FULL INFORMED ROAD NETWORKS EVALUATION: SIMPLER, MAYBE BETTER

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Abstract - The aim of this work is to categorize the current state of a road network, to determine quality of service and to assess the need to establish a program for maintenance or investment with respect to an evaluation of the user's network satisfaction. It was designed to obtain information on the level of service provided and road network conditions, using a series of hypothetical questions. The instruments (logical functions or predicates) used considered only two or three attributes, so that respondents are able to easily comprehend and evaluate the scenarios presented to them. On the other hand, the hypothetical scenarios within each instrument were generated by varying the levels of the attributes entropy in a way that is specific to each of them, i.e., this study investigates the measurement of road network structure according to this assumption. Existing measures of heterogeneity, connectivity, accessibility, and interconnectivity are reviewed and supplemental measures are proposed, including measures of entropy, connection patterns, and continuity.

Keywords - Road Networks, Entropy, Logic Programming, Knowledge Representation and Reasoning, Artificial Neural Networks.

I. INTRODUCTION

Existing measures of heterogeneity, connectivity, accessibility, and interconnectivity are reviewed and supplemental measures are proposed, including measures of entropy, connection patterns, and continuity. The results show that the differentiated structures of road networks can be evaluated by the measure of entropy [1, 2]; predefined connection patterns of arterial roads can be identified and quantified by the measures of ringness, webness, beltness, circuitness, and treeness. A measure of continuity evaluates the quality of a network from the perspective of travelers. Proposed measures could be used to describe the structural attributes of complicated road networks quantitatively, to compare different network structures, and to explore the structural evolution of networks in the spatial and temporal context. These measures can find their applications in urban planning and transportation practice [3,4,5].

II. KNOWLEDGE REPRESENTATION AND REASONING

Knowledge Representation and Reasoning (KRR) practices may be understood as a process of energy devaluation [2]. A data item is to be understood as being in a given moment at a particular entropic state as untainted energy which is in the interval [0,1] and, according to the First Law of Thermodynamics is a quantity well-preserved that cannot be consumed in the sense of destruction, but may be consumed in the sense of devaluation. It may be introduced by dividing a certain amount of energy in terms of, viz [1]:

- Exergy, sometimes called available energy or more precisely available work, is the part of the energy which can be arbitrarily used after a transfer operation or, in other words, the entropy generated by it. In Fig.1 it is given by the dark colored areas;
- Vagueness, that denotes the energy values that may or may not have been consumed. In Fig.1 are given by the gray colored areas; and
- Anergy, that stands for an energetic potential that was not yet consumed, being therefore available; all of energy that is not exergy. In Fig.1 it is given by the white colored areas.

Which denote all possible energy's operations as energy consume practices. In order to make the process comprehensible, it will be presented in a graphical form. Taking as an example a group of 2 (two) questions that make the Ongoing Maintenance Questionnaire-Two-Item (OMQ – 2) [3,4,5], viz.

Q1 – Do you agree with the level of service provided;
and
Q2 – Would you make any changes to the level of service assessment?

on the assumption that a positive response to these questions will assist with the development of an effective ongoing maintenance program, which was worked out in terms of the scale, viz

strongly agree (4), agree (3), disagree (2), strongly disagree (1), disagree (2),agree (3), strongly agree (4)

Plus, a neutral one, neither agree nor disagree, which stands for uncertain or vague. The reason for the individual's answers is in relation to the query, viz (Table 1).

As an individual, how much would you agree with each question of the OMQ – 2 referred to above?

Questions	Scale							
	(4)	(3)	(2)	(1)	(2)	(3)	(4)	vagueness
Q1	x	x						
Q2						x	x	

Table 1 - OMQ – Single network user answer.

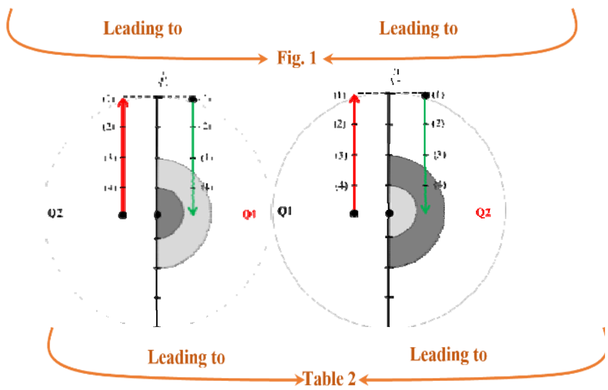

Figure 1: An assessment of the attained energy with respect to a single user answer to OMQ-2.

To Q1 one may have for the Best Case Scenario, viz.

$$\text{exergy}_{Q1} = \frac{1}{2}\pi r^2\Big]_0^{\frac{1}{4}\sqrt{\frac{1}{\pi}}} = \frac{1}{2}\pi\left(\frac{1}{4}\sqrt{\frac{1}{\pi}}\right)^2 - 0 = 0.03$$

$$\text{vagueness}_{Q1} = \frac{1}{2}\pi r^2\Big]_{\frac{1}{4}\sqrt{\frac{1}{\pi}}}^{\frac{2}{4}\sqrt{\frac{1}{\pi}}} = 0.10$$

$$\text{anergy}_{Q1} = \frac{1}{2}\pi r^2\Big]_{\frac{1}{4}\sqrt{\frac{1}{\pi}}}^{\sqrt{\frac{1}{\pi}}} = 0.47$$

and the Worst Case Scenario, viz.

$$\text{exergy}_{Q1} = \frac{1}{2}\pi r^2\Big]_0^{\frac{2}{4}\sqrt{\frac{1}{\pi}}} = 0.13$$

$$\text{vagueness}_{Q1} = \frac{1}{2}\pi r^2\Big]_{\frac{2}{4}\sqrt{\frac{1}{\pi}}}^{\frac{2}{4}\sqrt{\frac{1}{\pi}}} = 0$$

$$\text{anergy}_{Q1} = \frac{1}{2}\pi r^2\Big]_{\frac{2}{4}\sqrt{\frac{1}{\pi}}}^{\sqrt{\frac{1}{\pi}}} = 0.37$$

To Q2 one may have for the Best Case Scenario, viz.

$$\text{exergy}_{Q_2} = \frac{1}{2}\pi r^2\Big]_0^{\frac{1}{4}\sqrt{\frac{1}{\pi}}} = 0.03$$

$$\text{vagueness}_{Q_2} = \frac{1}{2}\pi r^2\Big]_0^{\frac{1}{4}\sqrt{\frac{1}{\pi}}} = 0.03$$

$$\text{anergy}_{Q_2} = \frac{1}{2}\pi r^2\Big]_{\frac{1}{4}\sqrt{\frac{1}{\pi}}}^{\sqrt{\frac{1}{\pi}}} = 0.47$$

and the Worst Case Scenario, viz.

$$\text{exergy}_{Q_2} = \frac{1}{2}\pi r^2\Big]_0^{\frac{1}{4}\sqrt{\frac{1}{\pi}}} = 0.03$$

$$\text{vagueness}_{Q_2} = \frac{1}{2}\pi r^2\Big]_{\frac{1}{4}\sqrt{\frac{1}{\pi}}}^{\frac{1}{4}\sqrt{\frac{1}{\pi}}} = 0$$

$$\text{anergy}_{Q_2} = \frac{1}{2}\pi r^2\Big]_{\frac{2}{4}\sqrt{\frac{1}{\pi}}}^{\sqrt{\frac{1}{\pi}}} = 0.37$$

Table 2 - Entropic states' best and the Worst-Case Scenarios for OMQ-2.

where the input for Q1 means that he/she strongly agrees (4) but does not rule out that he/she will agree (3) in certain situations. The inputs are be read from left to right, from strongly agree (4) to strongly disagree (1) (with increasing entropy), or from strongly desagree (1) to strongly agree (4) (with decreasing entropy), i.e., the markers on the axis correspond to any of the possible scale options, which may be used from bottom → top (from strongly agree (4) to strongly disagree (1)), indicating that the performance of the system decreases as entropy increases, or is used from top → bottom (from strongly disagree (1) to strongly agree (4)), indicating that the performance of the system increases as entropy decreases). The contribution of each individual to the system entropic state as untainted energy is evaluated as follows, viz [5].

However, once the System Performance, here given in terms of the User`s Network Satisfaction (UNS), depends on its entropic state, the data collected above can be structured in terms of the extension of predicate ongoing maintenance (om), viz [6].

$$\text{om: EXergy, VAgueness, User's Network Satisfaction,} \\ \text{Quality-of-Information} \rightarrow \{\text{True, False}\}$$

It is now possible to obtain an integrated view of the whole process, which is also presented in relation to the different types of energy (Fig.2). A formal description is set by Program 1.

which may now be depicted as the logical program (for the worst-case scenario) [6], viz.

$$\neg\,\text{om}(\text{EX, VA, SP, QoI}) \\ \leftarrow \text{not om}(\text{EX, VA, UNS, QoI}), \\ \text{not exception}_{\text{om}}(\text{EX, VA, UNS, QoI}). \\ \text{om}(0.26, 0, 0.97, 0.74).$$

Program 1. The extent of the ongoing maintenance predicate`s for the worst-case scenario.

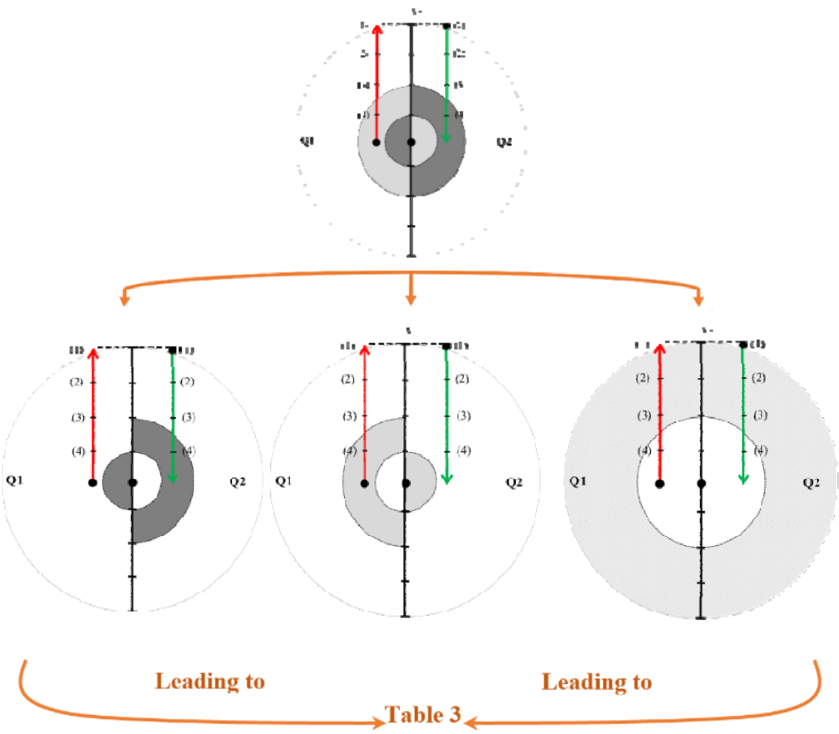

Figure 2: A graphical view of the ongoing maintenance predicate's extent obtained according to the answers of a single network user to OMQ - 2.

$Exergy^{BCS}$	$Vagueness^{BCS}$	UNS^{BCS}	QoI^{BCS}	$Exergy^{WCS}$	$Vagueness^{WCS}$	UNS^{WCS}	QoI^{WCS}
0.06	0.10	0.99	0.84	0.26	0	0.97	0.74

Table 3 - The OM predicate's extent obtained according to the answers of a single network user to OMQ - 2.

where the evaluation of UNS and QoI for the different items that make OMQ – 2 are given in the form, viz.

- UNS is figured out using$UNS = \sqrt{1 - ES^2}$, where ES stands for an exergy's value in the worst-case scenario (i.e., ES = exergy + vagueness), a value that ranges in the interval 0…1 (Fig. 3).

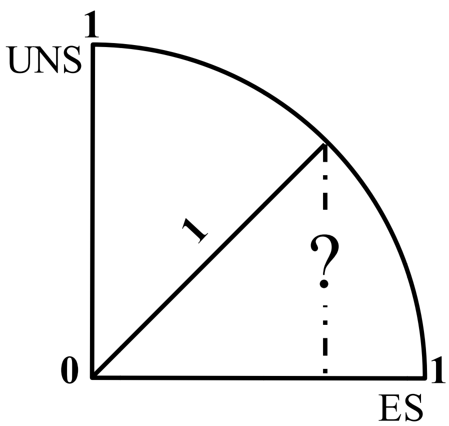

Figure 3: UNS evaluation.

$UNS = \sqrt{1 - (0.26 + 0)^2}$=0.97

- **QoI is evaluated in the form, viz.**

$$QoI = 1 - (exergy + vagueness)$$
$$QoI = 1 - (0.26 + 0) = 0.74$$

On the other hand, taking as an example a group of 3 (three) questions that make the Road Network-condition Questionnaire-Three-Item (RNQ – 3) [4], viz.

Q1 – What condition rating do you consider to be acceptable for a Class 3 arterial road?;
Q2 – What condition rating do you consider to be acceptable for a local access road?; and

Q3 – What condition rating do you consider to be acceptable for the unsealed roads?

on the assumption that a good categorization of the current condition of the road network will cause positive outcomes, it was worked out in terms of the scale, viz.
Very good (5), Good (4), Fair (3), Poor (2), Extremely poor (1), Poor (2), Fair (3), Good (4), Very good (5)

plus, a neutral one, neither agree nor disagree, which stands for uncertain or vague. The reason for the individual's answers is in relation to the query, viz.
As an individual, how much do you rate each one ofRNQ – 3 referred to above? (Table 4).

Questions	Scale									Vagueness
	(5)	(4)	(3)	(2)	(1)	(2)	(3)	(4)	(5)	
Q1								×		
Q2				×	×					
Q3										×

Table 4 - RNQ – 3 single network user answer.

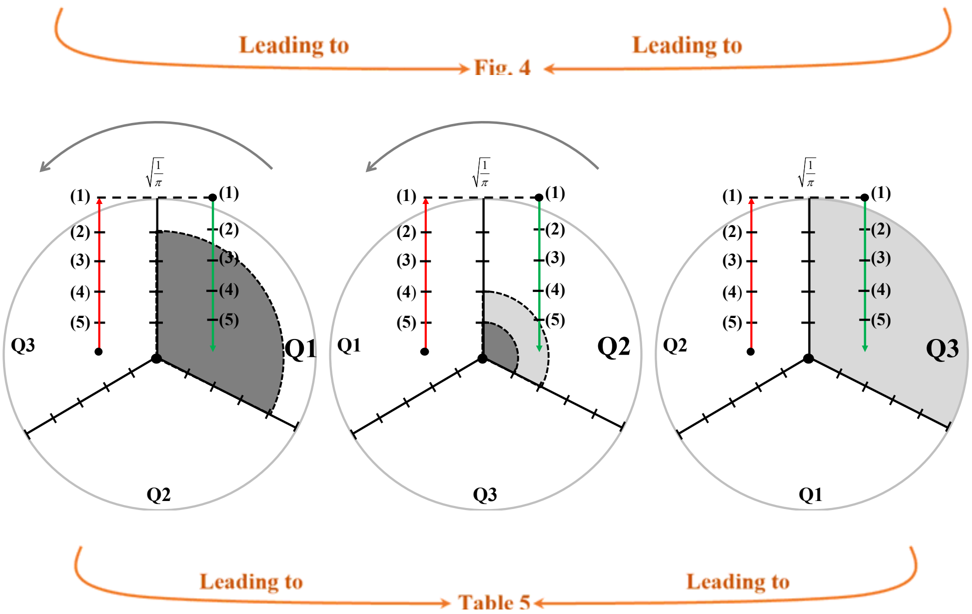

Figure 4: An assessment of the attained energy with respect to a single user answer to RNQ – 3.

Questions	Best Case Scenario	Worst Case Scenario
Q1	$\text{exergy}_{Q1} = \frac{1}{3}\pi r^2\Big]_0^{\frac{4}{5}\sqrt{\frac{1}{\pi}}} = \frac{1}{3}\pi\left(\frac{4}{5}\sqrt{\frac{1}{\pi}}\right)^2 - 0 = 0.21$	$\text{exergy}_{Q1} = \frac{1}{3}\pi r^2\Big]_0^{\frac{4}{5}\sqrt{\frac{1}{\pi}}} = 0.21$
	$\text{vagueness}_{Q1} = \frac{1}{3}\pi r^2\Big]_0^0 = 0$	$\text{vagueness}_{Q1} = \frac{1}{3}\pi r^2\Big]_0^0 = 0$
	$\text{anergy}_{Q1} = \frac{1}{3}\pi r^2\Big]_{\frac{4}{5}\sqrt{\frac{1}{\pi}}}^{\sqrt{\frac{1}{\pi}}} = 0.12$	$\text{anergy}_{Q1} = \frac{1}{3}\pi r^2\Big]_{\frac{4}{5}\sqrt{\frac{1}{\pi}}}^{\sqrt{\frac{1}{\pi}}} = 0.12$
Q2	$\text{exergy}_{Q_2} = \frac{1}{3}\pi r^2\Big]_0^{\frac{1}{5}\sqrt{\frac{1}{\pi}}} = 0.01$	$\text{exergy}_{Q_2} = \frac{1}{3}\pi r^2\Big]_0^{\frac{2}{5}\sqrt{\frac{1}{\pi}}} = 0.05$
	$\text{vagueness}_{Q_2} = \frac{1}{3}\pi r^2\Big]_{\frac{1}{5}\sqrt{\frac{1}{\pi}}}^{\frac{2}{5}\sqrt{\frac{1}{\pi}}} = 0.04$	$\text{vagueness}_{Q_2} = \frac{1}{3}\pi r^2\Big]_{\frac{2}{5}\sqrt{\frac{1}{\pi}}}^{\frac{2}{5}\sqrt{\frac{1}{\pi}}} = 0$
	$\text{anergy}_{Q_2} = \frac{1}{3}\pi r^2\Big]_{\frac{1}{5}\sqrt{\frac{1}{\pi}}}^{\sqrt{\frac{1}{\pi}}} = 0.32$	$\text{anergy}_{Q_2} = \frac{1}{3}\pi r^2\Big]_{\frac{2}{5}\sqrt{\frac{1}{\pi}}}^{\sqrt{\frac{1}{\pi}}} = 0.28$

Q3	$\text{exergy}_{Q_3} = \frac{1}{3}\pi r^2 \Big]_{0}^{0} = 0$ $\text{vagueness}_{Q_3} = \frac{1}{3}\pi r^2 \Big]_{0}^{\sqrt{\frac{1}{\pi}}} = 0.33$ $\text{anergy}_{Q_3} = \frac{1}{3}\pi r^2 \Big]_{\sqrt{\frac{1}{\pi}}}^{\sqrt{\frac{1}{\pi}}} = 0$	$\text{exergy}_{Q_3} = \frac{1}{3}\pi r^2 \Big]_{0}^{\sqrt{\frac{1}{\pi}}} = 0.33$ $\text{vagueness}_{Q_3} = \frac{1}{3}\pi r^2 \Big]_{\sqrt{\frac{1}{\pi}}}^{\sqrt{\frac{1}{\pi}}} = 0$ $\text{anergy}_{Q_3} = \frac{1}{3}\pi r^2 \Big]_{\sqrt{\frac{1}{\pi}}}^{\sqrt{\frac{1}{\pi}}} = 0$

Table 5 - Entropic states' best and the worst-case scenarios for RNQ – 3.

It is now possible to obtain an integrated view of the whole process, which is also presented in relation to the different types of energy (Fig. 5), viz.

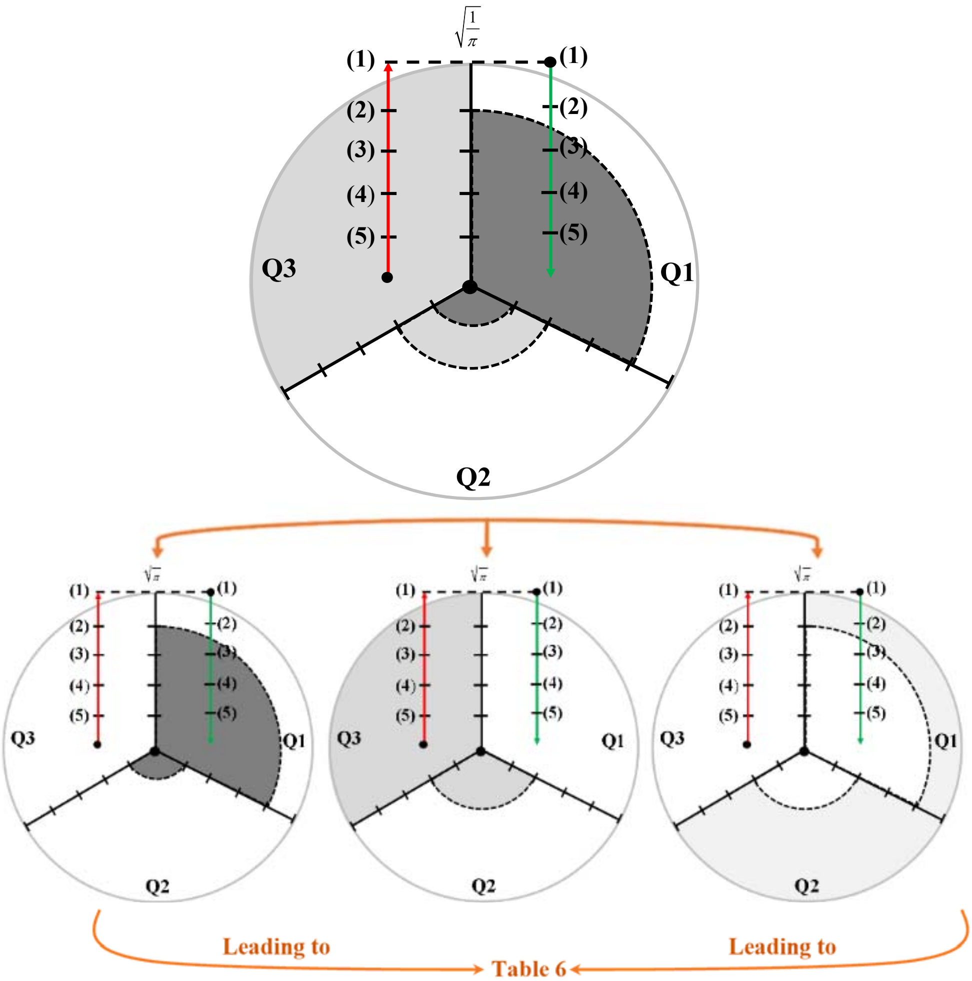

Figure 5: A graphical view of the Road Network predicate's extent obtained according to the answers of a single network user to RNQ – 3.

Exergy^{BCS}	Vagueness^{BCS}	UNS^{BCS}	QoI^{BCS}	Exergy^{WCS}	Vagueness^{WCS}	UNS^{WCS}	QoI^{WCS}
0.22	0.37	0.81	0.41	0.59	0	0.81	0.41

Table 6 - RNQ – 3 single network user answer.

It is now possible to obtain an integrated view of the whole process, which is also presented in relation to the different types of energy (Fig. 5), viz.

which may now be depicted as the logical program (it is being considered the worst-case scenario) [6], viz.

$\neg\, \text{rn}(\text{EX},\ \text{VA},\ \text{SP},\ \text{QoI}) \leftarrow \text{not rn}(\text{EX},\ \text{VA},\ \text{SP},\ \text{QoI}),$

$\text{not exception}_{\text{rn}}(\text{EX},\ \text{VA},\ \text{SP},\ \text{QoI})$

$rn(0.59, 0, 0.81, 0.41).$

Program 2. The extent of the road network's predicate (rn) for the worst-case scenario.

III. COMPUTATIONAL MAKE-UP

The following describes nothing less than a mathematical logic program that, through insights that are subject to formal proof, allows one to understand and even adapt the actions and attitudes of individuals or groups and toward them the organization as a whole. Assess the impact on the functioning and performance of the organization through logical inference.

$$\neg\, om(EX,\ VA,\ UNS,\ QoI) \leftarrow not\ om(EX,\ VA,\ UNS,\ QoI),$$
$$not\ exception_{om}(EX,\ VA,\ UNS,\ QoI).$$
$$om(0.26, 0, 0.97, 0.74).$$
$$\neg\, rn(EX,\ VA,\ UNS,\ QoI) \leftarrow not\ rn(EX,\ VA,\ UNS,\ QoI),$$
$$not\ exception_{rn}(EX,\ VA,\ UNS,\ QoI).$$
$$rn(0.59, 0, 0.81, 0.41).$$

Program 3. The make-up of the network`s knowledge base for a single user answer.

It is now possible to use this data to train an Artificial Neural Network (ANN) [7,8] (Fig. 6) in order to get on the fly an evaluation of the User`s Network Satisfaction (UNS). Indeed, assuming that one has a set of 30 (thirty) users, the training set may be gotten by making obvious the theorem, viz.

$\forall\ (EX_1, VA_1, UNS_1, QoI_1, EX_2, VA_2, UNS_2, QoI_2),$
$\neg\ (om(EX_1, VA_1, UNS_1, QoI_1), rn(EX_2, VA_2, UNS_2, QoI_2)).$

In every possible way, i.e., generating all the different possible sequences that combine the dimensions of the predicates om and rn, which in this case give a number of 435 and are given in the form, viz.

$\{ \{om(EX_1, VA_1, UNS_1, QoI_1), rn(EX_2, VA_2, UNS_2, QoI_2)\}, ...\} \approx \{ \{om(0.26,0,0.97,0.74), rn(0.59,0,0.81,0.41)\}, ...\}$

that act as input (75% to train, 25% to test) to the ANN (Fig.6). The ANN output (i.e., the UNS) is evaluated in the form, viz.

$\{ \{ (UNS_{om}, + UNS_{rn}) / 2\}, \ldots \},\ \approx \{ \{ (0.97 + 0.81) / 2 = 0.89\}, \ldots \}$

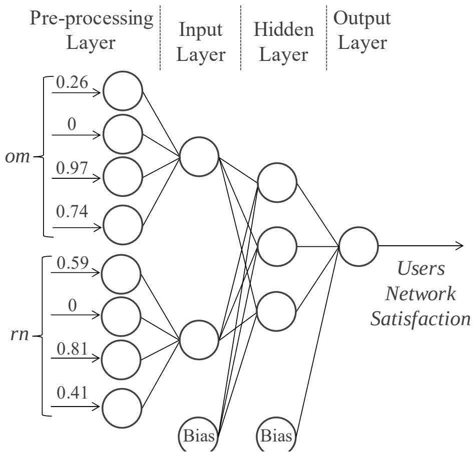

Figure 6: An abstract view of the ANN topology and their training process.

IV. CONCLUSIONS

In summary, it can be deduced from the results of this study that particular attention should be given to the characteristics of the tour operator or the type of travel when planning and designing road networks. The planning efforts should also be coordinated with all relevant authorities such as transit, urban planning or transportation, just to name a few. This may resolve contradictory goals. Finally, however, it should be emphasized that pedestrians in key areas should be given priority over all other modes of transport as they have to go everywhere, which in no few cases will be in opposition to plans of maintenance and investment on the network.

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