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An Analytical Study on Carbon Balance of Chandi Mandir Railway Station

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Abstract: Green House Gases are a necessary evil. They are necessary for the existence of life. There is an old age saying that anything excess is bad and dangerous. This adage is applicable in case of greenhouse gases .Green House Gases become an evil because of their abnormal increase in the atmosphere due to out of bound human activities.

Railway station is a transportation hub, carrying passengers and essential commodities and goods from one location to another. Railway station is a point of mass contact. In Railway station, there exist various infrastructure for movement of trains, passage of Goods Trains, Freight terminals, various facilities of passenger amenities, transportation facilities for commutation of passengers and staff, Electronic Gadgets for controlling train movements, passenger boarding, deboarding facilities etc. Congregation of huge no. of people and connected infrastructure results in fluctuation of various parameters of environment and ecology. As such, there is a need to study the environmental condition of a Railway station. However, as of now, there is limited study on carbon balance assessment of individual Railway station. Analyzing various aspects of sources of emission within the defined boundary of station and then quantifying the measures to counter such emissions thus finding the balance and based on that precisely defining the carbon Index of each Railway station across world particularly India will go a long way in the protection of environment. The instant study assesses the carbon balance of Chandi mandir Railway Station , a small non-suburban station under Ambala Division of Northern Railway, within its defined administrative and operational boundary. The evaluation of carbon Balance of this station is done as per the scope categories defined in Greenhouse Gas (GHG) Protocol and Life Cycle Assessment (LCA) principles. It categorizes Carbon emissions into Scope I, Scope II, and Scope III. Emissions from fuel use, electricity consumption (traction and non-traction), passenger and staff commutation, waste generation, and water use are quantified using suitable carbon conversion factors(CCF). Carbon sequestration from trees and grassland within station premises and carbon offsets from rooftop solar photovoltaic systems are also quantified. Then , carbon balance of the station is evaluated by subtracting total co2 sequestration from total carbon emission. Results obtained is that of total annual GHG emissions are approximately 103.7 tCO_2e, while sequestration potential is about 122.5 tCO_2e, thus, resulting in a net carbon-negative balance of −18.8 tCO_2e per year. The study brings out a scintillating fact that small railway stations can achieve carbon negativity through massive tree plantation, use of solar energy, EV, Biogas plant, Rainwater harvesting, adopting green building technology, optimum utilisation of natural light, reduction water wastage and ecofriendly waste management. A ten-point Recourse plan is suggested to achieve a sustainable carbon neutral Railway station. Based on carbon balance, railway stations are proposed to be classified into three categories, GREEN STATION, YELLOW STATION and RED STATION. In this study, a general guideline for small railway station is also suggested to formulate polices to achieve carbon neutrality of stations which would greatly influence the net zero target of India for the moderation of nationally determined contribution (NDC) of our country. This study is first of its kind assessment in India having huge potential in long run.

Keywords: Carbon balance, Railway station, GHG Protocol, carbon balance, scope categories, carbon emissions, Carbon sequestration, Sustainable Carbon neutral railway station, NDC.

I. INTRODUCTION

Our beautiful planet is reeling under a climate crisis today. This environmental catastrophe is the fallout of monstrous atmospheric temperature resulting unexpected natural calamities across globe. Recent devastating wild fire in carlifornia,flood in Europe, heatwave in India, flash flood and upheavals in Himalayan region such as sinking of Joshimath and rise in lightning deaths in India is a consequence of climate change. Today's climate crisis is owing to the imbalance in concentration of green house gases such as CO_2,CH_4 & N_2O.The fundamental cause of such imbalance is attributable to downward slide in plant-human ratio ,human lifestyle, urbanisation, exponential increase of mechanised motor vehicles and of course industrialization. In fact,plant-human ratio plays an important role in shifting the role of green house gases from a necessity to an evil.Decrease in plant population and increase in human population disturb the O_2 - CO_2 balance thus impacting the climate.

India is the most populous country in the world. India is the 3rd largest emitter of green house gases after China and America. It is a collective responsibility on the part of each and every country to take robust measures to curb climate crisis by decreasing emission of green house gases. Tree is life. Life is tree. That mantra is required to instilled in everybody's mind. This is the most important principle of climate action plan. The rapid increase in greenhouse gas (GHG) concentrations due to urbanization, industrialization, vehicular emissions and lifestyle changes has aggravated global climate change concerns. Railway stations are important mode of transportation due to its spread across length and breadth of country. Therefore, it is of paramount importance that the environmental health of railway stations should be assessed. Indian Railways, one of the world's largest rail networks, has set an ambitious target of net-zero carbon emissions by 2030. However, most existing studies focus on network-level emissions, rolling stock, or large junction stations. Small and wayside stations, which constitute the majority of India's approximately 7,300 railway stations has a huge potential for carbon credits by generating alternate energy through solar, Biogas, Rainwater harvesting and more and more green cover surrounding the stations which can compensate for urbanisewd large and junctioned stations. However, there is limited study on carbon balance of small Railway station. This study addresses this gap by assessing the carbon balance of Chandi mandir Railway Station and suggesting suitable recourse for sustainability of small railway stations.

II. STUDY AREA

Chandi mandir Railway Station (station code: CNDM) is a small non-suburban station located in Panchkula district, Haryana, under the Ambala Division of Northern Railway. The station serves the Chandi mandir Cantonment area and consists of three platforms. The operational boundary considered in this study extends longitudinally from the up home signal (Chandigarh end) to the down-home signal (Kalka end), laterally bounded by the cantonment area to the west and the national highway to the east. The station premises include passenger platforms, station buildings, staff quarters, parking areas, green spaces, and a rooftop solar photovoltaic installation.

III. DATA COLLECTION

The data pertaining to carbon emission within the station premises is divided into three categories-

A. Direct Emission

Which is referred as scope-I as per GHG protocol-The carbon emitted directly into the atmosphere is the direct emission. LPG for preparation of food and Generator used in the station for emergency in the event of current outage comes under this category.
Table 3.1 gives the Direct emission of CO_2 as per Scope-I of GHG Protocol.

Table 3.1 Direct Emission(scope-I)

scope category	emission type	source of emission	activity data per year
SCOPE-I	DIRECT EMISSION	LPG	1448.4 KG
		Burning of fossil fuel due to running of generator	zero
Total scope I			1448.4 kg

B. Indirect Emission

Referred as scope II as per GHG protocol -Carbon emitted into atmosphere indirectly from station premises is referred as indirect emission. Electricity and other energy used in the station comes under this category. Carbon is emitted during the production of electricity by conventional means such as hydel powerplant or Thermal power plant. This electricity is purchased by Railway authority for various uses in the station. Therefore, it is an indirect source of emission.
Table 3.2 gives the Indirect emission of CO_2 as per Scope-II of GHG Protocol.

Table 3.2 Indirect Emission(scope-II)

scope category	emission type	source of emission	activity data per year
SCOPE-II	INDIRECT EMISSION	Purchased Electricity	73614 kwh
Total scope II			73614 kwh

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C. Other Indirect Emission

Referred as SCOPE-III as per GHG PROTOCOL. These are emissions which arises due to station activities. This type of emission is otherwise referred as consequential emission which are beyond the control of station but accrued owing to station requirements. Prominent sources of scope -III emissions are-

Table 3.3 gives the other Indirect emission of CO_2 as per Scope-IIII of GHG Protocol.

Table 4.3 Other Indirect Emission(scope-III)

scope category	emission type	source of emission	activity data per year
SCOPE-III	OTHER INDIRECT EMISSION	passenger and Railway staff commutation (to & fro) to the station	18250 Trips
		waste generation	27375kg
		water use	20794050 litre
		paper use	negligible

D. Carbon Sequestration Data

Carbon sequestration or carbon sink is otherwise referred as carbon absorption. Data pertaining to various carbon absorption /carbon sink present in station premises are collected and documented through site visit.

Carbon sinks present in the Chandi mandir railway station are-

1) CO2 Sequestration From Trees

There are around 150 no. Of trees in the premises of chandi mandir railway station. Trees absorb CO_2 from atmosphere and act as a very good carbon capture and storage system which helps in reducing atmospheric temperature by reducing amount of CO_2 in the atmosphere. Hence, trees act as a patent remedy for mitigating global warming. Table 4.4 gives the detailed position of tree distribution in CNDM station.

Table 3.4 Tree Distribution in CNDM Station

SL NO.	LOCATION	NO. OF TREES
1	KALKA END CANTONMENT SIDE	13
2	KALKA END HIGHWAY SIDE	14
3	STATION BUILDING CANTONMENT SIDE	19
4	STATION BUILDING HIGHWAY SIDE	11
5	RAILWAY QUARTERS KALKA END	08
6	RAILWAY QUARTERS CHANDIGARH END	10
7	PLATFORM NO.1 CHANDIGARH END	07
8	PLATFORM NO.1 KALKA END	10
9	CHANDIGARH END CANTONMENT SIDE (HOME SIGNAL TO STARTER SIGNAL)	16
10	CHANDIGARH END HIGHWAY SIDE (HOME SIGNAL TO STARTER SIGNAL)	14
11	MAIN APPROACH ROAD TO STATION (CHANDIGARH SIDE)	05
12	MAIN APPROACH ROAD TO STATION (KALKA SIDE)	06
13	PARKING AREA	07
14	NEW CONSTRUCTION AREA	08
15	CAMP OFFICE	02
TOTAL		150 no.

2) CO2 Sequestration From Green Cover/Grass LAND-

In chandi mandir railway station boundary which stretches from UP HOME signal to DN HOME signal around 1100 meter has approximately 2 hectares of greenery/grassland.

Table 3.5 gives the detailed position of grassland/greenery/shrub distribution in CNDM station.

Table 3.5 Green cover/grassland/shrub Distribution in CNDM Station

SL NO.	LOCATION	Area of greenery/ grassland/shrub
1	KALKA END CANTONMENT SIDE	02 hectares (approx..)
2	KALKA END HIGHWAY SIDE	
3	STATION BUILDING HIGHWAY SIDE	
4	RAILWAY QUARTERS KALKA END	
5	RAILWAY QUARTERS CHANDIGARH END	
6	CHANDIGARH END CANTONMENT SIDE (HOME SIGNAL TO STARTER SIGNAL)	
7	CHANDIGARH END HIGHWAY SIDE	

3) Carbon Offset Data

Through information/data received from NORTHERN RAILWAY Ambala division Public authority vide RTI, a 10KWP capacity solar power system is currently operational at chandi mandir railway station. The average yearly electricity generation from solar power system at chandi mandir railway station is 8940 kwh.

IV. METHODOLOGY

A. Mechanism

The carbon balance assessment follows the GHG Protocol, classifying emissions into:

1) Scope I: Direct emissions from on-site fuel consumption (e.g., LPG).
2) Scope II: Indirect emissions from purchased electricity (traction and non-traction).
3) Scope III: Other indirect emissions, including passenger and staff commuting, waste generation, and water use.

Life Cycle Assessment (LCA) principles and a bottom-up approach were applied to quantify emissions and sequestration within the defined boundary.

B. Emission Estimation

Activity data were collected through site surveys, official railway records, and RTI responses. Emissions were calculated using the relation:

$$\text{Emissions } (CO_2e) = \text{Activity Data} \times \text{Emission Factor}$$

India-specific emission factors from IPCC guidelines, Central Electricity Authority (CEA), Central Pollution Control Board (CPCB), and relevant national sources were used.

C. Carbon Sequestration and Offsets

Carbon sequestration from trees was estimated using allometric equations based on tree diameter at breast height (DBH), accounting for above-ground and below-ground biomass. Grassland sequestration was estimated using standard per-hectare absorption rates. Carbon offsets from renewable energy were quantified based on annual electricity generation from rooftop solar photovoltaic systems.

D. Carbon Balance

The net carbon balance was calculated as:

$$\text{Carbon Balance} = \text{Total Emissions} - \text{Total Sequestration}$$

A negative value indicates a carbon-negative (environmentally positive) station.

Below table 4.1 gives the mechanism of quantification of carbon balance.

Table 4.1 Mechanism of calculation of carbon balance

carbon emission	carbon sink	carbon balance
CO2 equivalent=Activity x CCF CCF = carbon conversion factor	(i)AGB (i.e. above ground biomass) = 34.4703 – 8.0671D + 0.6589D^2 kg where D=Diameter of tree at a height of 1.37m from ground (ii)BGB (i.e. below ground biomass) = AGB X0.15 kg (iii)TB (i.e. total biomass) = (AGB + BGB) kg (iv)CARBON CONTENT= Out of total biomass present in the tree, only 50% is stored as carbon content in the tree. (v) CO_2 equivalent = 0.5 x TB X 44/12	Carbon balance = carbon emission – carbon sink

V. RESULTS

A. GHG Emissions

Based on emission data detailed vide table 4.1,4.2 & 4.3,total CO_2 emission is quantified by multiplying activity data with suitable carbon conversion factor.

Table 5.1 gives the detailed quantification of total emission of CNDM station.

Table 5.1 Total Carbon Emission in Chandi Mandir Railway Station

sl no.	activity data	unit	conversion factor	total emission
1	LPG=1448kg (SCOPE-1)	Kg	2.983 Data source-IPCC 2006 GUIDELIBE	4319.38kg co2e/year
2	GENERATOR=nil (SCOPE-1)			
3	ELECTRICITY= 73614kwh (SCOPE-2)	Kwh	0.708 DATA source-CEA REPORT	52118.12 kg co2 e/year
4	FUEL CONSUMPTION DUE TO VEHICULAR MOVEMENT= 18250 trips (SCOPE-3)	Trips	0.2 DATA Source-MORTH + PCRA	3650 kg co2e/year
5	WASTE GENERATION AND DISPOSAL 27375kg (SCOPE-3)	Kg	1.29 Data source-IPCC and CPCB	35313.75 kgco2/year
6	Water use 20794050 litre (SCOPE-3)	Liter	0.0004 kg per litre	8317.62 kg co_2e/year
6	PAPER USAGE =negligible (SCOPE-3)			
7	EMBODIED CARBON DUE TO ONGOING CONSTRUCTION (SCOPE-3)		NOT TAKEN INTO ACCOUNT	
8	EMISSION FROM HUMAN BEING /passenger footfall		Not taken into account	
	TOTAL			103718.87 kg= 103.72-ton co2 e/year

Total carbon Emission in the station is evaluated under three scope categories I, II & III as defined in GHG PROTOCOL. The total value of Emission is found to be 103718.87 kg per year(in the year 2024) out of which SCOPE-I Emission is 4319.38 kg(**4.16%**),SCOPE-II Emission is 52118.12kg(**50.25%**) and SCOPE-III Emission is 47281.37kg(**45.59%**).

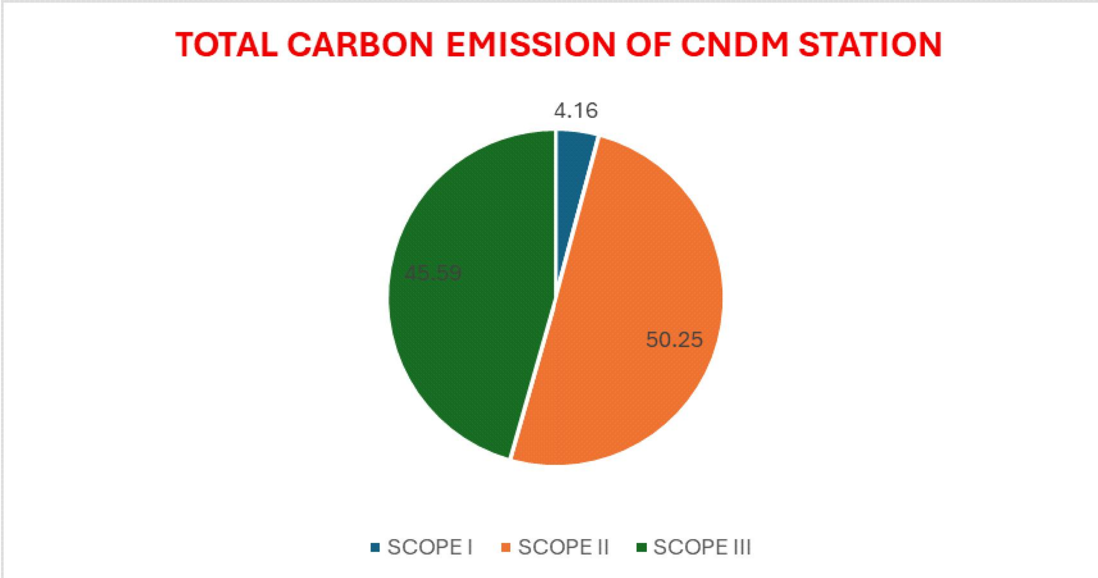

Figure 5.1 Scope wise % of total carbon emission of CNDM Station

From above, it is evident that carbon Emission is maximum due to purchased Electricity(scope-II).

B. Carbon Sequestration and Offsets

The station premises contain approximately 150 mature trees and about 2 hectares of grassland. Total annual carbon sequestration from natural sinks was estimated at **122.5 tCO_2e**, with trees contributing over 99% of the absorption. A 10 kwp rooftop solar photovoltaic system generates approximately 8,940 kWh annually, further reducing grid electricity dependence.

1) CO2 Sequestration from Trees

The detailed quantification of CO2 sequestration from trees is illustrated below-

Total no. of trees =150

Average dia of trees=30cm

$AGB=34.4703 – 8.0671D + 0.6589D^2$

BGB=0.15 X AGB

TB=AGB + BGB

CARBON CONTENT=0.5 X TB

CO_2 equivalent = CARBON CONTENT X 44/12

Table 5.2 gives the detailed quantification of total sequestration from trees of CNDM station.

Table 5.2 Carbon Sink due to trees in Chandi Mandir Railway Station

	AGB	BGB	TB	CARBON CONTENT	CO_2 equivalent
FOR ONE TREE	385.4673	57.82	443.2873	414.3773	1519.3834 kg
FOR 150 TREES	57820.095	8673.0142	66493.1092	33246.5546	121904.033kg

Carbon sequestration due to presence of trees in the premises of Chandi Mandir Railway station is evaluated. The total sequestration value is found to be 121904.033kg per year.

2) CO2 Sequestration from Green Cover/Grassland

The detailed quantification of CO2 sequestration from green cover/grassland is illustrated below-
Area of grassland/greenery = 02 hectres
Sequestration potential of grassland/greenery=0.29 tonne per hectre
Carbon sequestration through grassland/shrub/greenery=2 x 0.29 x 1000 =580kg per year

3) Total Sequestration of CO_2 in CNDM

Total value of carbon Absorption is calculated by adding total Carbon sequestration due to trees and Carbon Sequestration due to existence of grassland/greeneries/Shrubs in the boundaries of the Station. Total Carbon absorption in the station is found to be 122480 kg per year.
Table 5.3 gives the total sequestration of CO_2 in CNDM station.

Table 5.3 Total Carbon sequestration in Chandi Mandir Railway Station

SL NO.	SOURCES OF CARBON SINK	TOTAL SEQUESTRATION PER YEAR
1	TREES/PLANTS	121904.03 kg per year
2	GRASSLAND/GREENERY/SHRUBS	580kg per year
3	WETLAND	0
TOTAL		122.48 ton $co_{2e/year}$

C. Carbon Balance

Total Carbon Emission of the station is derived and found to be 103.72 tonne per year(in the year 2024) vide table 5.1.Total Carbon Absorption value is derived and is found to be 122.48 tonne per year vide table 5.3 .From the value of total Emission and Sequestration, it is evident that Carbon absorption is more than emission. Carbon Balance of the Chandi Mandir Railway Station can be quantified to determine the environmental Health of this Railway Station. Carbon balance is worked out by subtracting Carbon sequestration from Carbon emission.
Carbon balance = Carbon emission – Carbon sequestration
103.72 tonne - 122.48 tonne
= - 18.76 tonne i.e. Emission is less than sequestration value.
Table 5.4 gives the Carbon Balance of Chandi Mandir Railway Station

Table 5.4 Carbon Balance of Chandi Mandir Railway Station

CARBON EMISSION OF CNDM	CARBON ABSORPTION OF CNDM	CARBON BALANCE OF CNDM
103.72 tonne per year	122.48 tonne per year	-18.76 tonne per year

Total annual emissions from Chandi mandir Railway Station were estimated at approximately **103.7 tCO_2e**. Scope II emissions from purchased electricity constituted the largest share (50% approx), followed by Scope III emissions (46% approx..), primarily from waste generation, commuting, and water use. Scope I emissions from LPG consumption were relatively low. The comparison of emissions and sequestration indicate a net carbon balance of **−18.8t CO_2e per year**, indicating that Chandi mandir Railway Station is carbon-negative.

VI. DISCUSSION

The findings of study reveals that small railway station has enormous potential to achieve net zero carbon policy the Government. To further consolidate the potentiality of small railway station, a ten point recourse plan is suggested for a sustainable carbon neutral railway station-

Based on carbon balance, railway stations can be classified as:

- Green Stations: Emissions lower than sequestration potential.
- Yellow Stations: Emissions approximately equal to sequestration.
- Red Stations: Emissions exceed sequestration.

Such classification can assist policymakers to achieve national decarbonization target.

A general guideline is contemplated as below for augmentation of environmental performance of small railway Stations-

1) Encroachments in small Railway station should not be allowed. Unrestricted encroachments and infringements are one of major causes of environmental degradation of small railway stations.
2) Slums in the boundaries of small Railway station should be strictly discouraged. Development of slums in and around causes serious environmental hazards.
3) There should not be any large scale **vacant space** in the premises of small railway stations.It acts as a catalyst for cropping of slum and encroachments which affects environmental health of small railway station.
4) Small railway stations should be dust free, litter free and plastic free.These three elements are hazards having serious ramifications.
5) Uncleaned and dirty toilets creates nuisance.Toilets should be cleaned on regular basis.
6) Drains should not be clogged and open.
7) Leakage of water should be checked
8) Sporadic and localized dumping of debris in the station should be strictly prohibited.
9) Scientific plantation of trees should be aggressively taken up in all small railway stations to create additional carbon sink .It is an important remedy to counter global warming.
10) Entire surroundings of small railway station should be covered with a thick green belt to absorb dust and cooling effect.
11) Additional greeneries/grassland should be created to control emissions.
12) Renewable energy should be extensively used in small railway stations to reduce green houses gases.

13) Rooftop solar panels should be installed on a large scale in small railway station for energy conservation and emission reduction.
14) Rooftop rain water harvesting facility should be set up in small railway stations
15) Frequent checking and water audit to minimize water wastage.
16) Recycling of water for cleaning of platform and gardening.
17) A robust waste management should be put in place in each and every small railway station.
18) Provision of three bin system in the small railway station for segregation and disposal of waste on regular basis.
19) Recycling of plastic and other materials should be extensively adhered to.
20) Create awareness in general masses for a clean station.
21) There should be optimum use of natural light.
22) Promote digitization in small railway station.
23) Regular sprinkling to control dust because dust is one of the most dangerous health hazards.
24) Avoid diesel DG sets in small railway stations.
25) Discourage diesel driven auto rickshaws in the small railway stations.
26) Use of electric vehicles to reduce emission.

VII. CONCLUSIONS

Chandi Mandir Railway Station is an Eco-friendly Railway Station as per the scope category guideline illustrated in GHG PROTOCOL. Chandi mandir Railway Station was found to be carbon negative. This study presents a practical methodology for assessing the carbon balance of small railway stations. The research flags the importance of small railway stations in shaping the national climate action plan and sustainability targets.

VIII. ACKNOWLEDGEMENTS

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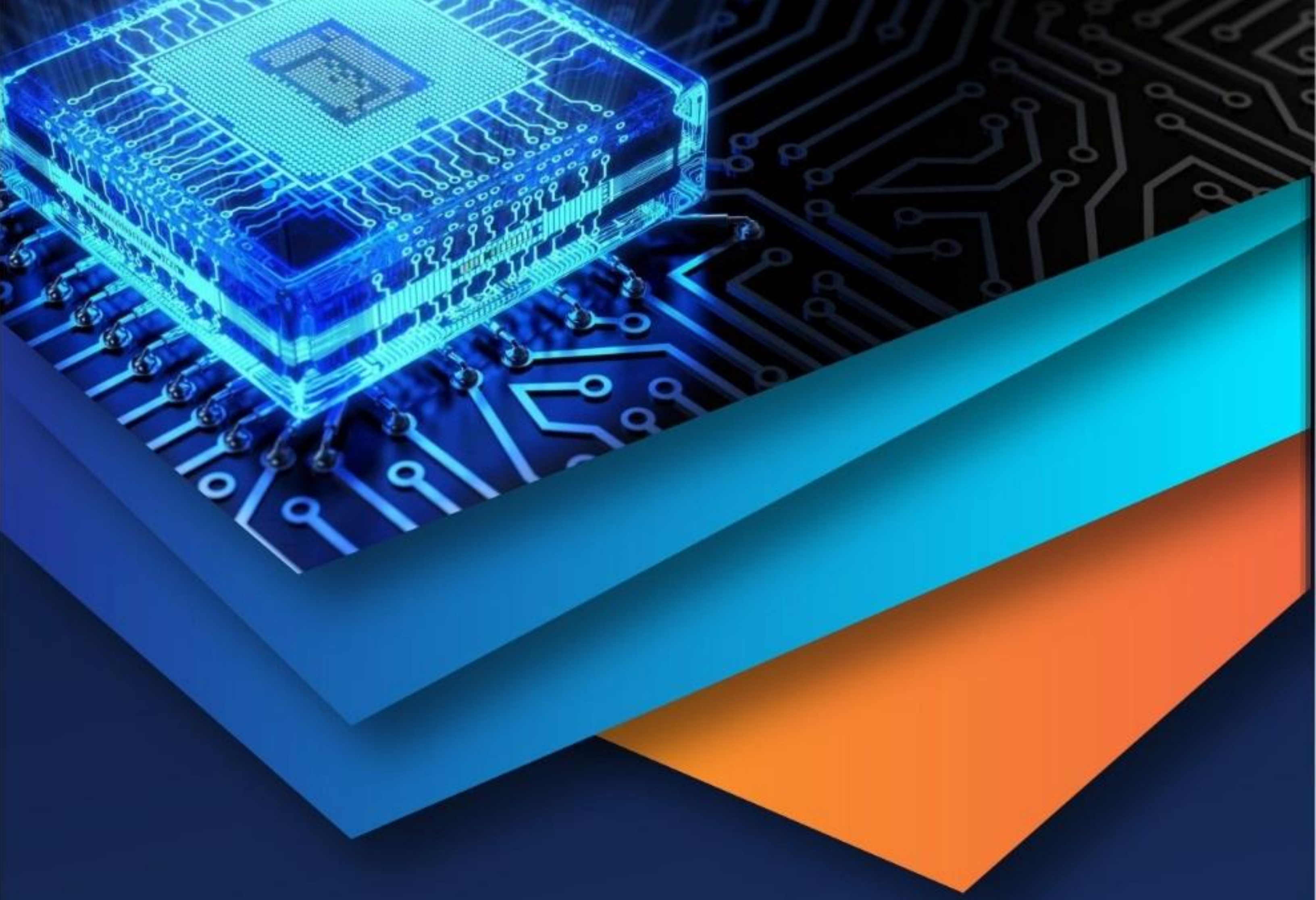

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