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UrbanFlow360: A Cloud-Native Architecture for Real-Time Urban Traffic Congestion Prediction

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Abstract: UrbanFlow360 is a cloud-native Software-as-a- Service (SaaS) platform for real-time traffic congestion prediction and urban traffic analytics. Developed using a modular mi- croservice architecture and containerized with Docker, the system integrates predictive machine learning pipelines and offers live analytics through an interactive Streamlit dashboard. This paper details the end-to-end development lifecycle of UrbanFlow360, including dataset preprocessing, model training, application de- velopment, containerization, and deployment on AWS Elastic Container Registry (ECR) and Amazon EC2. The architecture demonstrates best practices in reproducibility, portability, and scalability of intelligent transportation systems.
Index Terms: Traffic prediction, cloud-native, AWS, machine learning, Streamlit, ECR, EC2, Docker, containerization, urban analytics, smart cities

I. INTRODUCTION

Urban areas face mobility challenges due to rising vehicle volumes, infrastructure limitations, and unpredictable conges- tion. Traditional systems fall short in providing predictive insights.

UrbanFlow360 addresses this gap using cloud-native tech- nologies. It enables real-time traffic congestion prediction via a browser-based dashboard powered by Streamlit and deployed through AWS infrastructure.

II. TEAM AND CONTRIBUTIONS

1) Akash Tiwari: Cloud and DevOps lead — EC2, Docker, ECR, IAM roles.
2) Aashish Dewangan: Data preprocessing and ingestion — handled wide CSVs, JSONs, and schema design.
3) Kishan Kumar Bouri: ML pipeline development and training.
4) Yash Mathur: Streamlit frontend integration and UI/UX refinement.

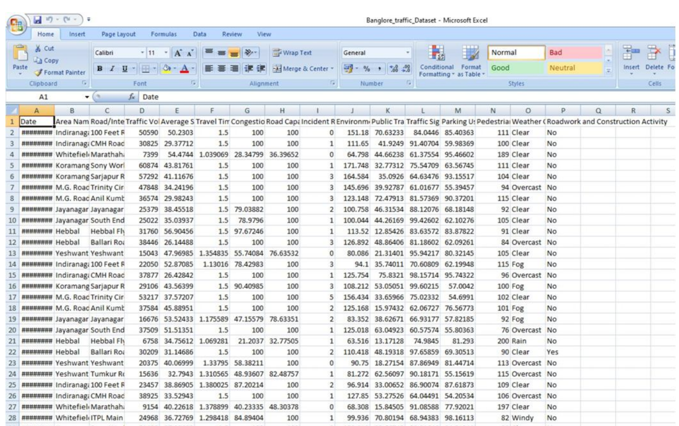
III. DATASET DESCRIPTION

Data was collected from traffic logs across Delhi and Bangalore. A sample of the uploaded dataset is shown in Figure 1.

IV. PREPROCESSING PIPELINE

We designed a consistent preprocessing flow to normalize column names, fill missing values, and encode categorical features.

1) Missing value imputation



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Date	Area Nam	Road/Inte	Traffic Vol	Average S	Travel Tim	Congestio	Road Capa	Incident R	Environm	Public Tra	Traffic Sig	Parking Us	Pedestria	Weather (	Roadwork and Construction Activity
2	########	Indiranag	100 Feet R	50590	50.2303	1.5	100	100	0	151.18	70.63233	84.0446	85.40363	111	Clear	No
3	########	Indiranag	CMH Road	30825	29.37712	1.5	100	100	1	111.65	41.9249	91.40704	59.98369	100	Clear	No
4	########	Whitefiel	Marathah	7399	54.4744	1.039069	28.34799	36.39652	0	64.798	44.66238	61.37554	95.46602	189	Clear	No
5	########	Koramang	Sony Worl	60874	43.81761	1.5	100	100	1	171.748	32.77312	75.54709	63.56745	111	Clear	No
6	########	Koramang	Sarjapur R	57292	41.11676	1.5	100	100	3	164.584	35.0926	64.63476	93.15517	104	Clear	No
7	########	M.G. Road	Trinity Cir	47848	34.24196	1.5	100	100	3	145.696	39.92787	61.01677	55.39457	94	Overcast	No
8	########	M.G. Road	Anil Kumb	36574	29.98243	1.5	100	100	3	123.148	72.47913	81.57369	90.37201	115	Clear	No
9	########	Jayanagar	Jayanagar	25379	38.45518	1.5	79.03882	100	2	100.758	46.31534	88.12076	68.18148	92	Clear	No
10	########	Jayanagar	South End	25022	35.03937	1.5	78.9796	100	1	100.044	44.26169	99.42602	62.10276	105	Clear	No
11	########	Hebbal	Hebbal Fly	31760	56.90456	1.5	97.67246	100	1	113.52	12.85426	83.63572	83.87822	91	Clear	No
12	########	Hebbal	Ballari Roa	38446	26.14488	1.5	100	100	3	126.892	48.86406	81.18602	62.09261	84	Overcast	No
13	########	Yeshwant	Yeshwant	15043	47.96985	1.354835	55.74084	76.63532	0	80.086	21.31401	95.94217	80.32145	105	Clear	No
14	########	Indiranag	100 Feet R	22050	52.87085	1.13016	78.42983	100	3	94.1	35.74011	70.60809	62.19948	115	Fog	No
15	########	Indiranag	CMH Road	37877	26.42842	1.5	100	100	1	125.754	75.8321	98.15714	95.74322	96	Overcast	No
16	########	Koramang	Sarjapur R	29106	43.56399	1.5	90.40985	100	3	108.212	53.05051	99.60215	57.0042	100	Fog	No
17	########	M.G. Road	Trinity Cir	53217	37.57207	1.5	100	100	5	156.434	33.65966	75.02332	54.6991	102	Clear	No
18	########	M.G. Road	Anil Kumb	37584	45.88951	1.5	100	100	2	125.168	15.97432	62.06727	76.56773	101	Fog	No
19	########	Jayanagar	Jayanagar	16676	53.52433	1.175589	47.15579	78.63351	2	83.352	38.62671	66.93177	57.82185	92	Fog	No
20	########	Jayanagar	South End	37509	51.51351	1.5	100	100	1	125.018	63.04923	60.57574	55.80363	76	Overcast	No
21	########	Hebbal	Hebbal Fly	6758	34.75612	1.069281	21.2037	32.77505	1	63.516	13.17128	74.9845	81.293	200	Rain	No
22	########	Hebbal	Ballari Roa	30209	31.14686	1.5	100	100	2	110.418	48.19318	97.65859	69.30513	90	Clear	Yes
23	########	Yeshwant	Yeshwant	20375	40.06999	1.33795	58.38211	100	0	90.75	18.27154	87.86949	81.44714	113	Overcast	No
24	########	Yeshwant	Tumkur Ro	15636	32.7943	1.310565	48.93607	82.48757	1	81.272	62.56097	90.18171	55.15619	115	Overcast	No
25	########	Indiranag	100 Feet R	23457	38.86905	1.380025	87.20214	100	2	96.914	33.00652	86.90074	87.61873	109	Clear	No
26	########	Indiranag	CMH Road	38925	33.52943	1.5	100	100	1	127.85	53.27526	64.04491	54.20534	106	Overcast	No
27	########	Whitefiel	Marathah	9154	40.22618	1.378899	40.23335	48.30378	0	68.308	15.84505	91.08588	77.92021	197	Clear	No
28	########	Whitefiel	ITPL Main	24968	36.72769	1.298418	84.89404	100	1	99.936	70.80194	68.94383	98.16113	82	Windy	No
29	########	Koramang	Sony Worl	51459	27.32652	1.5	100	100	0	152.918	29.66742	98.01646	94.51319	99	Clear	No

Fig. 1. Uploaded CSV preview showing traffic metrics

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2) Time and weekday feature extraction
3) Encoding and scaling

Figure 2 visualizes this pipeline.

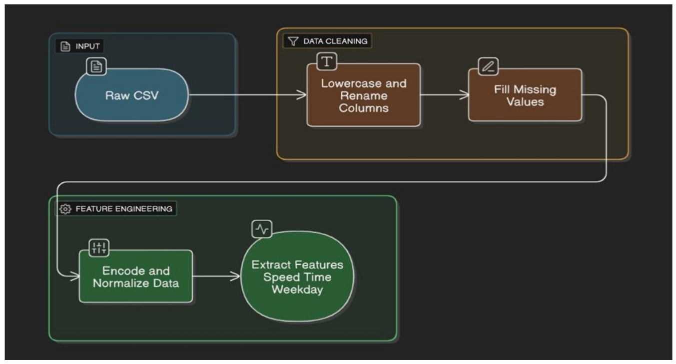

Fig. 2. Preprocessing stages for input data

V. ARCHITECTURE OVERVIEW

UrbanFlow360's modular architecture includes preprocess- ing, model inference, UI, and cloud deployment.

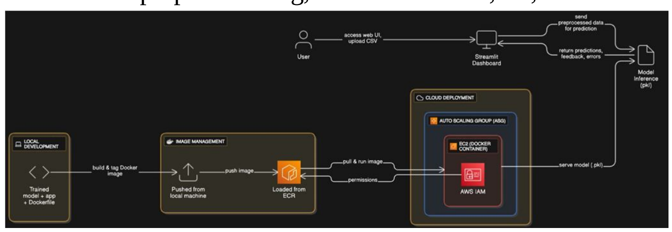

Fig. 3. UrbanFlow360 system architecture

VI. MODEL DEVELOPMENT

A. Algorithm

We used Random Forest Regressor for its interpretability and robustness.

B. Training

```
model = RandomForestRegressor()
model.fit(X_train, y_train)
joblib.dump(model, "model.pkl")
```

C. Evaluation

We measured accuracy using:

- Mean Absolute Error (MAE)
- Root Mean Square Error (RMSE)
- R2 score

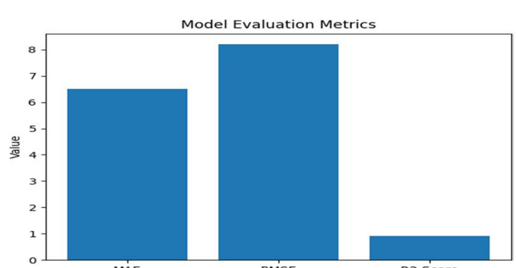

Fig. 4. Model performance metrics

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VII. FRONTEND AND STREAMLIT INTEGRATION

Users interact via a Streamlit-based dashboard.

```
if predict_button:
    result_df = predict_csv_congestion(df, city)
    st.dataframe(result_df)
    st.bar_chart(result_df['Congestion'].
        value_counts())
```

Figure 5 shows file upload and city selection.
Figure 6 shows the prediction output with congestion chart.

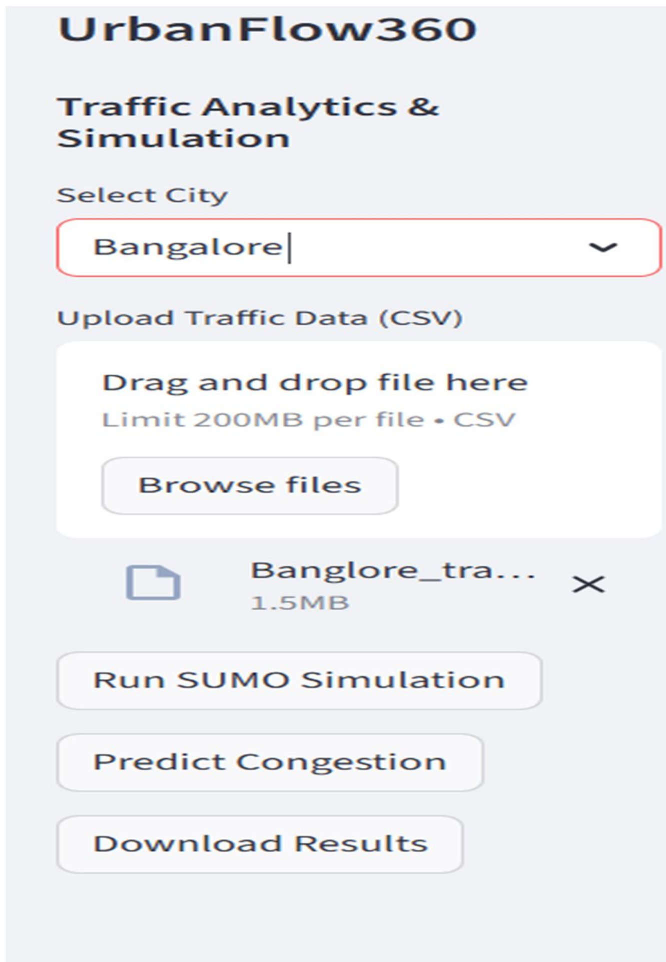

Fig. 5. Streamlit sidebar for file upload and city selection

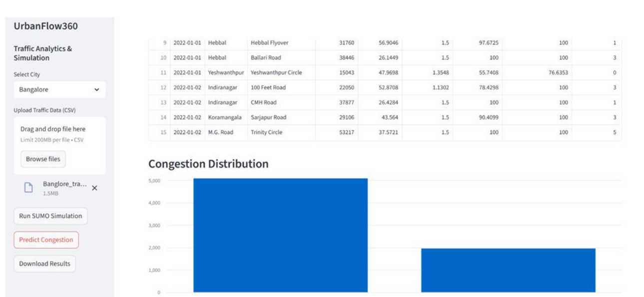

Fig. 6. Predicted congestion and bar chart output

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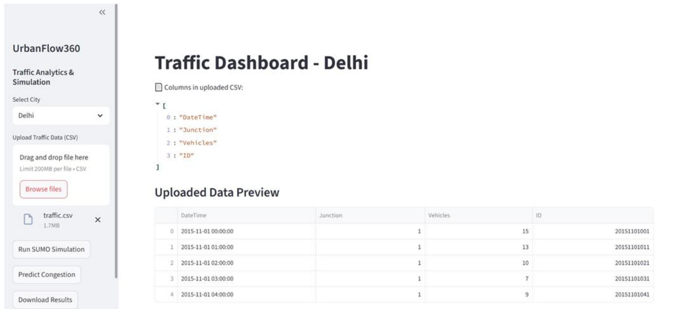

Fig. 7. Complete UI view after running predictions

VIII. DOCKER CONTAINERIZATION

UrbanFlow360 is packaged in Docker for reproducibility.

A. *Dockerfile*

```
FROM python:3.10-slim
WORKDIR /app
COPY . .
RUN pip install -r requirements.txt
CMD ["streamlit", "run", "frontend/app.py"]
```

B. *Push to ECR*

```
docker build -t urbanflow360 .
docker tag urbanflow360:latest \
  631158448576.dkr.ecr.ap-south-1.amazonaws.com/
      urbanflow360-backend:latest
docker push 631158448576.dkr.ecr.ap-south-1.
    amazonaws.com/urbanflow360-backend:latest
```

IX. AWS DEPLOYMENT (EC2 + ECR)

We deployed the model as a Docker container on EC2 after pushing it to ECR.

1) Create IAM role and ECR repo
2) Push Docker image to ECR
3) Launch EC2, SSH, pull image
4) Run app: docker run -p 8501:8501 urbanflow360

X. RESULTS

The app performed well on city-level congestion predictions.

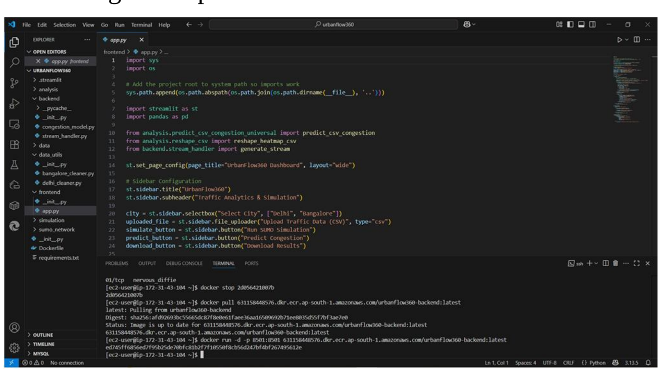

Fig. 8. Docker image pushed to AWS ECR

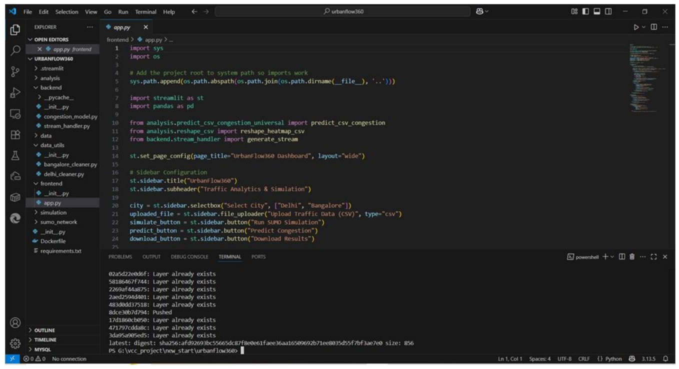

Fig. 9. SSH terminal on EC2 running Docker container

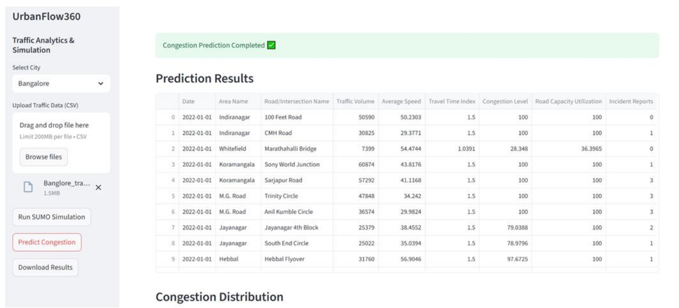

Fig. 10. Deployed dashboard accessed via EC2 public IP

Area	Avg Speed (km/h)	Predicted Congestion (%)
Koramangala	43.8	92.1
M.G. Road	29.9	85.5
Whitefield	54.5	21.2

TABLE I

SAMPLE CONGESTION PREDICTIONS FOR BANGALORE

Fig. 11. Bar chart visualization of congestion levels

XI. COMPARISON WITH EXISTING TOOLS

1) Dashboards like TomTom offer historic data, not predic- tions.
2) Our tool allows CSV uploads + real-time ML predictions.
3) Dockerized, portable, and open-source.

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XII. CONCLUSION

UrbanFlow360 bridges cloud computing and urban mobility analytics. It is portable, scalable, and accessible to both cities and researchers. Future work includes multi-city support, live APIs, and SUMO integration for simulation.

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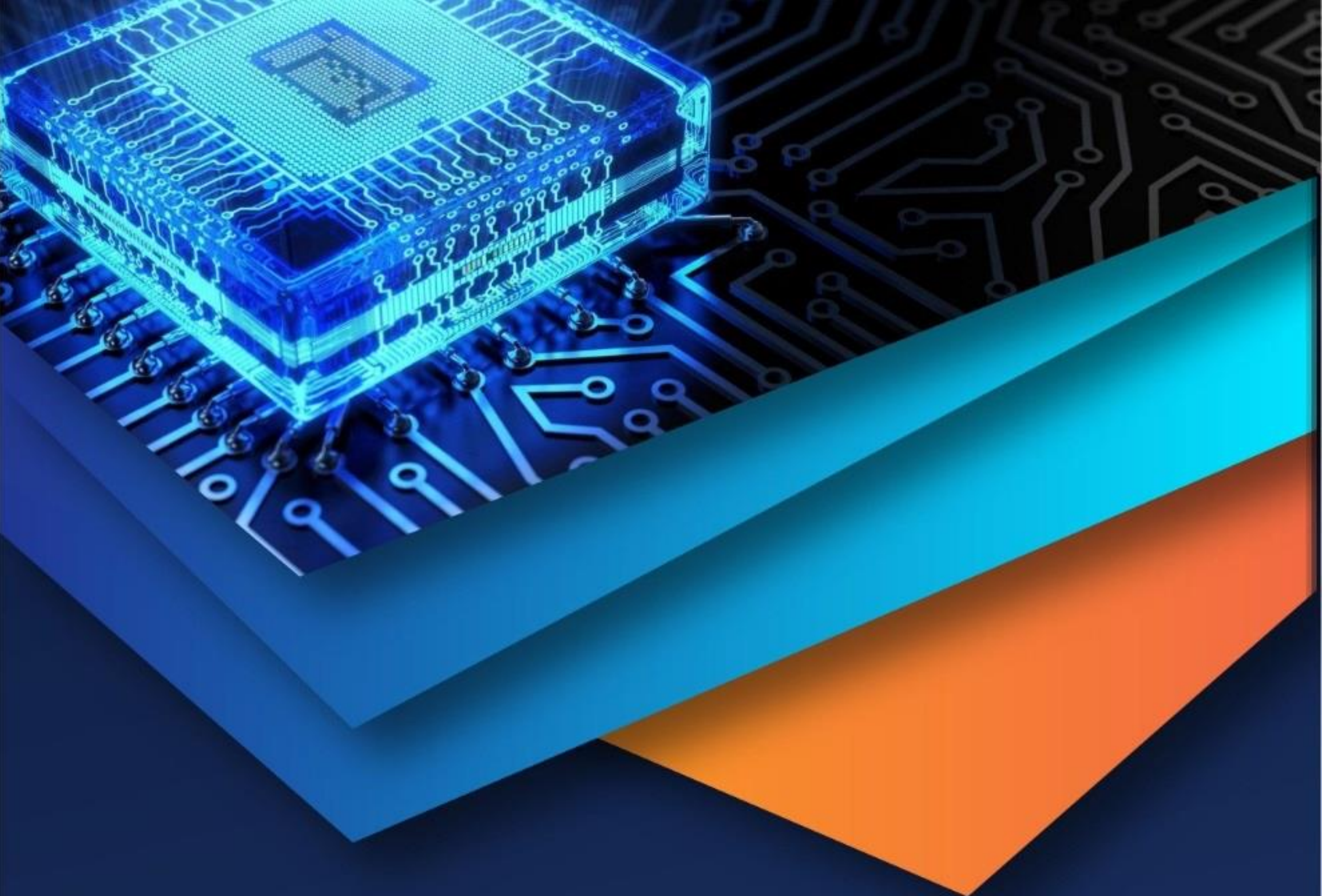
[4] Scikit-learn - https://scikit-learn.org
[5] Docker Docs - https://docs.docker.com/
[6] GitHub Repo - https://github.com/KishanBouri/urbanflow360



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