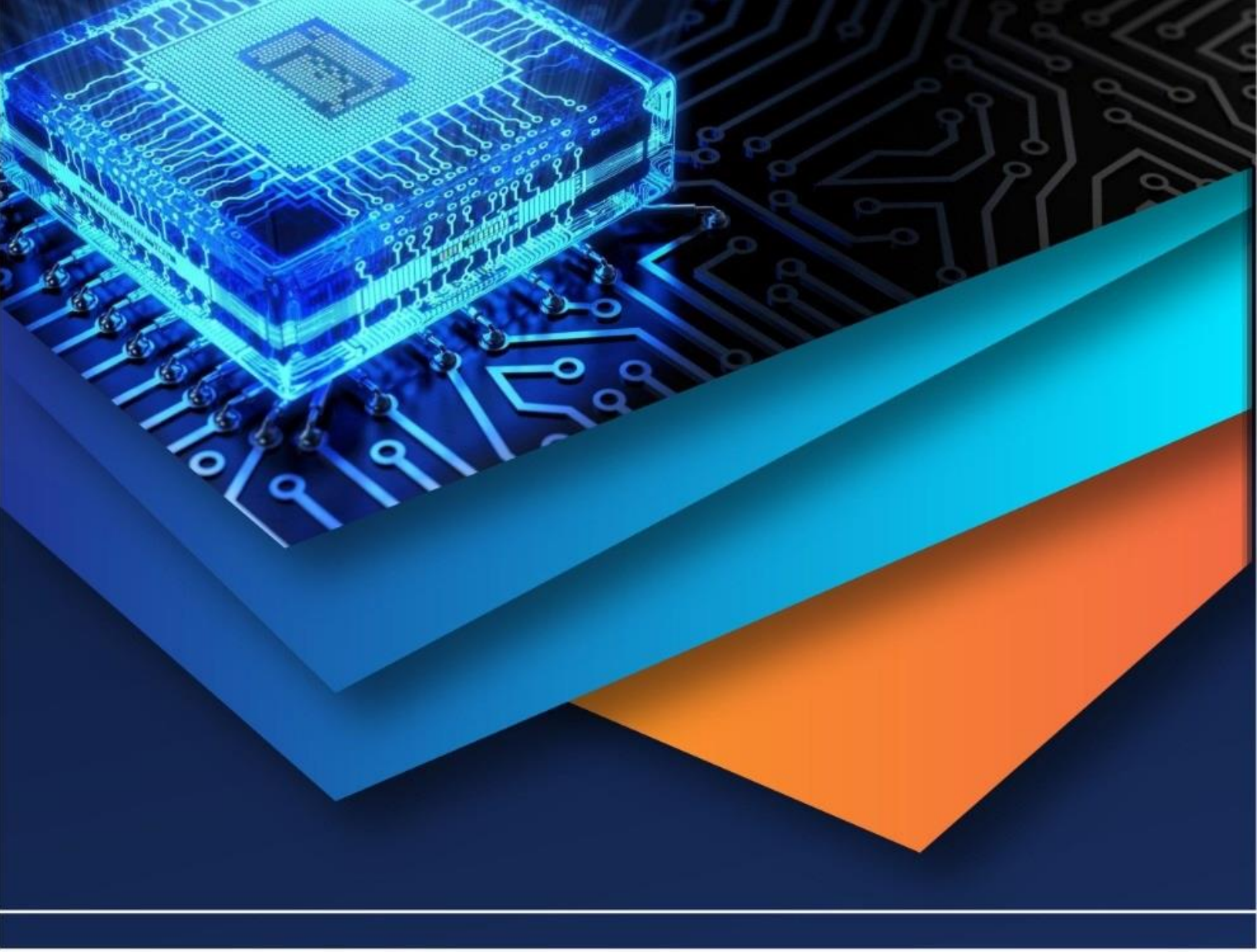

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