Comparative Analysis Of Predictive Models For Ultimate Bending Moment In Reinforced Concrete Beams: Artificial Neural Networks Vs. Regresion In Excel-Based Predictive Analysis

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Abstract- *In this thesis, shows an analytical study regarding RCC (reinforced cement concrete) beam. ANN is used in order to estimate and predict the ultimate bending moment of a RCC beam. A total of 105 dataset of simply supported beams are considered in the study. The neural network has been trained using MATLAB tool as it contains different training networks and application of training algorithm can be done easily. The data are arranged in a format such that 7 input parameters cover the geometrical and loading properties of beams and the corresponding output is the ultimate bending moment. Several input parameters are considered in the study such as the width (b) in the range (300-470 mm), effective depth (d) in the range of (450-6200 mm), Characteristics compressive strength of concrete (Fck) in between range (20-30 N/mm2), yield strength of steel (Fy) in the range of (250-415 N/mm2), Area of steel (Ast) in the range of (942.5-1963 mm2), Actual depth of neutral axis (Xu) in the range of (67.038-197.663 mm) and limiting depth of neutral axis (Xulim) in the range of (238.5-297.6 mm) for the RCC beam, and only the ultimate bending moment (143.04-201.39 kn-m) is calibrated as the output variable. The input parameters have been taken as per the reference from previous works in the literature and reference book. The performance of the proposed artificial neural network model was compared to the regression analysis by MS-Excel. The comparative analysis demonstrated that the ANN model made more accurate predictions than the REGRESSION BY EXCEL.*

Keywords- RCC, ANN, concrete beam, MATLAB, ultimate bending moment, REGRESSION

I. INTRODUCTION

Artificial Neural Network (ANN) is a subfield of' the artificial intelligence technology that has gained strong popularity in it rather large array of engineering applications where conventional analytical methods arc difficult to pursue or show inferior performance. Specifically ANNs have shown a good potential to successfully model complex input/output relationships where the presence of non-linearity and inconsistent/noisy data adversely affects other approaches. ANN model is robust and Fault tolerant. ANN can also work with qualitative, uncertain and incomplete information, making it highly promising for inverse problems in structural engineering.

The primary objective of the ANN is to accurately predict the ultimate bending moment of an RC beam given certain input parameters. These input parameters may include factors such as the dimensions of the beam, the material properties of concrete and steel, the loading conditions, etc.

Modeling Complex Relationships: Traditional analytical methods for predicting bending moments in RC beams often rely on simplifying assumptions and equations derived from empirical data. However, these methods may not capture all the complex interactions between input variables accurately. ANNs are capable of modeling nonlinear relationships between inputs and outputs without requiring explicit equations. They can capture complex patterns and correlations in the data, making them suitable for predicting the bending moment in RC beams, which is influenced by a multitude of factors.

II. IDENTIFY, RESEARCH AND COLLECT IDEA

I have seen in old research studies that, only the experimental results were compared with predicted results or errors were identified between them and no attempt was made to correct the best result from experimental by focusing on the predicted result in any research. I used this as a base and first of all collected data of 105 beams using 456:2000 and after that calculated its ultimate moment values having the result was according to the is 456:2000 code, which can used as the experimental data for my thesis and after that I created a neural network on the basis of given input and output. Results were compared to the experimental results and shows that the predicted result was more accurate and are able to resist more stresses generated as compare to earlier in the beam with more accuracy.

III. METHODOLOGY

Discussing artificial neural network for the plan of shaft, at that point neural network is useful for relapse and example grouping in down to earth cases which really makes artificial neural network a significant device to tackle and manage numerous complex common and auxiliary designing issues. What's more, work estimation is a standout amongst the most significant utilization of neural network. Neural nets which are otherwise called neural network really the registering framework which can be prepared to become familiar with a perplexing connection between information informational collections and target informational indexes.

3.1 SELECTION OF DATA SET

The reason for preparing a network is to find progressively precise solutions and got future information. The network utilizes the preparation gathering to get the connection between the information and yield variable. The all out real (test) information parameter utilized in this neural network model is taken from the writing done in past section and its range has been made to perform and to prepare the network.

Input and output variable

INPUT ;	**RANGE ;**
Width of bram (b)	**300-470 (mm)**
Effective depth of beam (d)	**450-620 (mm)**
Charecteristic strength of concrete (f_{ck})	**m-20 to m-30 (N/mm^2)**
Grade of steel (f_y)	**Fe-250 & fe-415 (N/mm^2)**
Actual depth of neutral axis (x_u)	**67.038-197.66 (mm)**
Limiting depth of neutral axis (x_{ulim})	**238.5-297.6 (mm)**
Area of steel (A_{st})	**942.5-1963 (mm^2)**
OUTPUT ;	
Ulitimate bending moment (m_u)	**143.047-201.398 (kn-m)**

3.2 ACTUAL AND PREDICTED ULTIMATE BENDING MOMENT VALUES

S.NO.	Actual Ultimate bending moment (kn-m)	Predicted Ultimate bending moment BY ANN (kn-m)
1	156.6836511	156.6903
2	159.3994787	159.4021
3	162.0965623	162.0967
4	164.7757945	164.7746
5	167.438012	167.4364
6	170.084	170.0826
7	172.7144964	172.7138
8	175.3301948	175.3304
9	177.931748	177.9329
10	180.5197711	180.5216
11	143.0475826	143.0453
12	144.8898473	144.8895
13	146.7254228	146.7262
14	148.554584	148.5558
15	150.3775908	150.3788
16	152.1946896	152.1956
17	154.0061134	154.0066
18	155.8120835	155.8122
19	157.6128095	157.6127
20	159.4084906	159.4086
21	170.272227	170.2702
22	172.1821575	172.1815
23	174.087003	174.087
24	175.9869473	175.9872
25	177.8821656	177.8825
26	179.7728245	179.7731
27	181.6590832	181.6593
28	183.5410934	183.5413
29	185.4189999	185.4192
30	187.2929411	187.2931
31	189.163049	189.1631
32	191.0294502	191.0293
33	192.8922654	192.8919
34	194.7516104	194.7513
35	196.6075958	196.6076
36	163.7726459	163.7726
37	166.3722605	166.3714
38	168.9568799	168.9559
39	171.5272181	171.5266
40	174.0839446	174.084
41	176.6276875	176.6285
42	179.1590372	179.1606
43	181.6785484	181.6805
44	184.1867434	184.1886

45	186.6841143	186.6854
46	146.4671161	146.4675
47	148.2612184	148.2621
48	150.0499692	150.0508
49	151.8335887	151.834
50	153.6122847	153.6121
51	155.3862542	155.3855
52	157.1556838	157.1545
53	158.9207503	158.9194
54	160.6816216	160.6806
55	162.438457	162.4385
56	173.6496404	173.6496
57	175.5178743	175.518
58	177.3820404	177.3823
59	179.2422855	179.2424
60	181.0987497	181.0985
61	182.9515665	182.9511
62	184.8008631	184.8003
63	186.6467609	186.6462
64	188.4893757	188.4889
65	190.3288182	190.3285
66	192.1651942	192.1649
67	193.9986048	193.9984
68	195.8291466	195.829
69	197.6569122	197.6571
70	199.4819902	199.4828
71	168.4986424	168.4973
72	171.0207817	171.0197
73	173.5304249	173.5299
74	176.0281672	176.0283
75	178.5145663	178.5154
76	180.9901459	180.9914
77	183.4553976	183.4566
78	185.910784	185.9115
79	188.3567403	188.3562
80	190.7936765	190.791
81	148.7468051	148.7478
82	150.508799	150.5097
83	152.2663335	152.2668
84	154.0195918	154.0194
85	155.7687472	155.7681
86	157.5139639	157.5129
87	159.2553973	159.2543
88	160.9931948	160.9926
89	162.7274963	162.728
90	164.4584346	164.4609
91	175.9012493	175.901
92	177.7416856	177.7419
93	179.578732	179.579
94	181.4125109	181.4126
95	183.2431391	183.2431
96	185.0707278	185.0707
97	186.895383	186.8954
98	188.7172058	188.7174
99	190.5362929	190.5366
100	192.3527363	192.353
101	194.1666244	194.1667
102	195.9780412	195.9779
103	197.7870674	197.7867
104	199.59378	199.5934
105	201.3982531	201.3983

3.3 COMPARISONS OF IS 456 RESULT AND ANN RESULT

S.n.	Actual bending moment by IS 456 code	Predicted bending moment by ANN	Error	Square Error
1	156.6836511	156.6903	0.006648911	4.4208E-05
2	159.3994787	159.4021	0.002621265	6.87103E-06
3	162.0965623	162.0967	0.000137656	1.89491E-08
4	164.7757945	164.7746	-0.00119449	1.42681E-06
5	167.438012	167.4364	-0.001611958	2.59841E-06
6	170.084	170.0826	-0.001400044	1.96012E-06
7	172.7144964	172.7138	-0.000696445	4.85035E-07
8	175.3301948	175.3304	0.000205181	4.20994E-08
9	177.931748	177.9329	0.00115198	1.32706E-06
10	180.5197711	180.5216	0.001828944	3.34504E-06
11	143.0475826	143.0453	-0.002282602	5.21027E-06
12	144.8898473	144.8895	-0.000347319	1.2063E-07

13	146.7254228	146.7262	0.000777193	6.04029E-07
14	148.554584	148.5558	0.001216033	1.47874E-06
15	150.3775908	150.3788	0.001209161	1.46207E-06
16	152.1946896	152.1956	0.000910405	8.28838E-07
17	154.0061134	154.0066	0.000486551	2.36732E-07
18	155.8120835	155.8122	0.000116499	1.35719E-08
19	157.6128095	157.6127	-0.000109514	1.19934E-08
20	159.4084906	159.4086	0.000109372	1.19622E-08
21	170.272227	170.2702	-0.002027038	4.10888E-06
22	172.1821575	172.1815	-0.000657468	4.32264E-07
23	174.087003	174.087	-2.96385E-06	8.78442E-12
24	175.9869473	175.9872	0.000252682	6.38481E-08
25	177.8821656	177.8825	0.000334428	1.11842E-07
26	179.7728245	179.7731	0.000275472	7.58846E-08
27	181.6590832	181.6593	0.000216767	4.69879E-08
28	183.5410934	183.5413	0.000206581	4.26759E-08
29	185.4189999	185.4192	0.000200079	4.00317E-08
30	187.2929411	187.2931	0.000158934	2.52599E-08
31	189.163049	189.1631	5.09663E-05	2.59756E-09
32	191.0294502	191.0293	-0.000150191	2.25574E-08
33	192.8922654	192.8919	-0.000365413	1.33527E-07

34	194.7516104	194.7513	-0.000310375	9.63329E-08
35	196.6075958	196.6076	4.16983E-06	1.73875E-11
36	163.7726459	163.7726	-4.58712E-05	2.10417E-09
37	166.3722605	166.3714	-0.000860488	7.4044E-07
38	168.9568799	168.9559	-0.000979875	9.60156E-07
39	171.5272181	171.5266	-0.000618092	3.82037E-07
40	174.0839446	174.084	5.54332E-05	3.07284E-09
41	176.6276875	176.6285	0.000812465	6.60099E-07
42	179.1590372	179.1606	0.001562844	2.44248E-06
43	181.6785484	181.6805	0.001951645	3.80892E-06
44	184.1867434	184.1886	0.001856584	3.4469E-06
45	186.6841143	186.6854	0.001285655	1.65291E-06
46	146.4671161	146.4675	0.000383919	1.47394E-07
47	148.2612184	148.2621	0.000881645	7.77298E-07
48	150.0499692	150.0508	0.000830754	6.90153E-07
49	151.8335887	151.834	0.000411326	1.69189E-07
50	153.6122847	153.6121	-0.000184671	3.41036E-08
51	155.3862542	155.3855	-0.000754176	5.68781E-07
52	157.1556838	157.1545	-0.001183759	1.40129E-06
53	158.9207503	158.9194	-0.001350301	1.82331E-06

54	160.6816216	160.6806	-0.001021611	1.04369E-06
55	162.438457	162.4385	4.29976E-05	1.84879E-09
56	173.6496404	173.6496	-4.03804E-05	1.63057E-09
57	175.5178743	175.518	0.000125651	1.57881E-08
58	177.3820404	177.3823	0.000259629	6.74072E-08
59	179.2422855	179.2424	0.00011452	1.31149E-08
60	181.0987497	181.0985	-0.000249707	6.23538E-08
61	182.9515665	182.9511	-0.000466498	2.1762E-07
62	184.8008631	184.8003	-0.000563086	3.17066E-07
63	186.6467609	186.6462	-0.00056086	3.14564E-07
64	188.4893757	188.4889	-0.000475687	2.26278E-07
65	190.3288182	190.3285	-0.000318228	1.01269E-07
66	192.1651942	192.1649	-0.000294227	8.65695E-08
67	193.9986048	193.9984	-0.000204778	4.19341E-08
68	195.8291466	195.829	-0.000146581	2.14859E-08
69	197.6569122	197.6571	0.000187825	3.52781E-08
70	199.4819902	199.4828	0.000809836	6.55834E-07
71	168.4986424	168.4973	-0.001342393	1.80202E-06
72	171.0207817	171.0197	-0.001081657	1.16998E-06
73	173.5304249	173.5299	-0.000524896	2.75516E-07
74	176.0281672	176.0283	0.00013284	1.76465E-08
75	178.5145663	178.5154	0.000833694	6.95046E-07
76	180.9901459	180.9914	0.001254138	1.57286E-06
77	183.4553976	183.4566	0.00120237	1.44569E-06
78	185.910784	185.9115	0.000715954	5.12591E-07
79	188.3567403	188.3562	-0.000540347	2.91974E-07
80	190.7936765	190.791	-0.002676537	7.16385E-06
81	148.7468051	148.7478	0.000994932	9.8989E-07
82	150.508799	150.5097	0.000900954	8.11719E-07
83	152.2663335	152.2668	0.000466462	2.17587E-07
84	154.0195918	154.0194	-0.000191812	3.67917E-08
85	155.7687472	155.7681	-0.000647226	4.18902E-07
86	157.5139639	157.5129	-0.001063897	1.13188E-06
87	159.2553973	159.2543	-0.001097299	1.20407E-06
88	160.9931948	160.9926	-0.000594834	3.53828E-07
89	162.7274963	162.728	0.000503657	2.53671E-07
90	164.4584346	164.4609	0.002465415	6.07827E-06
91	175.9012493	175.901	-0.000249275	6.21382E-08

92	177.7416856	177.7419	0.000214396	4.59658E-08
93	179.578732	179.579	0.000268024	7.18369E-08
94	181.4125109	181.4126	8.90795E-05	7.93516E-09
95	183.2431391	183.2431	-3.91312E-05	1.53125E-09
96	185.0707278	185.0707	-2.78106E-05	7.73428E-10
97	186.895383	186.8954	1.70113E-05	2.89386E-10
98	188.7172058	188.7174	0.000194179	3.77056E-08
99	190.5362929	190.5366	0.000307136	9.43326E-08
100	192.3527363	192.353	0.000263664	6.95187E-08
101	194.1666244	194.1667	7.56442E-05	5.72204E-09
102	195.9780412	195.9779	-0.000141169	1.99287E-08
103	197.7870674	197.7867	-0.000367359	1.34953E-07
104	199.59378	199.5934	-0.000380042	1.44432E-07
105	201.3982531	201.3983	4.69466E-05	2.20398E-09
MSE				**0.000000709**

3.4 COMPARISONS OF IS 456 RESULTS AND REGRESSION RESULTS

S.N.	**Actual bending moment by IS 456 code**	**Predicted bending moment by REGRESSION**	**Error**	**Square Error**
1	156.6836511	157.6389998	0.955348757	0.912691248
2	159.3994787	160.1008492	0.701370487	0.49192056
3	162.0965623	162.535838	0.439275629	0.192963078
4	164.7757945	164.9452452	0.169450688	0.028713536
5	167.438012	167.33027	-0.107741989	0.011608336
6	170.084	169.6920377	-0.391962352	0.153634485
7	172.7144964	172.0316055	-0.682890961	0.466340065
8	175.3301948	174.3499674	-0.980227447	0.960845848
9	177.931748	176.6480589	-1.283689109	1.647857729
10	180.5197711	178.9267614	-1.593009636	2.5376797
11	143.0475826	141.6669763	-1.380606309	1.906073781
12	144.8898473	143.756156	-1.133691305	1.285255976
13	146.7254228	145.8325577	-0.89286512	0.797208123
14	148.554584	147.8967064	-0.657877529	0.432802843
15	150.3775908	149.949099	-0.428491832	0.18360525
16	152.1946896	151.9902056	-0.204483953	0.041813687
17	154.0061134	154.0204718	0.014358391	0.000206163
18	155.8120835	156.04032	0.228236453	0.052091879
19	157.6128095	158.0501507	0.437341168	0.191267297
20	159.4084906	160.0503444	0.641853802	0.411976303
21	170.272227	169.7965402	-0.475686	0.226278002

			874	
22	172.1821575	171.7974049	-0.384752606	0.148034568
23	174.087003	173.789127	-0.297875992	0.088730107
24	175.9869473	175.7720369	-0.21491037	0.046186467
25	177.8821656	177.7464495	-0.135716062	0.018418849
26	179.7728245	179.7126646	-0.060159962	0.003619221
27	181.6590832	181.6709681	0.011884843	0.00014125
28	183.5410934	183.6216329	0.080539434	0.0064866
29	185.4189999	185.5649193	0.145919385	0.021292467
30	187.2929411	187.5010761	0.208135077	0.04332021
31	189.163049	189.430341	0.267291986	0.071445006
32	191.0294502	191.3529411	0.323490951	0.104646395
33	192.8922654	193.2690938	0.376828427	0.141999663
34	194.7516104	195.1790071	0.427396719	0.182667955
35	196.6075958	197.08288	0.475284206	0.225895076
36	163.7726459	165.5317966	1.759150692	3.094611158
37	166.3722605	167.8271101	1.45484958	2.116587299
38	168.9568799	170.1009351	1.144055197	1.308862294
39	171.5272181	172.3542948	0.827076748	0.684055947
40	174.0839446	174.5881487	0.50420411	0.254221785
41	176.6276875	176.8033969	0.175709323	0.030873766
42	179.1590372	179.0008851	-0.15815206	0.025012074
43	181.6785484	181.1814086	-0.497139745	0.247147926
44	184.1867434	183.3457158	-0.841027571	0.707327375
45	186.6841143	185.4945119	-1.189602488	1.415154081
46	146.4671161	145.9332226	-0.533893458	0.285042225
47	148.2612184	147.9304004	-0.330817951	0.109440517
48	150.0499692	149.9173557	-0.1326135	0.01758634
49	151.8335887	151.8945088	0.060920077	0.003711256
50	153.6122847	153.8622568	0.249972139	0.06248607
51	155.3862542	155.8209761	0.434721946	0.18898317
52	157.1556838	157.7710231	0.615339324	0.378642484
53	158.9207503	159.7127356	0.791985278	0.627240681
54	160.6816216	161.6464342	0.964812554	0.930863264
55	162.438457	163.5724232	1.133966165	1.285879263
56	173.6496404	173.9498149	0.300174539	0.090104754
57	175.5178743	175.5290514	0.011177067	0.000124927
58	177.3820404	177.4476328	0.065592448	0.004302369
59	179.2422855	179.3591645	0.116879035	0.013660709
60	181.0987497	181.2638983	0.165148571	0.027274051
61	182.9515665	183.162074	0.210507541	0.044313425

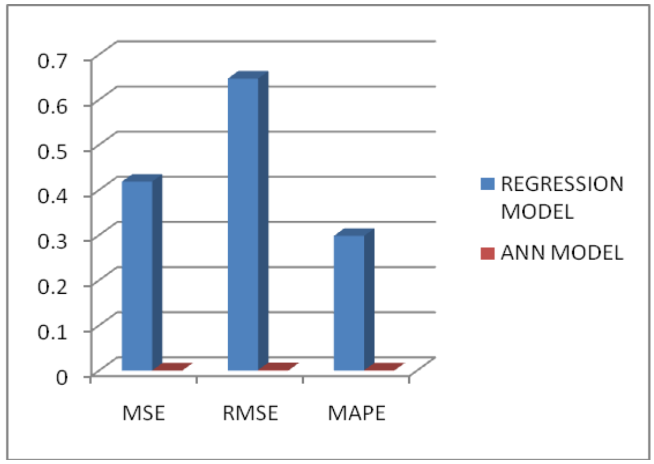
62	184.8008631	185.0539206	0.253057475	0.064038086
63	186.6467609	186.9396561	0.292895237	0.08578762
64	188.4893757	188.819489	0.330113287	0.108974783
65	190.3288182	190.6936182	0.364799931	0.13307899
66	192.1651942	192.5622338	0.397039548	0.157640403
67	193.9986048	194.4255176	0.42691281	0.182254547
68	195.8291466	196.2836435	0.45449688	0.206567414
69	197.6569122	198.1367778	0.479865603	0.230270997
70	199.4819902	199.9850798	0.503089683	0.253099229
71	168.4986424	170.0383639	1.539721504	2.370742309
72	171.0207817	172.2226535	1.20187183	1.444495895
73	173.5304249	174.389036	0.858611097	0.737213016
74	176.0281672	176.5383641	0.510196976	0.260300954
75	178.5145663	178.6714373	0.156871031	0.02460852
76	180.9901459	180.7890058	-0.201140038	0.040457315
77	183.4553976	182.8917744	-0.563623271	0.317671192
78	185.910784	184.9804056	-0.930378422	0.865604008
79	188.3567403	187.0555233	-1.301217024	1.693165743
80	190.7936765	189.117715	-1.675961535	2.808847067
81	148.7468051	148.0220897	-0.724715369	0.525212367
82	150.508799	149.9579329	-0.550866	0.303453563
			194	
83	152.2663335	151.8852573	-0.381076231	0.145219094
84	154.0195918	153.8044131	-0.215178664	0.046301857
85	155.7687472	155.7157315	-0.053015693	0.002810664
86	157.5139639	157.619526	0.105562066	0.01114335
87	159.2553973	159.5160934	0.260696135	0.067962475
88	160.9931948	161.4057155	0.412520683	0.170173314
89	162.7274963	163.2886593	0.561162999	0.314903912
90	164.4584346	165.1651785	0.706743928	0.49948698
91	175.9012493	175.3856027	-0.515646624	0.265891441
92	177.7416856	177.2615186	-0.480166963	0.230560312
93	179.578732	179.1313396	-0.447392404	0.200159963
94	181.4125109	180.9952857	-0.417225173	0.174076845
95	183.2431391	182.853567	-0.389572152	0.151766461
96	185.0707278	184.7063832	-0.364344602	0.132746989
97	186.895383	186.5539251	-0.341457916	0.116593508
98	188.7172058	188.3963744	-0.320831372	0.10293277
99	190.5362929	190.2339049	-0.302387922	0.091438456
100	192.3527363	192.0666824	-0.286053	0.081826878

			978	
101	194.1666244	193.8948651	-0.271759222	0.073853075
102	195.9780412	195.7186047	-0.259436429	0.067307261
103	197.7870674	197.5380461	-0.249021296	0.062011606
104	199.59378	199.3533278	-0.240452285	0.057817301
105	201.3982531	201.1645826	-0.233670478	0.054601892
MSE				0.41832

IV. RESULTS AND DISCUSSION

S. N.	MODEL COMPARISION	MEAN SQUARE ERROR (MSE)	ROOT MEAN SQUARE ERROR (RMSE)	MEAN AVERAGE PERCENTAGE ERROR (MAPE)
1	IS CODE METHOD AND ANN BASED RESULT	0.000001215	0.0011	0.00042
2	IS CODE METOD AND REGRESSION IN EXCEL BASED RESULT	0.4183	0.6467	0.2981

4.1 GRAPHICAL COMPARISON BETWEEN THE ACTUAL ULTIMATE BENDING MOMENT AND PREDICTED BENDING MOMENT



V. CONCLUSIONS

In this study, an ANN model was developed to predict the ultimate bending moment of RC beams to resist flexural failure. 105 specimens were derived from experimental data to produce an ANN model for predicting the ultimate bending moment. The performance of the proposed ANN model was compared to the IS 456:2000 guide.

In this thesis, we conducted a comprehensive study comparing the predictive capabilities of Artificial Neural Networks (ANN) and regression models executed via Excel. Our analysis focused on predicting bending moments and evaluating the accuracy of these predictions.

The results demonstrated that the ANN model significantly outperformed the regression model in terms of accuracy. Specifically, the ANN achieved a percentage error accuracy of 99.98%, mean square error accuracy of 99.89%, and root mean square error accuracy of 99.99%. These findings highlight the superior predictive power of ANN over traditional regression models.

The substantial improvement in accuracy with the ANN model underscores its potential as a more reliable and effective tool for prediction tasks in various applications. This research provides a strong foundation for further exploration and application of ANN in predictive modeling, encouraging the adoption of advanced machine learning techniques for enhanced accuracy and efficiency.

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