ARTIFICIAL INTELLIGENCE MODEL FOR SUSTAINABILITY MEASUAREMENT

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Annotation
The article analyses the main dimensions of organizational sustainability, their possible integrations into artificial neural network. In this article authors performing analyses of organizational internal and external environments, their possible correlations with 4 components of sustainability, and the principal determination models for sustainability of organizations. Based on the general principles of sustainable development organizations, a artificial intelligence model for the determination of organizational sustainability has been developed. The use of self-organizing neural networks allows the identification of the organizational sustainability and the endeavour to explore vital, social, antropogenical and economical efficiency. The determination of the forest enterprise sustainability is expected to help better manage the sustainability.

Keywords
sustainability, artificial intelligence, self-organizing neural networks, sustainable organizational environment.

1 INTRODUCTION

In the real world, an organization functioning in a certain region generates many different types of data while performing functions assigned to it. When we examine the sustainability of such an organization or individual components of the organizational sustainability, we are dealing with the data describing each component of the organizational sustainability, the analysis of which presents a complex task, especially when the data of individual components of the organizational sustainability reflect a complex and integrated phenomenon, the sustainability of the entire organization. Organizational sustainability is generally characterized by a large amount of multicomponent indicators and indicator values. In the scientific literature, the data describing any component of organizational sustainability are commonly known as multidimensional data. It is very important for the persons in charge of organizational sustainability to retrieve the necessary information from the available multidimensional data which could help to understand the distribution of the forest enterprise sustainability level, i.e. the distribution of organizational sustainability across individual components of the forest enterprise sustainability as well as the reasons for a respective sustainability level of the forest enterprise. Use of a visualization method for a self-organizing neural network makes this task easier.

The analysis of the scientific literature on sustainable development leads to the observation that a substantial work has been done in this field however very little attention is given to the assessment of organizational sustainability in scientific literature. The researches carried out in Lithuania have not examined the topic of organizational sustainability assessment in detail.

According to Dzemydienė [4], the science of artificial intelligence provides perspective for modern computer systems development. Artificial intelligence techniques enable simplification of the complex sustainable development processes of organizations and their more effective management however the expert assessment of the sustainable development indicators remains the essential condition for the application of this type of technique.

As an alternative to contemporary models of the sustainable development of organizations, we hereby present the model for the determination of organizational sustainability to facilitate targeted interventions inducing the sustainable development of an organization, performed by the sustainable development organizations' experts.

Forest enterprises play an enormous role in the competitive ability of a certain region. First of all, forest enterprises are large-scale forest managers acting in accordance with the Law on State and Municipal Enterprises and having the legal form of a state enterprise. Furthermore, forest enterprises own and exploit one of the basic natural assets of our country, a forest specifically, which shall serve the prosperity of the State and its citizens and preserve the landscape stability and the environment quality [5]. Forest enterprises, at their own expense, restore cut down forests and plant new ones, develop and supervise them, protect them against fires, pests and diseases, and exercise environmental and recreational measures. The consensus of opinion is that the main purpose of the forest enterprise activities is sustainable forest management in order to meet the public needs for wood and other forest products and to perform the protective and recreational functions of forests. For this reason, it is appropriate to determine and examine the external and internal sustainability of Lithuanian forest enterprises.

Research subject: sustainability of Lithuanian forest enterprises. Research objective: To determine the levels of vital, social, antropogenical and economical efficiency and sustainability in forty Lithuanian forest enterprises on the basis of the developed artificial intelligence model for the determination of organizational sustainability. Research techniques: Analysis of Lithuanian and foreign scientific literature on sustainable development, statistical data analysis, questionnaire survey, expert assessment, simulation, ranking method for determining the indicator significance, visualization method for a self-organizing neural network – the unified distance matrix.

2 MATERIALS AND METHODS

On the grounds of the organizational environment model developed by Brownlie [1] whereby the breakdown of different organizational environment components in levels is explicitly presented, and the sustainable organizational environment model developed by us, the levels of internal and external sustainability can be distinguished.

Examination and assessment of organizational sustainability at two different levels allow us to determine the sustainability of internal and external organizational environment which is closely associated with the components functioning in internal and external environments. In addition, such analysis of organizational sustainability at different levels allows more accurate considerations on a respective level of organizational sustainability.

To illustrate the simplified determination and visualization process of the external and internal sustainability of the forest enterprise, we have developed a artificial intelligence model for the determination of the forest enterprise sustainability.

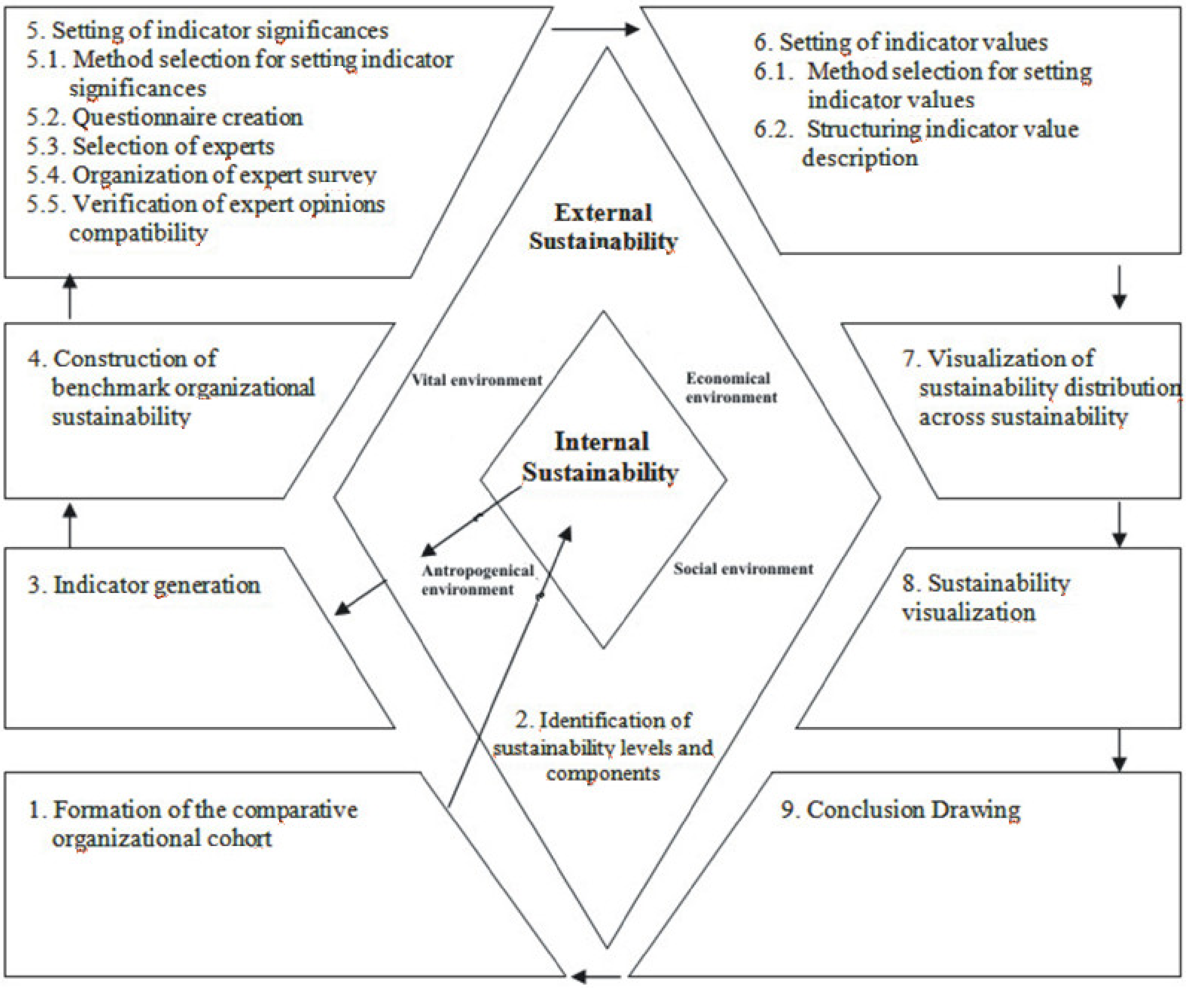

Fig. 1 Artificial Intelligence Model for Determination of Organizational Sustainability
Source: Compiled by the authors.

The representation of the model for determination of organizational sustainability in Fig. 1 shows that the simplified determination process of a certain organization's sustainability (a forest enterprise, in the given case) can be divided into 9 basic stages. In the central part of the model (the second stage of the model), an intervention in the internal and external organizational environment is visualized, wherein the identified vital, social, and antropogenical internal and external environments form the basis for the creation of sustainable organizational environment.

The formation of the comparative organizational cohort is the first stage of the determination process of the forest enterprise sustainability, in which the model input function is actualized. The identification of sustainability levels and components is the second (intermediate) stage of the determination process of the forest enterprise sustainability which provides two sustainability levels and four sustainability components specifying the levels at which the determination process of the forest enterprise sustainability will be carried out, and the organizational sustainability components across which sustainability distribution will be identified. In the given case, we are going to examine only the external sustainability of the forest enterprise.The generation of indicators is the third (intermediate) stage of the determination process of the forest enterprise sustainability. At this stage, the indicator-generating function of sustainable development researchers or professionals responsible for the sustainable development of the organization is actualized. The construction of the benchmark organizational sustainability is the fourth stage of the determination of organizational sustainability. The setting of indicator significances is the fifth stage of the determination of organizational sustainability which consists of the following five substages: a method selection for setting indicator significances, the creation of a questionnaire, the selection of experts, the organization of the expert survey, and the verification of expert opinions compatibility. The selection of methods to be used at the first and the fifth substages should have both, quantitative and qualitative reasoning. Prior to the expert selection procedure, it would be appropriate to have the expert selection criteria for the selection of experts. One of the most important expert selection criteria are their experience and academic qualification.

The setting of indicator values is the sixth stage of the determination of organizational sustainability which consists of the following two substages: the method selection for setting indicator values and structuring the indicator value description.

Visualization of sustainability distribution across the components of sustainability is the seventh stage of the determination of organizational sustainability. At the given stage, the U-matrix is generated by means of visualization methods for self-organizing neural networks. The U-matrix values are represented in the self-organizing map.

Separate U-matrixes are generated for each component of external and internal organizational sustainability, allowing for the identification of the internal and external vital, social, antropogenical and economical efficiency of each organization or, in other words, the identification of the internal and external organizational sustainability distribution across the vital, social, antropogenical and economical components of organizational sustainability.

Sustainability visualization is the eighth stage of the determination of organizational sustainability.

Conclusion drawing is the ninth stage of the determination process of the forest enterprise sustainability, in which the model output function is actualized. At this stage, the new knowledge derived during all the previous stages of the sustainability determination process is summarized. This knowledge helps to make appropriate decisions in the positive inducement of organizational sustainability.

During the determination process of a particular forest enterprise's external sustainability, we can have a real time record of the values of a set of respective indicators of sustainability components which, if appropriately aggregated, can reflect the external sustainability of the organizational environment (see the seventh stage of the determination of organizational sustainability).

Each indicator of the forest enterprise sustainability is associated with a particular component of organizational sustainability, and the indicator value of organizational sustainability is in all cases related to time and a certain respective sustainability component of the sustainability level. In determining the sustainability of a certain forest enterprise, we can have a real time record of the values of a set of respective indicators of sustainability components which, if integrated into self-organizing maps (SOM), can turn into quantitatively expressed distances between each of the forest enterprises in question, by the values of which the organizational environmental sustainability of each forest enterprise can be determined.

In order to determine the forest enterprise external sustainability and its distribution across sustainability components, it is appropriate to use the the visualization methods for self-organizing neural networks and to generate the U-matrix Moreover, the U-matrix values should be placed on the self-organizing map to identify the existing data clusters.

To make the aforementioned comprehensible, we introduce the steps for creating the U-matrix and the self-organizing map of the forest enterprise external sustainability multidimensional dataset:

1. A set of the indicator values for the forest enterprise external sustainability and for the vital, social, antropogenical and economical components of sustainability consistent with the benchmark organizational sustainability is analysed. The given set presents the description of 20 quantitative indicators of external sustainability consistent with the benchmark sustainability for each forest enterprise and organization.
2. The size and topology of a self-organizing map is formed, based on the existing number of training vectors (21, in this case) and the values of the components of the vector M_{kl} are assigned.
3. A training process for the neural network is carried out during which the neurons- winners are identified.
4. A self-organizing map is produced.
5. Based on the data of the self-organizing neural network, the U-matrix is generated which represents the distances between neighbouring neurons that are calculated using Kohonen's (2001) formula:

$$\left\| M_p - M_{kl} \right\| \tag{1}$$

Where:

M_P is the neuron neighbouring the M_{kl} neuron

Self-organizing maps (SOM) have the essential advantage to perform high accuracy multidimensional data clustering and visualization operations. It is for this reason that the use of self-organizing maps in the visualization of multidimensional components of organizational sustainability is quite attractive Stefanovič and Kurasova [9].

In the scientific literature, one can come across a comparatively large number of visualization methods for self-organizing neural networks (component planes, histograms, etc.). The U-matrix is one of more popular visualization methods for self-organizing neural networks. The U-matrix is made up of distances between the neighboring neurons of the self-organizing neural network. E.g., with a dataset consisting of 4 columns and 150 rows, the U-matrix will be a vector of 150 rows and 4 columns. After generating the U-matrix from the initial data, its values must be placed on the self-organizing map which typically consists of rectangular or hexagonal neurons. The scientists Kraaijveld, Mao, Jain [8] proposed a visualization method for self-organizing neural networks by means of which the average distances between neighbouring neurons are presented in gray or coloured scale tones. If the average distances between neighbouring neurons are short, the map components matching these neurons are light-coloured; longer distances between neighbouring neurons are dark-coloured. Consequently, the data clusters existing on the self-organizing map are determined by light tones and the margins are determined by darker tones Kohonen [7], Dzemyda and Kurasova [2].

The visualization method for self-organizing neural networks, the U-matrix, was tested usung the multidimensional data model Fisher (1936) - the four-dimensional Fisher's iris dataset akin to the multidimensional data of organizational sustainability components.

It should be noted that the determined respective external level of organizational environmental sustainability has a strong influence on the external components functioning within organizational environments Dzemyda and Tiešis [3].

3 RESULTS AND DISCUSSION

Distribution visualization and determination of the forest enterprise sustainability are possible only if the vital, social, antropogenical and economical levels of external and internal efficiency for each forest enterprise have been defined showing the distribution of the forest enterprise external sustainability across all the components of sustainability. Besides, it‘necessary do generate artificial intelligence organizational sustainability determination model for organizations quantitative sustainability measurement.

In addition, the set quantitative values for the vital, social, antropogenical and economical levels of each forest enterprise's external efficiency account for the derived overall level of the forest enterprise external sustainability.

The vital levels of the forest enterprise external efficiency occasionally show the progress made by the forest enterprise within the external vital organizational environment.

We maintain that the U-matrix is one of more popular visualization methods for self-organizing neural networks. In our case, the U-matrix is made up of distances between the neighboring neurons of the self-organizing neural network, which are placed in the generated U-matrix of the forest enterprise vital external efficiency multidimensional dataset.

The table below shows a fragment of the U-matrix of the forest enterprise vital external efficiency multidimensional dataset, which represents the distances between neighbouring neurons of the self-organizing neural network between forest enterprises and the benchmark organizational sustainability.

Tab. 1 Fragment of U-matrix of Forest Enterprise Vital External Efficiency Multidimensional Dataset

	Forest Enterprise																			
No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
BOS	4.81	5.49	2.61	4.36	4.57	4.24	5.13	5.58	4.93	3.93	4.10	3.22	4.38	6.98	3.64	3.43	3.96	4.19	4.04	3.04
	Forest Enterprise																			
No.	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
BOS	5.76	5.69	4.43	4.35	3.66	4.93	6.77	6.69	4.62	3.47	5.78	4.83	5.03	2.89	7.45	4.61	3.53	4.75	3.76	5.97

Here:

1. Vilnius Forest Enterprise
2. Nemenčinė Forest Enterprise
3. Ukmergė Forest Enterprise
4. Švenčionėliai Forest Enterprise
5. Trakai Forest Enterprise
6. Šalčininkai Forest Enterprise
7. Jonava Forest Enterprise
8. Kaišiadorys Forest Enterprise
9. Prienai Forest Enterprise
10. Kaunas Forest Enterprise
11. Kėdainiai Forest Enterprise
12. Raseiniai Forest Enterprise
13. Kretinga Forest Enterprise
14. Šilutė Forest Enterprise
15. Kuršėnai Forest Enterprise
16. Tytuvėnai Forest Enterprise
17. Šiauliai Forest Enterprise
18. Pakruojis Forest Enterprise
19. Joniškis Forest Enterprise
20. Radviliškis Forest Enterprise
21. Kupiškis Forest Enterprise
22. Biržai Forest Enterprise
23. Rokiškis Forest Enterprise
24. Panevėžys Forest Enterprise
25. Telšiai Forest Enterprise
26. Rietavas Forest Enterprise
27. Mažeikiai Forest Enterprise
28. Jurbarkas Forest Enterprise
29. Tauragė Forest Enterprise
30. Anykščiai Forest Enterprise
31. Zarasai Forest Enterprise
32. Utena Forest Enterprise
33. Ignalina Forest Enterprise
34. Alytus Forest Enterprise
35. Valkininkai Forest Enterprise
36. Varėna Forest Enterprise
37. Druskininkai Forest Enterprise
38. Veisiejai Forest Enterprise
39. Šakiai Forest Enterprise
40. Marijampolė Forest Enterprise

BOS: Benchmark Organizational Sustainability

Table 1 shows the vital efficiency levels of the benchmark sustainability of each forest enterprise and organization that are based on a certain distance existing between the benchmark sustainability of the forest enterprise and organization. The less the distance, the higher the level of efficiency which declares a more significant progress made by a relevant forest enterprise within the external vital organizational environment in respect of other forest enterprises concerned.

It can be maintained that Ignalina Forest Enterprise is making an average progress within the external vital organizational environment. This is confirmed by Ignalina Forest Enterprise vital external efficiency level of 5.03 positioning between the benchmark organizational sustainability and the maximum and minimum average distance of respective forest enterprises.

The social levels of the forest enterprise external efficiency occasionally show the progress made by the forest enterprise within the external social organizational environment.

Social efficiency levels of the benchmark sustainability of each forest enterprise and organization that are based on a certain distance existing between the benchmark sustainability of the forest enterprise and organization. The analysis of the data provided in the above table shows that the maximum distance of 8.92 exists between Ignalina Forest Enterprise and the benchmark organizational sustainability. Consequently, Ignalina Forest Enterprise is making the least progress within the external social organizational environment in comparison with other forest enterprises. This is confirmed by the lowest social external efficiency level recorded among all the forest enterprises. Meanwhile, the minimum distance of 6.45 exists between Šiauliai Forest Enterprise and the benchmark organizational sustainability. As a result, Šiauliai Forest Enterprise is making the most progress within the external social organizational environment in comparison with other forest enterprises as confirmed by the highest social external efficiency level recorded among all forest enterprises concerned.

It can be maintained that Trakai and Veisiejai Forest Enterprises are making an average progress within the external social organizational environment. This is confirmed by Trakai and Veisiejai Forest Enterprises social external efficiency level of 7.70 positioning between the benchmark organizational sustainability and the maximum and minimum average distance of respective forest enterprises.

The antropogenical levels of the forest enterprise external efficiency occasionally show the progress made by the forest enterprise within the external antropogenical organizational environment.

We maintain that the U-matrix is one of more popular visualization methods for self-organizing neural networks. In our case, the U-matrix is made up of distances between the neighboring neurons of the self-organizing neural network, which are placed in the generated U-matrix of the forest enterprise antropogenical external efficiency multidimensional dataset.

Antropogenical efficiency levels of the benchmark sustainability of each forest enterprise and organization that are based on a certain distance existing between the benchmark sustainability of the forest enterprise and organization. The less the distance, the higher the level of efficiency which declares a more significant progress made by a relevant forest enterprise within the external antropogenical organizational environment in respect of other forest enterprises concerned.

The economical levels of the forest enterprise external efficiency occasionally show the progress made by the forest enterprise within the external economical organizational environment.

We maintain that the U-matrix is one of more popular visualization methods for self-organizing neural networks. In our case, the U-matrix is made up of distances between the neighboring neurons of the self-organizing neural network, which are placed in the generated U-matrix of the forest enterprise economical external efficiency multidimensional dataset.

Economical efficiency levels of the benchmark sustainability of each forest enterprise and organization that are based on a certain distance existing between the benchmark sustainability of the forest enterprise and organization. The less the distance, the higher the level of efficiency which declares a more significant progress made by a relevant forest enterprise within the external economical organizational environment in respect of other forest enterprises concerned.

It can be maintained that Trakai Forest Enterprise is making an average progress within the external economical organizational environment. This is confirmed by Trakai Forest Enterprise economical external efficiency level of 10.22 positioning between the benchmark organizational sustainability and the maximum and minimum average distance of respective forest enterprises.

The levels of the forest enterprise external sustainability occasionally show the progress made by the forest enterprise within the external organizational environment.

We maintain that the unified U-matrix is one of more popular visualization methods for self-organizing neural networks. In our case, the U-matrix is made up of distances between the neighboring neurons of the self-organizing neural network, which are placed in the generated U-matrix of the forest enterprise economical internal efficiency multidimensional dataset.

External sustainability levels of the benchmark sustainability of each forest enterprise and organization that are based on a certain distance existing between the benchmark sustainability of the forest enterprise and organization. The analysis of the data provided in the above table shows that the maximum distance of 16.82 exists between Jurbarkas Forest Enterprise and the benchmark organizational sustainability. Consequently, Jurbarkas Forest Enterprise is making the least progress within the external organizational environment in comparison with other forest enterprises. This is confirmed by the lowest external sustainability level recorded among all the forest enterprises. Meanwhile, the minimum distance of 14.04 exists between Kėdainiai Forest Enterprise and the benchmark organizational sustainability. As a result, Kėdainiai Forest Enterprise is making the most progress within the external organizational environment in comparison with other forest enterprises as confirmed by the highest external sustainability level recorded among all forest enterprises concerned.

It can be maintained that Tytuvėnai Forest Enterprise is making an average progress within the external organizational environment. This is confirmed by Tytuvėnai Forest Enterprise external sustainability level of 15.43 positioning between the benchmark organizational sustainability and the maximum and minimum average distance of respective forest enterprises. Having generated the U-matrix from the training dataset of overall internal and external sustainability components of the forest enterprise, we present its values in Kohonen map, in which neurons are arranged on a hexagonal lattice.

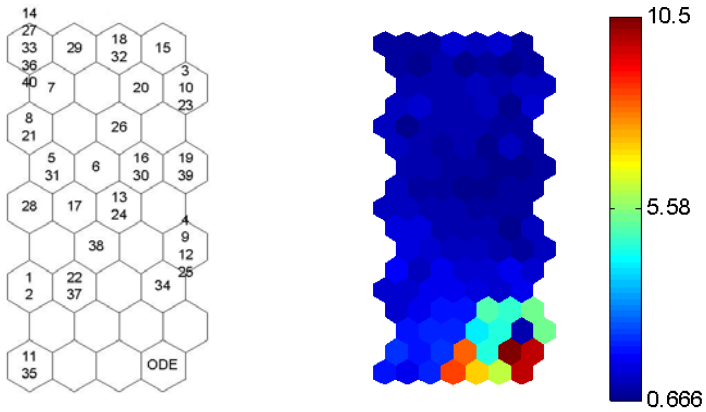

Fig. 2 Self-Organizing Neural Network of Forest Enterprise Sustainability

Source: Compiled by the authors

1. Vilnius Forest Enterprise
2. Nemenčinė Forest Enterprise
3. Ukmergė Forest Enterprise
4. Švenčionėliai Forest Enterprise
5. Trakai Forest Enterprise
6. Šalčininkai Forest Enterprise
7. Jonava Forest Enterprise
8. Kaišiadorys Forest Enterprise
9. Prienai Forest Enterprise
10. Kaunas Forest Enterprise
11. Kėdainiai Forest Enterprise
12. Raseiniai Forest Enterprise
13. Kretinga Forest Enterprise
14. Šilutė Forest Enterprise
15. Kuršėnai Forest Enterprise
16. Tytuvėnai Forest Enterprise
17. Šiauliai Forest Enterprise
18. Pakruojis Forest Enterprise
19. Joniškis Forest Enterprise
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29. Tauragė Forest Enterprise
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39. Šakiai Forest Enterprise
40. Marijampolė Forest Enterprise

BOS: Benchmark Organizational Sustainability

Fig. 2 shows that that the self-organizing Kohonen map (neural array) of the forest enterprise sustainability, generated by the author by means of training without the teacher, has organized itself using the prepared in advance training set of the economical sustainability component of the internal sustainability of 40 forest enterprises. In this case, the training set of the forest enterprise sustainability comprised 40 indicators meanwhile the self-organizing Kohonen map of the forest enterprise sustainability is composed of 4x9 neurons which are visualized at the nodes of a two-dimensional map. Each element of Kohonen map corresponds to n-dimensional vector (n = 40 in the given research because 40 indicators desribing the level of the forest enterprise sustainability are present).

The analysis of the self-organizing Kohonen map of the forest enterprise sustainability indicates that the neighbouring nodes in the input vector space of the artificial neural network are represented close to each other on Kohonen map thus forming clusters of different sizes. All the distances between neighbouring neurons on Kohonen map are represented by the relevant tones of a coloured scale.

The data clusters existing on Kohonen map are clearly visible and identified by relevant colour visualizations of the map components and the actualized clear positioning of each organization in question on Kohonen map. All this confirms the aforementioned levels of the forest enterprise sustainability.

It should be stressed that the generated self-organizing Kohonen map of the forest enterprise sustainability presented above provides a lot of additional valuable information that could be used for a deeper insight into the levels of the forest enterprise sustainability and the causes of their appropriate level which lie in the primary indicator value descriptions of the forest enterprise sustainability and in the datasets of the primary indicator value descriptions of the forest enterprise sustainability.

4 CONCLUSIONS

1. The sustainable development of forest enterprises can be induced by regulated, spontaneous or planned interventions which can be formed both, internally and externally, and which can be directed to the employees functioning within the internal environment of the organization or to the local/regional-scale customers, suppliers, partners and community members operating within the external environment of the organization.

2. The developed and described model for the determination of organizational sustainability explains the determination process of a certain organization's sustainability, which consists of 9 basic stages, however it does not reveal all the side factors governing the determination process of organizational sustainability (decision-making, grouping of responsible persons, task assignment, coordinating actions, primary data collection, etc.).

3. The self-organizing maps (SOM) have the essential advantage to perform high accuracy multidimensional data clustering and visualization operations. It is for this reason that the use of self-organizing maps for the transformation of multidimensional components of organizational external sustainability into two-dimensional space is quite attractive.

4. The analysis of the data provided in a fragment of the U-matrix of the forest enterprise vital external efficiency multidimensional dataset showed that Valkininkai Forest Enterprise is distinguished for the minimum vital efficiency which is argued by the maximum distance of 7.45 existing between Valkininkai Forest Enterprise and the benchmark organizational sustainability. Meanwhile Ukmergė Forest Enterprise is distinguished for the maximum vital efficiency which is argued by the minimum distance of 2.61 existing between Ukmergė Forest Enterprise and the benchmark organizational sustainability.

5. The analysis of the data provided in a fragment of the U-matrix of the forest enterprise social external efficiency multidimensional dataset showed that Ignalina Forest Enterprise is distinguished for the minimum

social efficiency which is argued by the maximum distance of 8.92 existing between Ignalina Forest Enterprise and the benchmark organizational sustainability. Meanwhile Šiauliai Forest Enterprise is distinguished for the maximum social efficiency which is argued by the minimum distance of 6.45 existing between Šiauliai Forest Enterprise and the benchmark organizational sustainability.

6. The respective vital, social, antropogenical and economical levels of the forest enterprise efficiency indicate the distribution of each forest enterprise's external sustainability and account for the causes of levels of a certain external sustainability.

7. The analysis of the data provided in a fragment of the U-matrix of the forest enterprise external sustainability multidimensional dataset proved that Jurbarkas Forest Enterprise is distinguished for the lowest level of external sustainability which is confirmed by the maximum distance of 16.82 existing between Jurbarkas Forest Enterprise and the benchmark organizational sustainability. Meanwhile, the minimum distance of 14.04 existing between Kėdainiai Forest Enterprise and the benchmark organizational sustainability proves that Kėdainiai Forest Enterprise is distinguished for the highest external sustainability level.

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