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Olga G. Berestneva [1], Professor, Doctor of Technical Sciences;
Alexei A. Tikhomirov [2], Professor, Doctor of Economic Sciences;
Andrey I. Trufanov [3], Associate Professor, Candidate of Physical and Mathematical Sciences;
Maria V. Kuklina [4], Associate Professor, Candidate of Economic Sciences;
Dmitriy V. Kobylkin [5], Candidate of Geographical Sciences;
Natalia E. Krasnoshtanova [6], Candidate of Geographical Sciences;
Victor N. Bogdanov [7], Candidate of Geographical Sciences;
Elena A. Istomina [8], Candidate of Geographical Sciences;
Eduard A. Batotsyrenov [9], Candidate of Geographical Sciences;
Denis A. Dirin [10], Associate Professor, Candidate of Geographical Sciences;
Antonina N. Savvinova [11], Associate Professor, Candidate of Economic Sciences;
Victoria V. Filippova [12], Associate Professor, Candidate of Historical Sciences;
Erdenebaatar Altangerel [13], Professor, Doctor of Technical Sciences;
Zolzaya Dashdorj [14], Associate Professor, PhD

NETWORK METRICS IN SUSTAINABLE DEVELOPMENT OF REMOTE TERRITORIES

[1] Tomsk Polytechnic University, Tomsk, Russia, ogb6@yandex.ru;
[2] Inha University, Incheon, Republic of Korea, alexeitikhomirovprof@gmail.com;
[3, 4] Irkutsk National Research Technical University, Irkutsk, Russia, [3] troufan@gmail.com, [4] kuklina-kmv@yandex.ru;
[5, 6, 7, 8] V.B. Sochava Institute of Geography SB RAS, Irkutsk, Russia, [5] agrembrandt@inbox.ru, [6] knesun@mail.ru, [7] victvss@gmail.com, [8] elenaistoma@gmail.com;
[9] Baikal Institute of Nature Management SB RAS, Ulan-Ude, Russia, edikbat@gmail.com; [10] Institute of Earth Sciences, University of Tyumen, Tyumen, Russia, d.a.dirin@utmn.ru;
[11] Institute of Natural Sciences, M.K. Ammosov North-Eastern Federal University, Yakutsk, Russia, sava_73@mail.ru;
[12] The Institute for Humanities Research and Indigenous Studies of the North SB RAS, Yakutsk, Russia, filippovav@mail.ru;
[13, 14] Mongolian University of Science and Technology, Ulaanbaatar, Mongolia, [13] erka@must.edu.mn, [14] zolzaya.dashdorj@gmail.com

Abstract. Significant part of Russian Arctic, Siberian, and Far Eastern regions contain sparsely populated terrains interconnected with the other world through poor transportation arteries (infrastructures, corridors, gates). It is notable that remoteness as a rule is concurrent with tough climatic and other natural conditions indigenous people encounter such as long severe winter, earthquakes, avalanches, floods, etc. In this regard, it seems important to perform interdisciplinary works that reveals the problems and their solutions for the socio-economic and environmental systems of such remote areas. Even Sustainable Development Goals, pertinent Global indicator framework, and targets of the 2030 Agenda are considered within world society people in the trenches feel those often are too far from practical usage. Numerous indicators proposed to assess moving towards the Goals leave the situation in many cases vague and obscure. The current work attempts to reduce to a reasonable minimum the number of metrics just to assess sustainability of entities in specific network model of socio-economic and natural environment of a territory. These comprehensive metrics are concurrent to ordinary measures of network connectivity, augmented with robustness and efficiency. The results might be useful to provide local, regional, and national policymakers with efficient and effective instruments while choosing territory development programs.

Keywords: hard-to-reach terrains, sustainable development, SDGs and associated targets, unique indicators, cross-disciplinarity, network science, metrics.

Берестнева Ольга Григорьевна [1], профессор, д-р техн. наук;
Тихомиров Алексей Анатольевич [2], профессор, д-р экон. наук;
Труфанов Андрей Иванович [3], канд. физ.-мат. наук, доцент;
Куклина Мария Владимировна [4], доцент, канд. экон. наук;
Кобылкин Дмитрий Владимирович [5], канд. географ. наук;
Красноштанова Наталья Евгеньевна [6], канд. географ. наук;
Богданов Виктор Николаевич [7], канд. географ. наук;
Истомина Елена Александровна [8], канд. географ. наук;
Батоцыренов Эдуард Аюрович [9], канд. географ. наук;
Дирин Денис Александрович [10], доцент, канд. географ. наук;
Саввинова Антонина Николаевна [11], доцент, канд. экон. наук;
Филиппова Виктория Викторовна [12], доцент, канд. ист. наук;
Алтангерел Эрденебаатар [13], профессор, д-р техн. наук;
Дашдорж Золзая [14], доцент, доктор философии

СЕТЕВЫЕ ПОКАЗАТЕЛИ В УСТОЙЧИВОМ РАЗВИТИИ ОТДАЛЕННЫХ ТЕРРИТОРИЙ

[1] Россия, Томск, Томский политехнический университет, ogb6@yandex.ru;
[2] Республика Корея, Инчхон, Университет Инха, alexeitikhomirovprof@gmail.com;
[3, 4] Россия, Иркутск, Иркутский национальный исследовательский технический университет, [3] troufan@gmail.com , [4] kuklina-kmv@yandex.ru;
[5, 6, 7, 8] Россия, Иркутск, Институт географии им. В.Б. Сочавы СО РАН, [5] agrembrandt@inbox.ru, [6] knesun@mail.ru, [7] victvss@gmail.com, [8] elenaistoma@gmail.com; [9] Россия, Улан-Удэ, Байкальский институт природопользования СО РАН, edi-kbat@gmail.com;
[10] Россия, Тюмень, Институт наук о Земле Тюменского университета, d.a.dirin@utmn.ru; [11] Россия, Якутск, Институт естественных наук Северо-Восточного федерального университета им. М.К. Аммосова, sava_73@mail.ru; [12] Россия, Якутск, Институт гуманитарных исследований и изучения коренных народов Севера СО РАН, filippovav@mail.ru;
[13, 14] Монголия, Улан-Батор, Монгольский университет науки и технологии, [13] erka@must.edu.mn, [14] zolzaya.dashdorj@gmail.com

Аннотация. Значительная часть российских арктических, сибирских и дальневосточных регионов содержит малонаселенные территории, соединенные с остальным миром слаборазвитыми транспортными артериями (инфраструктурой, коридорами, проходами). Примечательно, что удаленность, как правило, сопровождается суровыми климатическими и другими природными условиями, с которыми сталкиваются коренные жители, такими как долгая суровая зима, землетрясения, лавины, наводнения и т. д. В этой связи представляется важным выполнение междисциплинарных работ, которые выявляют проблемы и их решения для социально-экономических и экологических систем таких отдаленных районов. Эксперты-прикладники считают, что Цели Устойчивого Развития (ЦУР) ООН, соответствующая им система глобальных показателей и задачи Повестки дня на период до 2030 года рассматриваемые в мировом обществе, слишком далеки от практического применения. Многочисленные показатели, предлагаемые для оценки продвижения к целям, во многих случаях оставляют ситуацию расплывчатой и неясной. В текущей работе предпринята попытка свести к разумному минимуму количество показателей для оценки устойчивости объектов в конкретной сетевой модели социально-экономической и природной среды территории. Эти всеобъемлющие показатели совпадают с обычными показателями сетевой связности, дополняемые надежностью и эффективностью. Результаты могут быть полезны для предоставления эффективных инструментов местным, региональным и национальным директивным органам при выборе программ развития территорий.

Ключевые слова: труднодоступные территории, устойчивое развитие, ЦУР и связанные с ними задачи, уникальные индикаторы, междисциплинарность, сетевая наука, метрики.

Introduction

Many terrains on the Earth still needs in better development to support well-being of local people. Mostly it concerns remote rural sites. Usually these are difficult to reach places, sparsely populated but extremely rich in natural resources.

It is notable that remoteness accompanies to significant natural wealth of such territories simultaneously with low or modest socio-economic situation. To achieve the sustainable development goals SDGs proposed by the United Nations 2030 Agenda it is important to supply with a novel cut-edge paradigm with models and practical instruments. Lack of notable studies of such terrains stimulates interest in conducting scientific research including multi- and cross-disciplinary ones. Contemporary investigations directs the efforts on provision of higher standards of living of indigenous people along protection of cultural and natural diversity both.

Because of countless interconnected actors within socio-economic and environment systems located on these terrains researches formulates the problem as a complex one [1]. One of the most productive platforms to deal with such problems is presented by Network Science [2] which proves its effectiveness and strengths in diverse domains and their crossovers.

Our previous works with clarification of geographical details, collecting interviews which indicates needs of residents, and elaboration of advanced network-based models of the socio-economic and environmental processes stimulates us to go further in scrutinizing the development prospects of the remote territories. As many works posit (e. g. [3]) unsustainability of the world on local, regional, national and global levels is the result of active human activities accompanied by damage of biosphere. Changing this dangerous world trajectory and provide sustainability in all respects on all levels for sake of current and future generations, has become contemporary challenge for the humankind. To monitor the trajectory a set of sustainability measures, indicators and indices have become in the centre of attention for policymakers, practitioners and explorers. Preparation and usage of such a set is not an easy task which only exacerbates by neighboring with the diversity of disciplines concomitant sustainability. The works (see [3]) noted that correction of the development trajectory toward sustainability is one of the key steps which include untangling complexity and unification of the socioeconomic and environmental dimensions of the issue.

Contemporary ICT approaches promote projects to support smart development of remote territories, rural , and urban both.

Among others the work [4] simulates the features of the implementation of smart city projects focused on solving the problems of the development of the Arctic. The authors proposed a methodology for the development of alternative options (scenarios) for the implementation of control algorithms. It was noted that the mandatory component of the control methodology is the control process and the analysis of the compliance of the results with the declared target indicators.

As [5] underlined rural environment represents a system which clearly demonstrates differences in development at local , national , and international scales. Such rural specificity and the significant shortage of indicators coherently reflect local regional, national and international needs.

In whole the manner to achieve sustainable development in line with its three key dimensions — economic, social and environmental (so called is formulated as balanced and integrated one. In this concern the UN [6] suggested **17 Sustainable Development Goals** with **169 associated targets** which compose integrated and indivisible entity. This concept was supported by all countries of the world. Also that was of value to monitor the progress towards the SDGs. closeness towards these Targets is accepted to be tracked by **232 specific Indicators** [7]. It is notable significant complexity of the indicators in their numerousness.

To overcome complexity and some confusion in such a set of indicators diverse domain experts operate the list in separate manner [8] just to filter their own needs. So this signals on the process reciprocal to trans disciplinarity.

In our field studies [9–18] through large interviews with local government representatives , it was detected that people understand the Goals but contemplate them through their own scope with regional and national indicators.

We definitely found that multitude of the indicators brings no inspiration for researchers, experts in industries and business, and for those who make decisions.

Perceiving this, the Inter-agency and Expert Group on SDG indicators (IAEG — SDG) [19] who suggested the platform with 232+ indicators , proposed to disaggregate the indicators. It means that individuals, organizations, and governments may apply the indicators that are best suited to the specificities of their domain to monitor their own progress towards sustainable development and then deliver data to the national repository. We should underline that such a disaggregation leads to the lost of integrity and wholeness of description and perception.

In regard with the multitude of the indicators in some respects this might include consideration in neocortical activity just the field that was deeply scrutinized by Dunbar [20]. He posited key number of social entities ~150, that individual human brain is able to operate with.

Further the series of typical group sizes of ~5,~15, ~50 and ~150, which forms so called Dunbar's circles [21] have been discussed.

However, our hypothesis is that key numbers are not limited with social brain activity only but those spread on diverse entities including measure, metric and indicators. In this concern we take into account that it is so difficult to subitize sets larger than approximately four elements excluding only if the elements constitute a pattern familiar for the individual [22].

The work [23] recalled that cognition is characterized by limited capacity: Individuals can operate simultaneously with four items in average. So it became more clear that it was introduced only three (not more) — item framework so called triple bottom line for diverse organizations to consider social, financial, and environmental results just to provide sustainable future and be responsible for that [24].

The subitizing phenomenon prompts that it should be a most suitable number for SDG indicators to share among the interested parties. In this regard we have tried to minimize the number to make the indicators more acceptable in theoretical, practical and cross-disciplinary significance.

1. Related works

Twenty years ago practical aspects of sustainable strategies considered as essentially complex and vaguely understood to be implemented as was underlined in [25]. Researches noted the complexity of the problem [3] due to tangled interconnectivity of numerous actors within socio-economic and environment components of territory systems. Moreover the components are interdependent , thus economic progress depends on both social and environmental assets, whereas both economic and social factors exert influence over environment.

The platform of Network Science was found extremely productive in diverse domains and their crossovers. Thus the paper [26] proposed to apply general network analysis to assess the set of 17 SDGs and to unveil underlined interconnection between them for further prospective design of decision support system focused on sustainability-driven polices of national scales.

The authors of [27] analyzed topologies of such dense settlements as cities. They contemplated diverse network metrics to characterize and compare the topologies. Some measures for such complex systems as cities were examined in [28]. Notably that [29] found the principal barriers of usage network-based connectivity techniques are announced as difficulties in selecting sites to explore and the shortage of landscape and distance data. The big plus which network approach brings as the practitioners reported is in graphical, quantitative and robust results.

2. Approaches and methods

Current interdisciplinary study put into the focus network science techniques.

The description of multilayer network for connecting the sustainable development goals (SDGs), targets and pertinent indicators supplied with the longitudinal datasets of The World Bank, 2018 was reported in [30], see Fig. 1.

The idea to apply network approach (mostly within graph theory) for ecological studies which often face with splitting and concomitant loss of landscape connectivity has been developed for some period [29, 31].

Usually, in network scope, landscape patches are considered as network nodes that might be binded. Such a network reflects the potential for living beings to migrate between habitats. Nodes should be connected in case when the span between habitats is not greater than threshold distance which the living bengs are able to cover.

Network approach for scrutinizing connectivity of landscape [32] provides mapping of interconnections between the pertinent processes and landscape topology. The papers [33, 34] shared how successful is the approach while applied toward wildlife sustainability through implementation of thorough protection programs. The study [31] used network-driven connectivity metrics both simple such as number of nodes (presented by space-anchored patches), number of connection (links) between nodes, and some special ones: Harary-index, integral connectivity indicator, and some others. These metrics characterize the landscape splitting process and are useful for detection of patches that matter. Thus these were attractive to use in the current study.

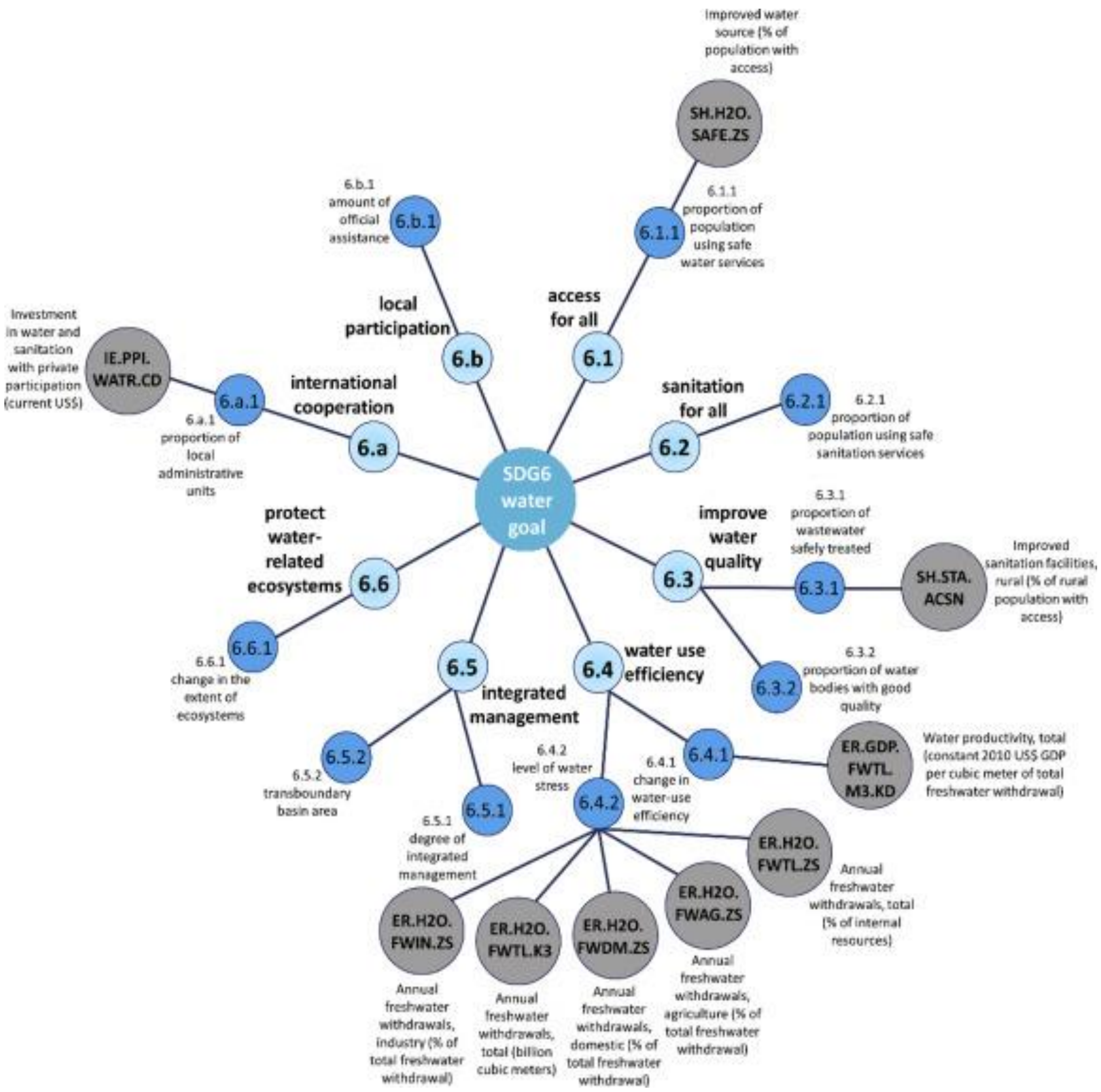

Fig. 1. Representation of World Bank data links in line with the SDG6 “water goal”. Source: [30]

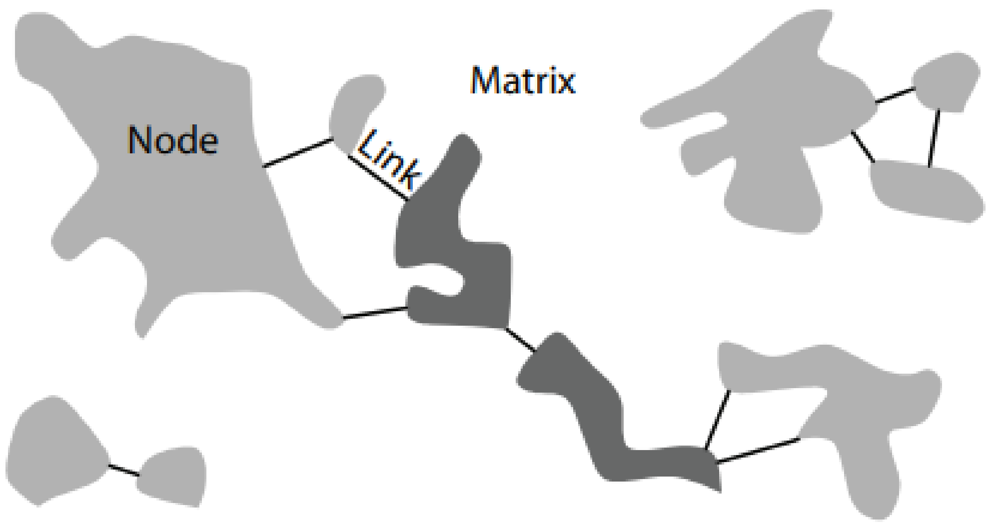

Fig. 2. Illustrative example: connectivity of natural habitats. Source: [31]

To contemplate network science to sustainability problems of remote territories with an enormous number of actors of different natures and levels a combined stem network model set was put in the center of the study [35].

Some basic network points to reduce the number of sustainability metrics to reasonable minimum are:

– An advanced enhanced spaced combined stem network (ESCSN) methodology [36] with its qualitative description has been suggested as a solid scope of complex systems.

– General network terminology has been utilized which promotes eliminating gaps between different disciplines and communities in context of combined stem networks.

– The models include numerous sorts of elements with formalized interactions of social, economic and environmenal networks.

– The proposed network approach is more comprehensive and deepens into the nature of studied domains if compare with graph techniques which concentrate on formal issues and tool specificities only.

3. Results

Simple and initial metrics of connectivity might be suggested for all the TBL landscapes: Social, economic, and environmental ones.

These three spheres affect each other. However, the comparability between them has not been quantified clearly, e. g. for social and economic ties [37], partly because of the inability to operationalize pertinent relationships taking into account classic theories, e. g. that of Granovetter [38].

Besides the simple elementary metrics (number of nodes, number of links) which are suitable to assess the connectivity of the the species of concern as the works [39–41] noted other various measures of concomitant graphs can be applied: graph diameter, correlation length, number of network clusters, and one might add others (e. g. average degree, degree distribution, average clusterization coefficient, etc.).

Additionally only few might be few of indicators are really of value to assess sustainability though connectivity metrics, which compose a pertinent vector Su with Su_1, Su_2, ..., Su_{nm} components, nm is number of chosen indicators. It is necessary to address these metrics to the network subspaces that were introduced in [36]: A, F, R, i. e. Su^A, Su^F, Su^R.

Moreover, if follow [36] and take into account that *local* spaced-anchored networks are components of pertinent *national* and *global* network systems) (Fig. 3) the vector of Su should be supplied with additional codes l, n, g: (Su^{Al}, Su^{An}, Su^{Ag}), (Su^{Fl}, Su^{Fn}, Su^{Fg}), (Su^{Rl}, Su^{Rn}, Su^{Rg}) which correspond different space scales.

Notably that the Su metrics thus can be different according to their scaled scale.

Also it is of sense to consider more specialized metrics of sustainability in regard with ability of the TBL components to be developed (in terms of efficiency) and to withstand their damage (in terms of robustness). In line with

Well-known everage efficiency of a network was introduced in 2001 by the Equation [42]:

$$E(G) = \frac{1}{n(n-1)} \sum_{\upsilon_i \neq \upsilon_j \in V} \frac{1}{d^*_{ij}}$$

Which implies under d^*_{ij} the shortest path between the nodes i and j, V $\{(v_i, v_j)\}$ is the set of n nodes.

This equation was applied in network studies of social insects. To accommodate it for the anchored-subspace ontology and its different scale stratification we indicate efficiencies as: (Eu^{Al}, Eu^{An}, Eu^{Ag}), (Eu^{Fl}, Eu^{Fn}, Eu^{Fg}), (Eu^{Rl}, Eu^{Rn}, Eu^{Rg}).

Classic Measure of Topological Robustness R was presented in [43]:

$$R = \frac{1}{N} \sum_{Q=1}^{N} s(Q).$$

Here N is the number of nodes in the network, $s(Q)$ gives the portion of nodes in the giant connected set after $Q = qN$ nodes been removed. The coefficient $1/N$ normalizes the value of robustness to compare networks of unequal sizes.

R should be supplied with pertinent notations to address those to the three subspaces and three scales: (Ru^{Al}, Ru^{An}, Ru^{Ag}), (Ru^{Fl}, Ru^{Fn}, Ru^{Fg}), (Ru^{Rl}, Ru^{Rn}, Ru^{Rg}).

To differ numerous actors in their heterogeneity such an approach [44] might be taken into account.

4. Discussion

Thus, the number of metrics for assessing sustainability of the terrain might be reduce to 27 if use the network approach in [36] interpretation. It is of value that not only administration (local and national), international institutions but evidently the most active industries as those of mining and tourism while elaboration and implementation the processes for remote territories (Fig. 3) in line with TBL balance take into consideration the metrics we proposed. This network base with small-numbered metrics promotes mutual understanding and collaboration focused on wellbeing of indigenous people , environment protection and interests of all the parties. More over in some practical cases it might be of sense to use only small part of the set of proposed metrics, nine of those or lesser.

One may add that in whole the SCSN model supplemented with proposed metrics promotes surmounting digital divide, level divide, and disciplinary divide as well.

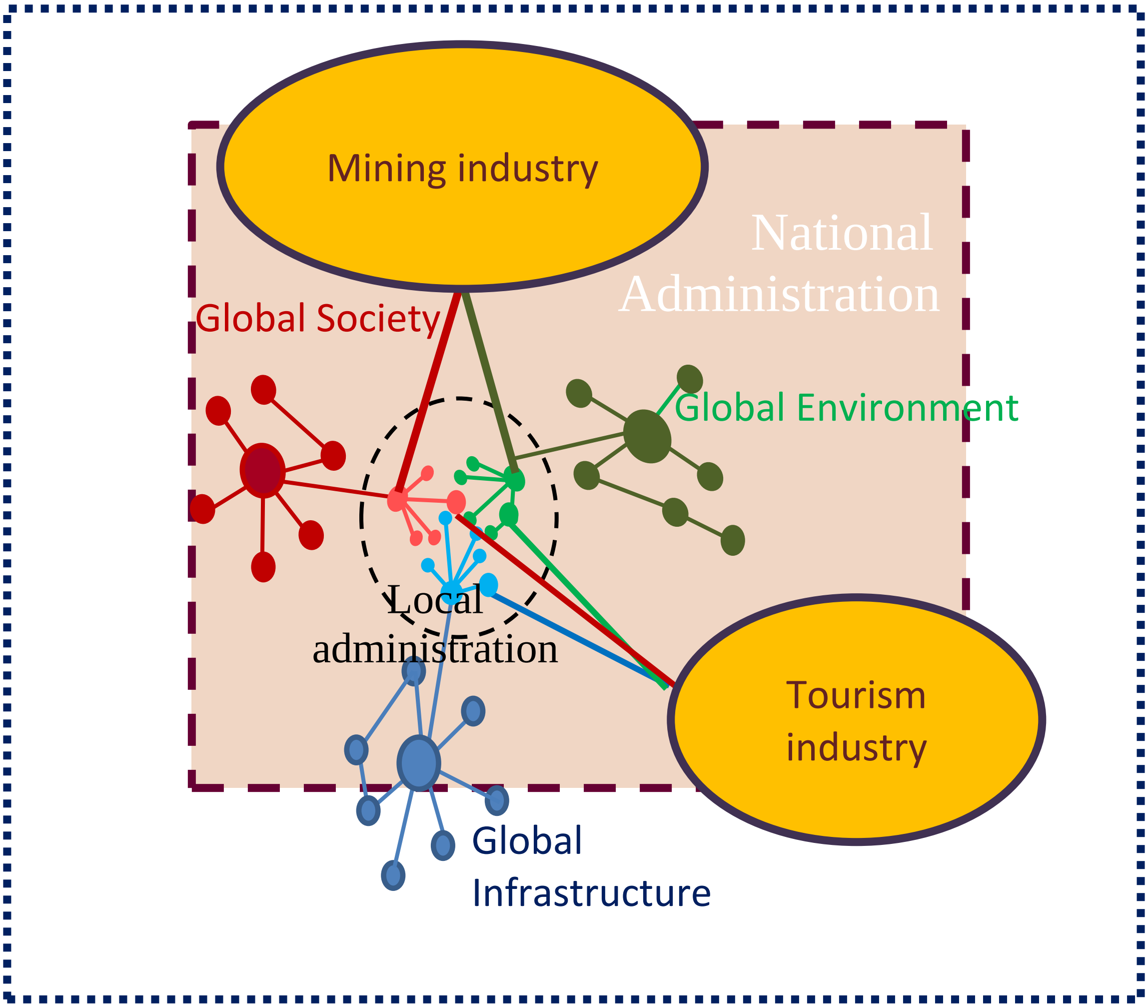

Fig. 3. ESCSN with scaling (Local, National and international) to implement TBL balance

Conclusions

The novelty of the study comprises proposed reasonable number of metrics to assess sustainability of the terrain in line with enhanced spaced combined stem network (ESCSN) model in local, national and global scales. These thorough metrics are based on ordinary network parameters and measures of efficiency and robustness.

In order to reduce to a reasonable minimum the number of SDG indicators from current global to national and local applicability advanced model augmented by Triple bottom line-oriented ranking of elements (ESCSN-TBL) has been suggested as a framework for comprehensive assessment of controversial programs for development of remote rural territories with vulnerable indigenous societies and fragile nature.

The ESCSN-TBL version of the model allows to operate with a smaller number of metrics through which it is possible to characterize sustainability and dynamics of the socio-economic and environmental processes.

The results might exert influence while engineering instruments and methods to provide local and regional administrations for the assessment and comparison of territory development processes.

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