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Analysis and Determination of Axle Load Spectra and Traffic Input for Pavement Design

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Abstract: ***This study examines the vehicle class distribution, hourly distribution factors, weekly distribution factors, monthly distribution factors, axle load spectra for each vehicle class, and each axle of each vehicle class for the WIM station installed on the N-55 highway to aid analysis and design of new Mechanistic-Empirical Pavement Design Guide. The maximum, minimum and permissible load limit for the different vehicle class, average gross vehicle weight (GWV) and permissible load limits also being incorporated. The directional distribution for north bound and south bound traffic were observed to be almost 50% for both directions, except for 5 axle trucks which was 74% for north bound and 26% for south bound. The truck class most prevalent on the highway were identified to be 3-axle tandem truck (47.50%) and also it was observed that 94.1% of this vehicle class carried load above permissible limits.***

Keywords: Traffic characteristics, Load distribution factor, Axle Load Spectra.

I. INTRODUCTION

In Pakistan, the mode of communication preferred for both passengers and freight traffic are the road transportation. The dependent factor for the sustainable socio-economic development is the communication facilities available in the country. These facilities may be in the form of road, rail, air or coastal infrastructure. To ensure the economic growth, the current facilities required to be spread out and renovated as well to keep up with the requirement of the economy[1]. Vehicle overloading and rail to road shift has led the road network to a premature deterioration[2]. As each pavement is to withstand a certain number of standard axle load. The number of vehicle trips / load repetition, axle load, axle and tire configuration, material and environmental/climate impact etc. are the factors effecting the performance[3]. Pakistan like most other developing countries is facing the problem of vehicle overloading. The vehicle loads plying on the roads are much heavier than the strength of road infrastructure of the country[2]. The road users increased today as compare to the traffic in the past. Also, the good transportation by railways has mostly shifted to roads which results in the increased freight traffic on the roads. The overall growth of the freight traffic overburdened the existing highways which results in increase traffic congestions, air pollution, maintenance cost, and travel time for the road users[4]. In Pakistan, the axle-load limits as shown in Fig. 1 have been introduced in the year 2000 based on the results of axle load survey. However, its physical implementation is yet not fully ensured, due to lack of enforcement/of leave. Furthermore, is the reluctance of truck owners to observe the laid down limits[5].

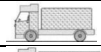
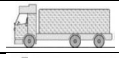
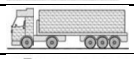
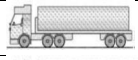
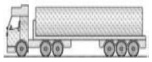
Class of Vehicle	Code	Picture	Permissible GVW (in Tons)
2 Axle Single	1 + 1		17.5
3 Axle Tandem	1 + Tandem		27.5
3 Axle Single	1 + 1 + 1		29.5
4 Axle Single Tandem	1 + 1 + Tandem		39.5
5 Axle Single Tridem	1 + 1 + Tridem		48.5
5 Axle Tandem Tandem	1 + Tandem + Tandem		49.5
6 Axle Tandem Tridem	1 + Tandem + Tridem		58.5

Fig. 1 NHA Permissible Gross Vehicle Weight (GVW)

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Researcher worked on axle load data and concluded results based on their studies. Some of the references are mentioned below. [6] analyzed data obtained from WIM station and concluded that the second axle (driving axle) of semitrailers with five axles (1+1+3) contributes more towards overloading. These overloading patterns were analyzed in Hungary with increasing gross vehicle weight (GVW). [7] stated in their study that the damaging effect on road pavement of the two axle trucks will be more as compared to three, four, five or six axle trucks. The larger number of axle will allow the load to distribute uniformly, hence, the damaging effect will be minimum. [8] studied the effect of different axle combinations for 120%, 135%, 150%, and 170% of Brazilian legal axle load. It was concluded that due to overloading, the pavement life decreases through fatigue failure. Since the road design is based on the number of ESALS and for overloaded trucks the ESALS will be high in number, thus reaching the design life at earlier. [9] developed axle load spectra for Washington State using the axle load data collected at WIM Stations. The developed load spectra were reasonable for pavement design. For tandem and tridem axles the axle spectra are slightly more conservative than the defaults while for single axles they are comparable to the default MEPDG defaults. [10] in a Canadian study collect axle load data aiming to obtain best possible default values for traffic input parameters required for the MEPDG. In their study they found that the axle load spectra have smaller number of heavily overloaded axles and the peaks between loaded and unloaded axles are more pronounced. They also found that the number and type of trucks, followed by the axle load spectra, have the predominant influence on the predicted pavement performance while certain input parameters such as hourly traffic volume adjustment factors, and axle spacing do not have any significant influence on the predicted pavement performance.

II. PROBLEM STATEMENT

To determine pavement thickness, AASHTO (American Association of State Highway and Transportation Officials) 1993 pavement design uses 18 kips Equivalent Single Axle Loads (ESALs) which are dependent on load equivalency factors (LEFs). The LEFs are based on factors such as pavement type, slab thickness or structural number, axle type, load and terminal serviceability index. The AASHTO method consider Present Serviceability Index (PSI) as a measure of the pavement performance[3]. The NCHRP (National Cooperative Highway Research Program) project 1-37 developed Mechanistic Empirical Pavement Design Guide (MEPDG). It uses Axle load distribution. The axle load spectra are based on the number of load application of different axle configuration within a certain weight classification range. The MEPDG expresses the performance on pavement in term of structural distresses (percent slabs cracked, fatigue cracking, rutting) and functional distresses (International Roughness Index (IRI)). Appropriate characterization of traffic data is required for the proper implementation of the MEPDG. There is a need for traffic data to be characterized to develop regional or statewide values. This requires extensive analysis of hourly distribution factors (HDFs), monthly distribution factors (MDFs), vehicle class distributions (VCDs) and development of axle load distributions.

III. STUDY AREA

Overload is the main problem for any pavement. The more freight traffic plying on the highway, the more it will be prone to overloading. Overloading is the cause of no physical implementation of axle load limits. The study area selected for the research purpose is the national highway N-55 in Pakistan. High volume and overloaded freight traffic as well as passenger traffic are the main problems with this section, which concludes with poor ride quality and discomfort for road users.

IV. WIM DATA ACQUISITION

The data analyzed in this study is obtained from WIM stations installed on National highway N-55. Both south bound and north bound directions traffic get covered from WIM station installed on this highway. For quantification of axle overloads, data obtained from WIM station must include information such as the type of vehicle passing, number of axles in the vehicle and the load carried by each axle of the vehicle.

V. VEHICULAR TRAFFIC AND AXLE LOAD SPECTRA

Vehicles are classified into different types and are used for different purpose. The number of passes and axle load defines the pavement structures parameters. The traffic input obtained as a result from data analysis include the following:

1) Traffic volume directional distribution factors;
2) Truck volume class distributions;
3) Traffic volume hourly distribution factors;
4) Single-axle load distributions;
5) Tandem-axle load distributions;
6) Tridem-axle load distributions;

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The hourly factors for the data is shown in the Fig. 2. the figure shows that more vehicle travels between 7 AM to 8 PM. The average vehicles per day are graphically shown in the Fig. 3. The average daily factor is graphically presented in Fig. 4. The day/night distribution for the vehicular traffic is presented in the Fig. 5. The directional distribution is presented in Fig. 6. Fig. 6 show the directional distribution for north bound and south bound traffic is almost 50%, except for 5 axle trucks. For 5 axle trucks the directional distribution is 74% for north bound and 26% for south bound. The weekly volume for the data is presented in Fig. 7. The number and type of vehicle class plying on the highway is essential piece of information because this information is directly related to the structural design of the pavement. The truck class most prevalent on the highway were

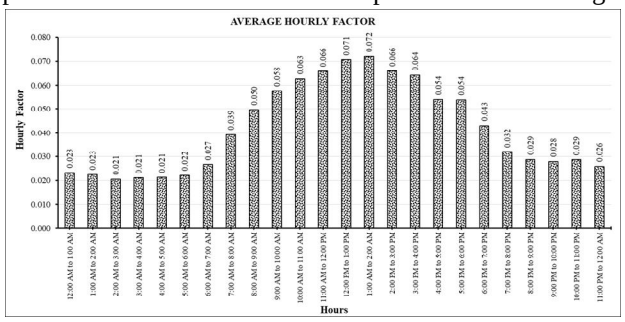


Fig. 2 Average Hourly Factor

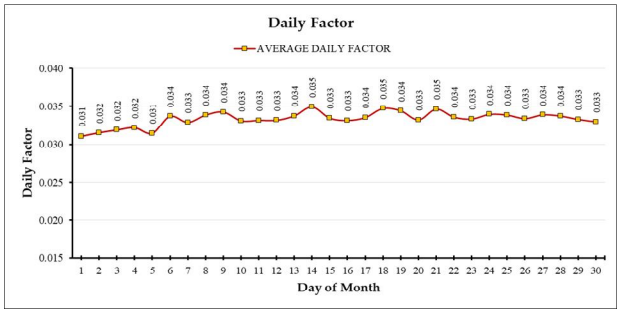


Fig. 3 Average Daily Factor

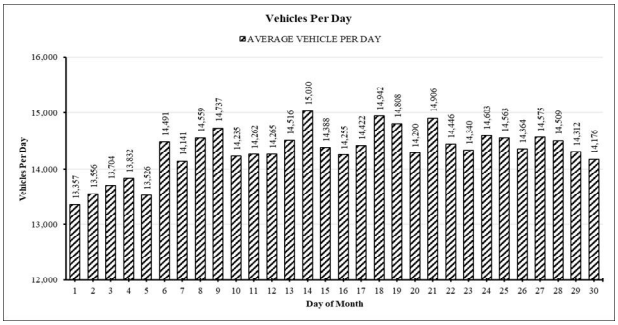


Fig. 4 Average Vehicle per Day

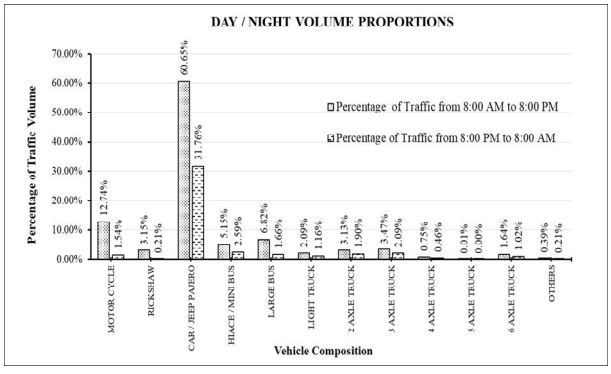


Fig. 5 Directional Distribution

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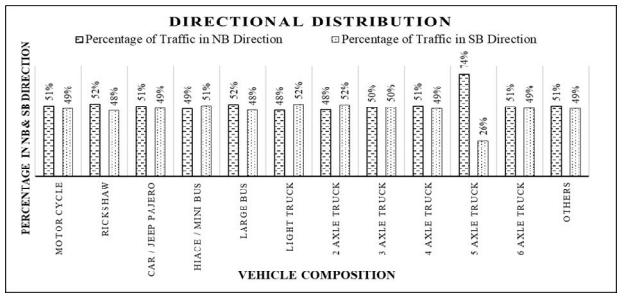


Fig. 6 Day / Night Distribution Factors

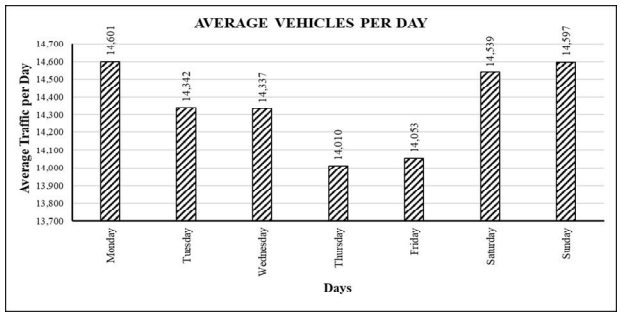


Fig. 7 Average Weekly Volume Factors

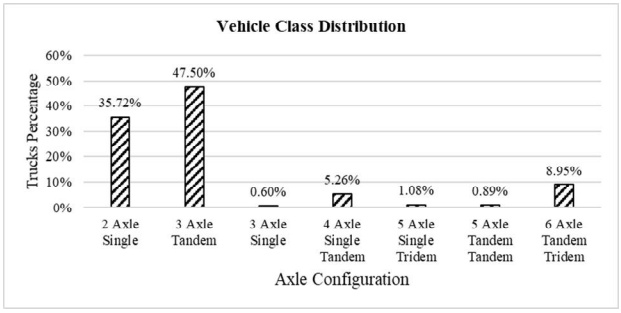


Fig. 8 Percent of trucks of different classes plying on National Highway

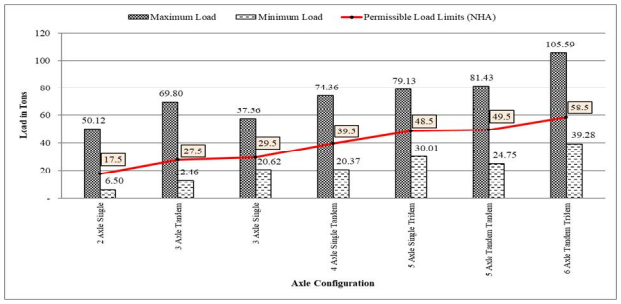


Fig. 9 Maximum, Minimum and Permissible Load Limit for Vehicle Classes

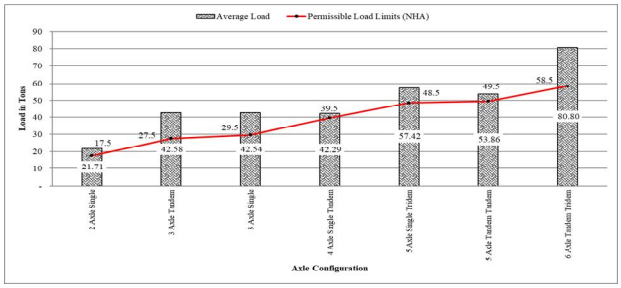


Fig. 10 Gross Vehicle Weight vs Permissible Load Limit

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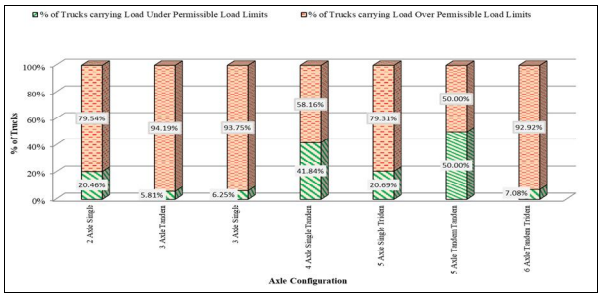


Fig. 11 Percent Trucks Carrying Load Under/Over Permissible Load Limit

Identified and presented in the Fig. 8. Fig. 8 shows that the 3-axle tandem truck is in excess followed by 2- axle single trucks with 47.50% and 35.72% respectively. The maximum, minimum and permissible load limit for the different vehicle class is presented in Fig. 9. A plot of average Gross Vehicle weight and permissible load limits is shown in Fig. 10. Percent of trucks carrying load under permissible load limits and precent of trucks carrying load over permissible load limits are shown in Fig. 11. For 2 axle single trucks, 20.46% vehicle carries wight under/within permissible limit while 79.54% carries overloaded weight. For 3 axle tandem, 5.81% vehicle carries wight under/within permissible limit while 94.19% carries overloaded weight. For 3 axle single, 6.25% vehicle carries wight under/within permissible limit while 93.75% carries overloaded weight. For 4 axle single tandem, 41.84% vehicle carries wight under/within permissible limit while 58.16% carries overloaded weight. For 5 axle single tridem, 20.69% vehicle carries wight under/within permissible limit while 79.31% carries overloaded weight. For 5 axle tandem tandem, 50% vehicle carries wight under/within permissible limit while 50% carries overloaded weight. For 6 axle tandem tridem, 7.08% vehicle carries wight under / within permissible limit while 92.92% carries overloaded weight. As shown in Fig. 11, the percentage of overloading for 3 axle tandem vehicles are more which are 94.1% followed by 3 axle single which are 93.75%. the least contribution to overloading is from 5 axle tandem tandem which are 50%.

VI. AXLE LOAD SPECTRA

Within a given weight classification range, axle load spectra classify traffic loading in terms of the number of load applications of various axle configurations (single, dual, tridem, and quad). Axle load distribution factors should be determined for load spectra to represent the percentage of total axle applications within each load interval for a specific axle type (single, tandem, tridem, and quad) and vehicle class. The axle load spectra for axle configuration are shown in Fig. 12 through Fig. 14.

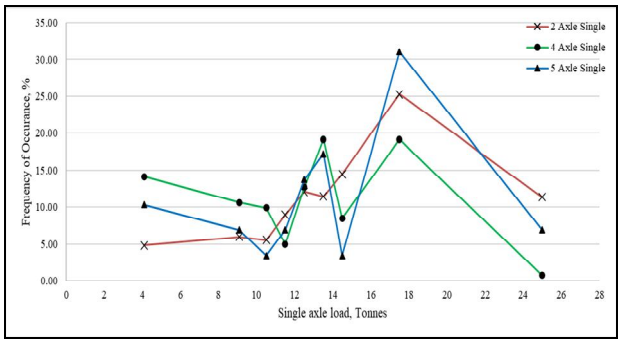


Fig. 12 Load Spectra for Single Axle

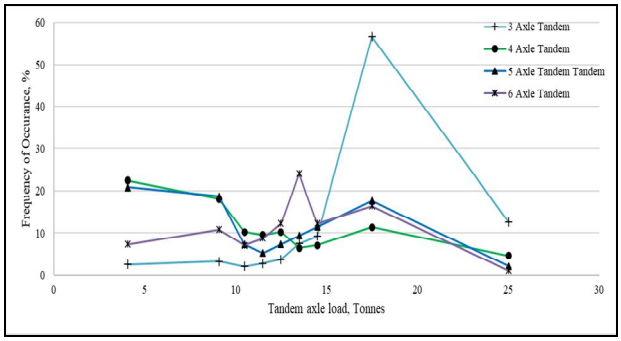


Fig. 13 Load Spectra for Tandem Axle

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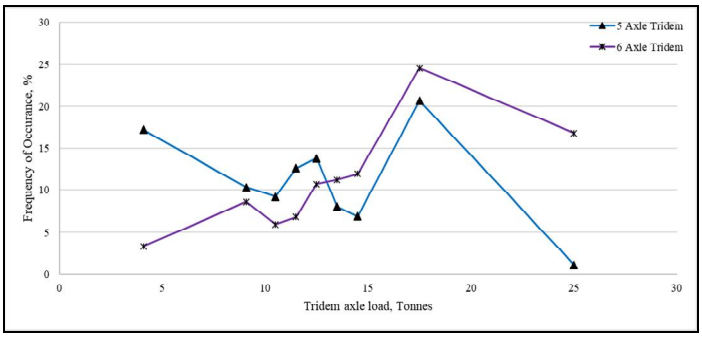


Fig. 14 Load Spectra for Tridem Axle

VII. CONCLUSIONS AND RECOMMENDATIONS

The proper implementation of MEPDG depends on the appropriate characterization of traffic data. But detailed traffic data is not always available for the previous years. Therefore, MEPDG identifies a hierarchical approach to develop required traffic inputs. The traffic data is classified into three levels. Level 1 uses site-specific data, which is the most accurate. Level 2 provides truck volume and weight data when the designer has modest knowledge of past and future traffic. Level 3 uses regional, statewide or default values. The study's goal was to characterize traffic data and make recommendations for traffic inputs to MEPDG. The data included vehicle class distribution (VCD), Weekly distribution factors (WDF), hourly distribution factors (HDF), and axle load spectra.

The main conclusions of the study are:

The directional distribution for north bound and south bound traffic is almost 50%, except for 5 axle trucks. For 5 axle trucks the directional distribution is 74% for north bound and 26% for south bound. The truck class most prevalent on the highway were identified and presented in the table below. Figure 8 shows that the 3-axle tandem truck is in excess followed by 2-axle single trucks with 47.50% and 35.72% respectively. The percentage of overloading for 3 axle tandem vehicles are more which are 94.1% followed by 3 axle single which are 93.75%. the least contribution to overloading is from 5 axle tandem tandem which are 50%. Average load, minimum, maximum, standard deviation and variance of each axle configuration plying on road network is presented in Table I. On National Highways due to lax axle load control regime, severe overloading was observed. The average load carried by trucks of different category (Axle configuration) on National Highways is much higher than allowable legal load limits, ensuing high damage factors, causing rapid deterioration / failure of roads, much before completion of design life. The percentage of overloading by axle configuration is provided in Table II.

TABLE I
Average Load, Minimum, Maximum, Standard Deviation and Variance of Each Axle Configuration

S. No	Axle Configuration	Permissible Load Limits (NHA)	Average Load (Tons)	Maximum Load (Ton)	Minimum Load (Ton)	Standard Deviation	Variance
1	2 Axle Single	17.5	21.71	50.12	6.50	6.06	36.75
2	3 Axle Tandem	27.5	42.58	69.80	12.46	8.26	68.17
3	3 Axle Single	29.5	42.54	57.56	20.62	8.96	80.22
4	4 Axle Single Tandem	39.5	42.29	74.36	20.37	11.83	139.86
7	5 Axle Single Tridem	48.5	57.42	79.13	30.01	13.62	185.63
8	5 Axle Tandem Tandem	49.5	53.86	81.43	24.75	16.64	276.92
11	6 Axle Tandem Tridem	58.5	80.80	105.59	39.28	12.82	164.28

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TABLE II
Percentage of Overloading by Axle Configuration

S. No.	Axle Configuration	Percentage Overloading
1	2 Axle Single	79.54%
2	3 Axle Tandem	94.19%
3	3 Axle Single	93.75%
4	4 Axle Single Tandem	58.16%
5	5 Axle Single Tridem	79.31%
6	5 Axle Tandem Tandem	50.00%
7	6 Axle Tandem Tridem	92.92%

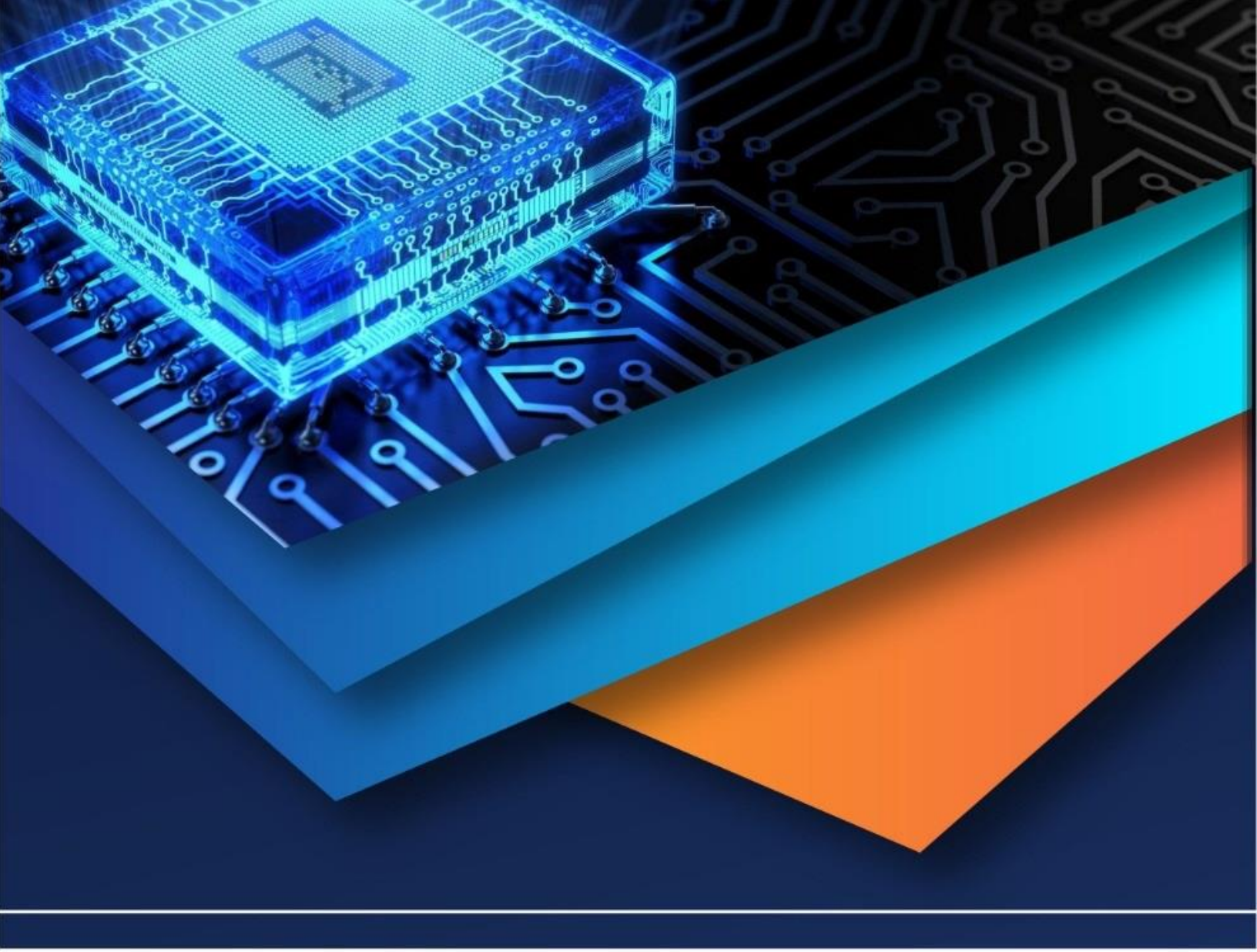
VIII. ACKNOWLEDGMENT

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