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## **Artificial Intelligence: The XXI Century Paradigm for Asphalt Pavement Modelling and Design**

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Some people believe that artificial intelligence allow computers to solve complex problems with almost no efforts. If they are thinking about asphalt pavement modelling and service life prediction, yes, they are right!

For that to become a reality is very easy; it's just necessary provide the computers with the necessary data, organized in a hierarchical way, train a neural network system and, *voilà*, the "artificial brain" is able to do predictions about the pavement service life.

The first step is to create an ultra-big database with the life history of the pavement. For that, it's necessary instrument an open-to-traffic highway section with sensors and register, vehicle-by-vehicle, all variables with influence in the asphalt pavement durability, including environment, vehicles and the structural response. Every time a vehicle crosses the section, all sensors are read and the data, recorded (Figure 1).

Then, the database needs to be "translated" into another language, the math language, with one vehicle per line, in order to allow the next-step, adjust every variable according its individual relative importance as a way to give the relative importance ("pavement damage") for every line. For that, a number of tools are available in the range of soft computing and equation systems. The result will be a matrix of performance, a source of "intelligence" to train the neural network (Figure 2).

Trained, the neural network will be able make predictions about the service life for asphalt pavements (Figure 3). The problems proposed to the neural network system need to be described in the exact same way was described the initial database, with data about the environment, vehicles and structural response (Figure 4). For the design of new pavements, the structural response can be simulated with finite elements software; for use in a pavement management system, the structural response can be found with a combination of *in situ* non-destructive tests (Benkelman beam, FWD, etc.) and finite elements modelling. The prediction made by the neural network will be valid for pavements using the same materials used in the instrumented section source for the initial database.

The Figure 5 shows a comparison between this proposed "futuristic approach" against the current equation of fatigue. In the future, all pavements will be managed and designed with tools using artificial intelligence.

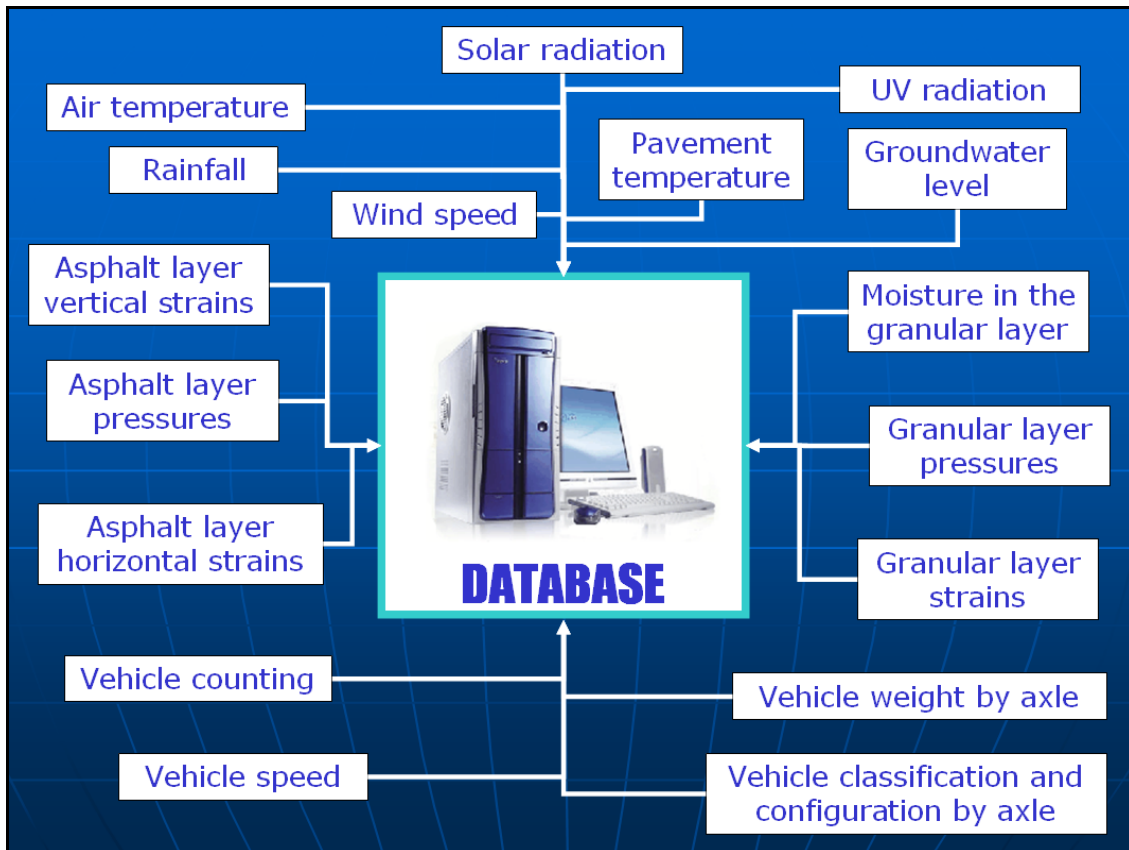


Figure 1 – Necessary variables for a database suitable for asphalt pavement modelling using artificial intelligence

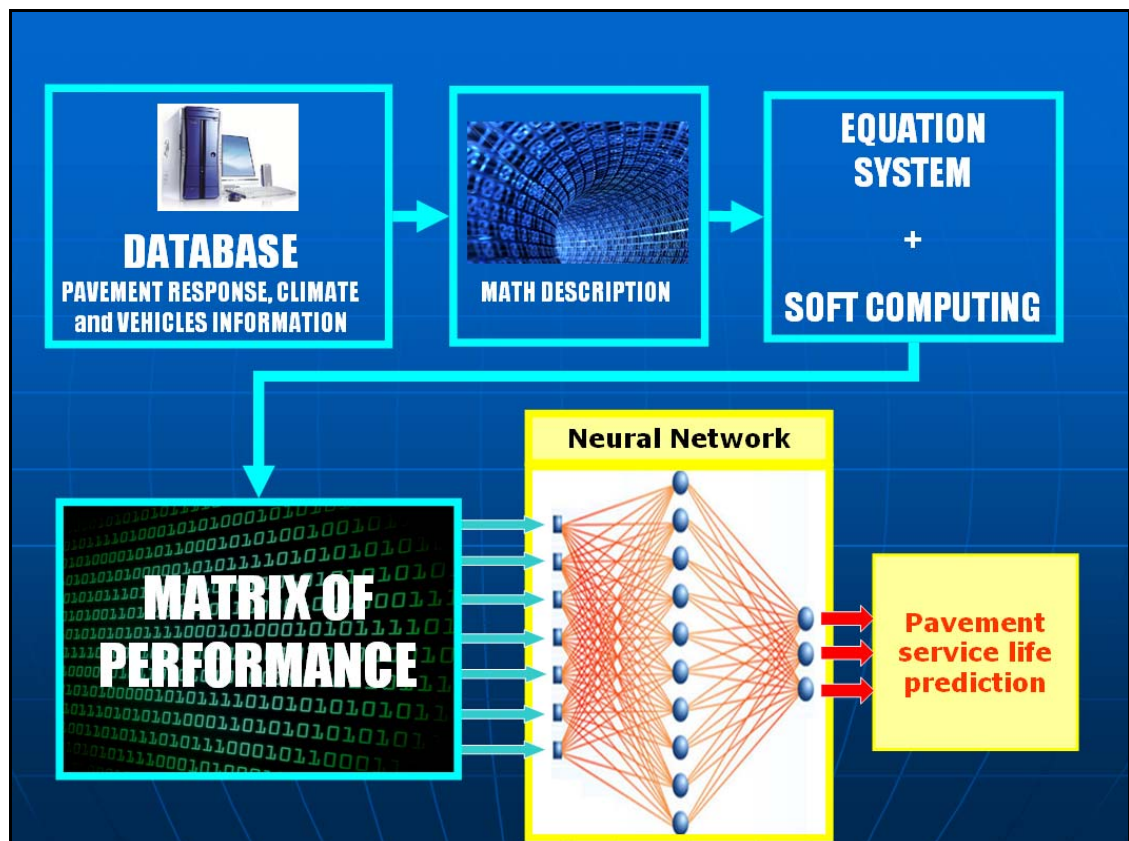


Figure 2 – The database with the history of the pavement is “handled” to become a matrix of performance to train the neural network system

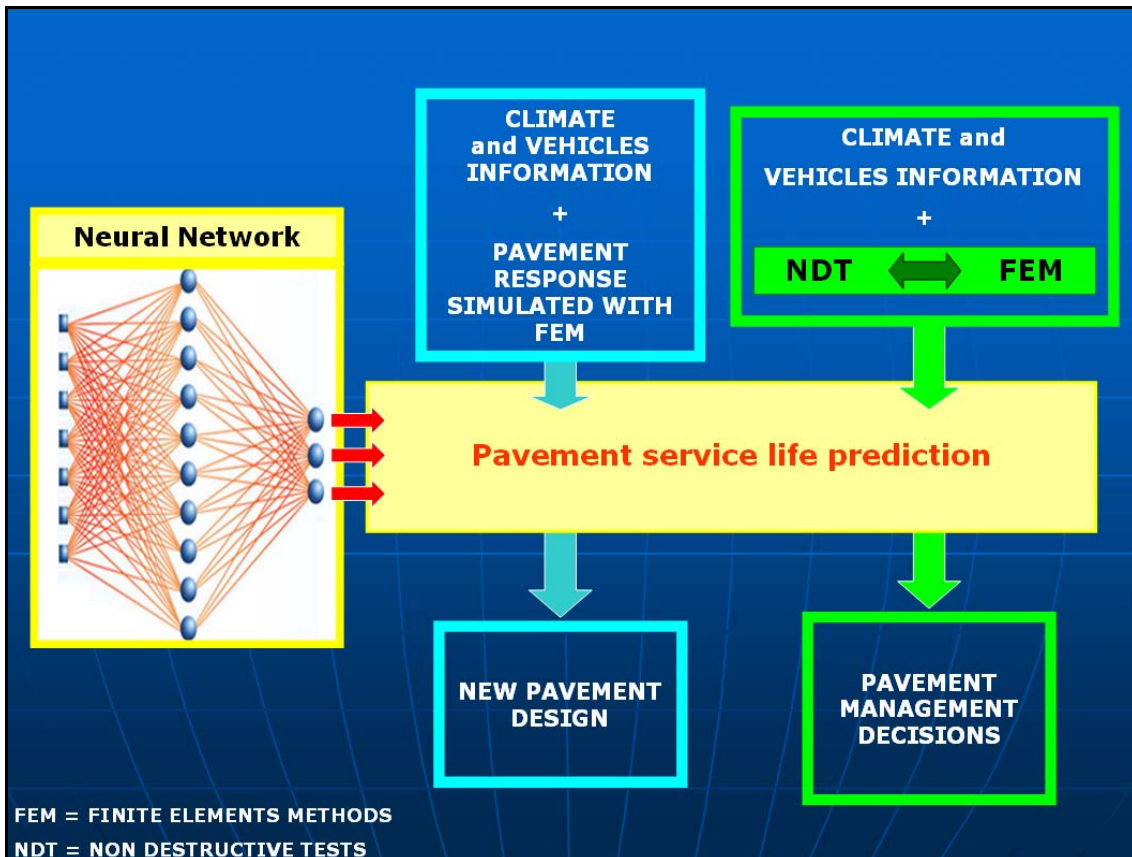


Figure 3 – The trained neural network system will do predictions about the service life for both, design new pavements and make decisions in a pavement management system

Variables (vehicles, environment and pavement response data) -> math													pavement damage
164,1800144	40,8500302	25,5966057	94,9264302	10741,3168803	89,6066930	64,8368234	256,5648779	195,3544620	...	...	...	...	118,2968887
100,2736005	41,3997626	34,3589193	67,8844469	11313,9104777	97,3408360	58,7421923	265,6232226	189,3197188	...	...	...	...	119,4879974
94,7562444	37,0023341	38,3853566	97,5621902	14077,4882752	101,1370999	60,7690223	272,3011737	199,9232755	...	...	...	...	134,2539785
146,0948500	45,2868755	39,4418070	57,7773418	15346,0127916	102,8311465	67,0577716	279,0847217	208,5111111	...	...	...	...	136,4838557
158,7917714	53,9775755	17,9869557	77,3901746	6073,1879542	72,2602559	50,4377571	232,0124465	179,3976939	...	...	...	...	108,8044536
14,707148	...	...	...	...	...	...	...	...	...	...	...	...	114,3402265
7,2829615	...	...	...	...	...	...	...	...	...	...	...	...	126,9134297
9,1199999	...	...	...	...	...	...	...	...	...	...	...	...	119,2092507
118,8143423	43,2321337	20,9074608	114,3741045	4419,4412017	67,9545769	51,2318187	227,6979320	168,5657457	...	...	...	...	97,17430704
150,4081666	44,6391169	63,6994688	112,1041368	4488,8846044	64,5698924	60,7341893	239,0718991	180,2078172	...	...	...	...	131,2716887
135,681253	...	...	...	...	...	...	...	...	...	...	...	...	110,5011919
72,829615	...	...	...	...	...	...	...	...	...	...	...	...	84,77453419
143,107148	...	...	...	...	...	...	...	...	...	...	...	...	105,5733689
74,470799	...	...	...	...	...	...	...	...	...	...	...	...	86,01666424
134,352407	...	...	...	...	...	...	...	...	...	...	...	...	113,7541042
77,915044	...	...	...	...	...	...	...	...	...	...	...	...	87,67310322
131,462927	...	...	...	...	...	...	...	...	...	...	...	...	103,9563734
92,135625	...	...	...	...	...	...	...	...	...	...	...	...	124,2395434
126,520603	...	...	...	...	...	...	...	...	...	...	...	...	117,7526602
107,879573	...	...	...	...	...	...	...	...	...	...	...	...	99,52567913
124,885437	...	...	...	...	...	...	...	...	...	...	...	...	132,6186304
98,809232	...	...	...	...	...	...	...	...	...	...	...	...	118,9209173
158,698668	...	...	...	...	...	...	...	...	...	...	...	...	108,204481
107,3076958	44,3974199	17,7598296	101,3556768	2419,1869759	67,3697787	38,6479549	220,3457147	166,7302876	...	...	...	...	91,78466017
164,3352762	45,0938439	22,9209446	68,1587398	9623,8208081	86,4041692	63,0531738	265,8239784	183,5888840	...	...	...	...	120,6520766

Every line register the "handled" data (environmental, vehicle characteristics and pavement structural response) related to the crossing of one single vehicle

**MATRIX OF PERFORMANCE**  
**SOURCE OF "INTELLIGENCE" TO TRAIN THE NEURAL NETWORK**

Proposed Pavement Design													pavement damage
49,58528479	13,88854472	67,91894921	14593,77643	100,4731813	62,28931206	292,8947858	202,6007009	136,0275909	...	...	...	...	Na?
53,9750667	10,86637723	75,37396882	4114,096163	64,03622904	50,38619233	235,7548272	173,4128898	100,1788908	...	...	...	...	Na?
38,81551186	12,086730	...	...	...	...	...	200,1308087	135,6554542	...	...	...	...	Na?
54,84367206	33,328132	...	...	...	...	...	167,3867667	101,6173612	...	...	...	...	Na?
42,58738867	22,668543	...	...	...	...	...	201,6626373	134,6461011	...	...	...	...	Na?
35,83165315	18,051484	...	...	...	...	...	196,3206881	127,479034	...	...	...	...	Na?
45,54931595	17,06907356	59,91619904	2010,4613691	63,27629022	41,20373394	217,9269794	164,6476378	92,28268157	...	...	...	...	Na?

**PROPOSED PAVEMENT DESIGN**

Pavement damage predictions made by the trained neural network system

Figure 4 – The neural network will be able to make predictions for problems proposed in the exact same way as was described the initial database used to generate the matrix of performance

# ARTIFICIAL INTELLIGENCE x equation of fatigue

17,2087473	60,2622227	66,338576	23,3729507	97,4982953	41,4223044	12,7934683	16,973916	895,210207	99,0796273	35,38958438	242,7885384	197,092221	94,8472631	10000
16,9470621	172,27678	204,5247007	61,80164	91,086495	50,3814484	46,37788979	89,6891029	1957,88243	69,82248772	62,8538971	261,7042466	197,8893886	122,0124952	10094

$$N = f1 \cdot (\epsilon_t)^{-f2} \cdot (E)^{-f3}$$

1. **Full scientific field-based approach with the damage described by the pavement itself**
2. **All variables considered in its exact importance**
3. **Each equation is rich in information**
4. **Millions of equations to support robust and accurate modelling**
5. **Full traffic profile**
6. **Full climate consideration**
7. **Full pavement structural response consideration**
8. **Scalable: allow accumulate the knowledge just adding new sets of sensors data in the initial database for improved accuracy and wide usability**
9. **All know and unknown factors considered in the modelling (visco-plasticity, nonlinearity, anisotropy, etc.)**
10. **New paradigm for pavement modelling and design**

1. **Obsolete laboratory-based approach**
2. **One variable + one constant**
3. **Three adjusting factors (f1, f2 and f3)**
4. **One equation good for "everything"**
5. **Unacceptable use of ESAL from other methods**
6. **Fixed temperature**
7. **One single strain ( $\epsilon_t$ )**
8. **No way to accumulate knowledge**
9. **Simplified to elastic and isotropic**
10. **Keep your faith and your soul will be saved**

Figure 5 – Comparison between the modelling using neural network trained with the matrix of performance against the current “technology” of the equation of fatigue