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SUSTAINABLE DEVELOPMENT DESIGN AND MANAGEMENT METHODOLOGY USING NATURAL SCIENCE UNITS

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Abstract. The design and management of social and economic systems, which are not coordinated with the possibilities of the natural environment, its reproductive capacity and the laws of nature, have created such trends, the effects of which neither the planet nor its inhabitants can withstand for a long time. Without management and outside of management, it is fundamentally impossible to move into a new quality and ensure sustainable development in the long term, covering the system of cycles - crises of modern world civilization. The purpose of this article is to describe a multi-level model for designing (planning) and managing the sustainable development of socioeconomic objects in the invariant coordinates' system using power (energy) units of measures. The novelty of the approach lies in the fact that, based on the analysis of socioeconomic, technical and environmental factors that determine the sustainable development, natural science meters are determined, reduced to universal power unit of measurement in systems that are open at the input and output in terms of energy. Within the framework of the proposed design model, the data of the Central Statistical Office of the EU, the World Bank and the United Nations Organization database were used for calculations. The main results presented in the article were calculated and primary interpreted for Latvia. Latvia's situation in the period 2008-2019 can be characterized as unsustainable development, and if it continues, it would mean long-term stagnation and further degradation.

Key words: sustainable development, system "nature-society-human", parameters of design and management, natural science units.

JEL code: E19, F69, Q59, R10

Introduction

Nowadays, many regions of the world face the risk of permanent destruction of existing systems and environments. The design and management of social and economic systems, which is not coordinated with the possibilities of the natural environment, its reproductive capacity and the laws of nature, has created such trends, the effects of which neither the planet nor its inhabitants can withstand for a long time. This is not about individual crises, but about a single systemic crisis of the global system "nature-society-human". Without management and outside of management, it is fundamentally impossible to move into a new quality and ensure sustainable development in the long term, covering the system of cycles - crises of modern world civilization. Development is sustainable for a certain cycle of the existence of the Living System (Bauer, 2002), if during this period there is a continuous increase in the efficiency of using the consumed power. In the transitions between cycles, the chronointegrity of development is destroyed, dimensional spatial-temporal gaps arise - crises that require breakthrough management technologies, where sustainable development becomes the strategic goal of managing the way out of the crisis. Sustainable development is achieved when management (i.e. decisions, plans, programs, projects and specific activities) is consistent with the law of conservation development of life. The resolution of contradiction in pair "opportunity - need" and the solution of the problem, is carried out through the design (planning), development and implementation of sustainable development tasks (Kuznetsov,2004).

The purpose of this article is to describe a multi-level model for designing (planning) and managing the sustainable development of socioeconomic objects in the invariant coordinates' system using power

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(energy) units of measures. The design procedure includes solving the following tasks: assessment of the existing condition; target selection; assessment of the required condition; projected efficiency estimates. Within the framework of the concept of ecological economics (Capra, Jakobsen, 2017) and taking into account the conclusions of the energy theory of cost (Costanza, 2004), in order to formalize the tasks of sustainable development, a sustainable development designing model was developed with the method of power and energy flows' changes analysing in open dynamic socioeconomic systems (Trusina, Jermolajeva, 2021).

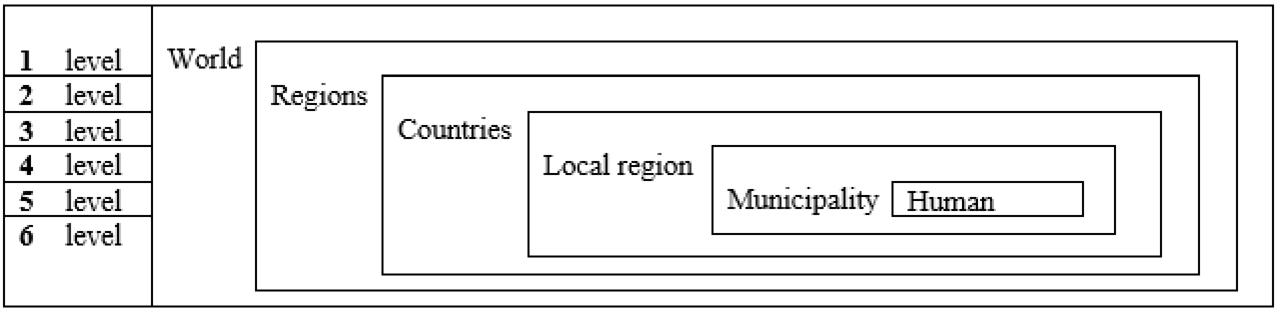
The novelty of the approach lies in the fact that based on the analysis of socioeconomic, technical and environmental factors that determine the sustainable development, natural science meters are determined, reduced to one unit of measurement in systems that are open at the input and output in terms of energy. This approach makes it possible to compensate for existing limitations in sustainable development design and management methods, as well as to formulate the relationship between the principle of sustainable development and the patterns of changes in the socioeconomic environment.

Within the framework of the proposed design model, the data of the Central Statistical Office of the EU (Eurostat), the World Bank (World Bank) and the United Nations Organization (UNDATA) were used for calculations. The main results presented in the article were calculated and primary interpreted for Latvia.

Theoretical discussion

Sustainable development design is an ideal image or a plan of purposeful changes for an Object limited in time and space with certain sustainable development requirements for the quality of results, possible resource spending frameworks and special organization. The reason for designing a sustainable development is a problem situation (negative changes) or an unsatisfied need, which gives rise to the idea of removing dissatisfaction, solving the problem situation, preventing or reducing negative changes in the "nature-society-human" system. Society should take into account several research methods in its interaction with nature: the "society-nature" system is an integral part of the "Life" system (Vernadsky, 2006) and cannot exist in isolation from the laws of its conservation and change; the system in a discrete-continuous mode exchanges flows with the surrounding natural and social environment - the system is open; the system is a dynamic complex network of flows interacting in time and space (energy, material, information and cost); connections and interactions of flows circulating in the system are generally non-linear; the system as a whole (and all its subsystems) has a certain positive value of free energy, essentially different from zero, which enables it to perform useful external work; the system of social production is developing steadily if there is a non-decreasing rate of growth in the efficiency of using its power, the measure of which is the growth rate of useful power; the system of social production degrades if there is a steady decrease in the growth rate of useful power (Shamaeva, 2019).

Sustainable development of the system is ensured by the following main factors: increase the efficiency of technologies; increase in the resource return coefficient; increasing the quality of flow control; increase in the density of useful power flows. If the increase in the system capacity (increase in free energy flow) is not provided by these factors, but by the increase in total energy consumption, then the development of the social production system does not take place, but rather its extensive growth. In the context of sustainable development design, the Object is a spatially limited part (subsystem) of the "nature-society-human" system, which has natural resources, population and a management system that conducts activities for life support and development management. Six levels of socioeconomic objects in the system "nature-society-human" are identified (Fig. 1): World, Region, Country, Local region, Municipality, Human. It can be defined as a nested system (Bolshakov, et.al, 2019).



Source: authors' construction

Fig. 1. **The designed object as the nested systems**

The description of the Object of one or the other level, as well as the mutual interaction of the Objects of different tiers is shown in Figure 2. Each Object (Tier 1) has an external environment (Tier 2) and its internal environment (Tier 3). At all tiers there is an interaction with the natural environment.

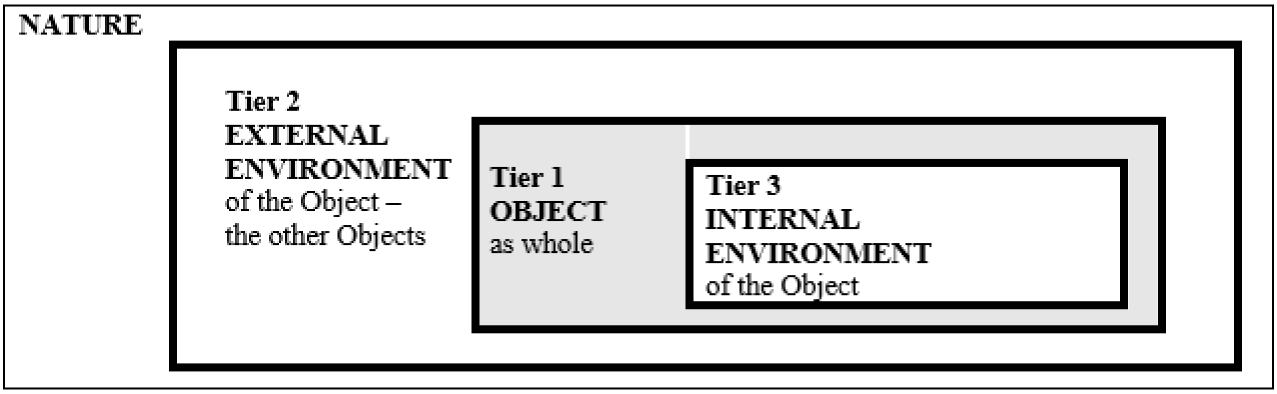


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Fig. 2. **Effect on the Object and mutual interaction at three different tiers**

In accordance with this classification, three methodological tasks are solved for each tier: 1) introduction of the concept of power or energy flows in the definition of sustainable development; 2) introduction invariant coordinate system in natural scientific units of power; 3) formalization of design process, using the power change analysis method. The solution of these tasks allows to perform: selection of integral criteria and counters; systematic evaluation of the existing and necessary condition; assessment of medium and long-term consequences of different solutions; predictive assessments of parametric dynamics of objects; selection of development goals of socioeconomic objects; calculation of effectiveness and value of proposals; development of medium and long-term plans for achieving the set sustainable development goals. All tasks to be solved are grouped into system blocks (Trusina, Jermolajeva, 2021) that determine the functional structure of the model. Designing the current state of the Object as a socioeconomic system according to the definition of the Object and Fig. 2 at three tiers is described below.

Tier 1: The designed Object as a whole

The Object as a whole is considered in relation to nature. In accordance with the law of conservation of power, the total power of an open system N is defined as the sum of useful (active) power P and loss power G. In accordance with the scheme of S.A. Podolinsky (Podolinsky, 2004), based on the law of conservation of power and having the form of a dual structure that connects an object with the natural environment, it is possible to define three basic equations of a socioeconomic object in its relationship with nature.

1) The power equation at the "input" or the total power N, which expresses the potential ability of the object to perform work per unit time (formula 1):

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$$N(t+1) = \alpha(t)N(t) \quad (1)$$

where $\alpha(t)$ - integrated power pass factor per cycle.

2) The power equation at the "output" or useful power P, expressing the ability of an object to perform external work per unit time (formula 2):

$$P(t+1) = \varepsilon(t)\varphi(t)N(t) \quad (2)$$

where $\varepsilon(t)$ -management and planning coefficient, φ(t) – technological excellence coefficient.

3) The power loss equation as the difference between the apparent and useful power (formula 3):

$$G(t) = N(t-1) - P(t) \quad (3)$$

The principle (criterion) of sustainable development asserts that the development of the socioeconomic system is supported sustainably in the long term, subject to conditions that are formalized in the form of a system of second-order differential equations for changes (Jermolajeva et al., 2022).

Next, it is possible to consider the model of integral assessment of the current state of the country. For this purpose, on the basis of equations, a system of integral social, economic and environmental indicators is introduced. In accordance with the model of system's power changes analysis (Trusina et al.,2022), the basic framework of universal indicators for determination and monitoring of sustainable development for designed object are presented in Table 1 and Table 2.

Table 1

Socioeconomic indicators

N	Indicators	Designations	Units	Source
1	Population	M(t)	capita	Official Database
2	Life expectancy	TA(t)	years	Official Database
3	GDP	GDP	Euro	Official Database
4	GDP per capita	PX	Euro	Official Database

Source: authors' construction

Table 1 and 2 are represented based on the data of official databases: the Central Statistical Office of the EU (Eurostat), the World Bank (World Bank) and the United Nations Organization (UNDATA).

Based on the proposed indicators, in order to better understand the state of the Object, indicators of the second and third level can be formed.

Table 2

Indicators of sustainable development model

N	Indicators	Design.	Units	Formulae
1	Full power (final consumption)	N(t)	GWt	Official Database
2	Power losses	G(t)	GWt	Formula (3)
3	Useful power (production)	P(t)	GWt	Formulae (2)
4	Standard of life	U(t)	kWt/cap	U(t) = P(t) / M(t)
5	Quality of environment	q(t)	x	q(t) = G(t-1) / G(t)
6	Quality of life	QoL	kWt/cap	QoL(t)=U(t)*q(t)* (TA(t)/100)
7	Technological efficiency	f	%	f(t)= P(t)/N (t)* 100
8	Electricity part in full power	E	%	E= N-Elec/ N*100
9	Productivity	PHP	kWt/cap	PHP=P(t) / LM(t)

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Source: authors' construction

All entered indicators have certain properties: all key social, economic and environmental indicators are interconnected and can be formalized using universal quantities; there are indicators that, in principle, should not be expressed in monetary units, they include: the life of any socio-natural system, the generalized technology perfection coefficient, the quality of the environment; all key indicators have a common legal basis and are a projection of the law of permanence of power in one or another specific coordinate system (social, economic, environmental).

Tier 2: The designed Object in relation with the external environment

In order to assess the Object in relation to the external environment, an integral assessment of the country's position on the world scale is introduced, introducing the following additional indicators.

1) Energy imports (EIMP) as part (%) of energy use in the Object
2) Relative weight (WM) of a country in useful power and world population: (formulae 4)

$$WM_i = p_i/m_i \quad (4)$$

3) Relative weight (WP) of a country in useful power and world gross domestic product (GDP) (formulae 5):

$$WP_i = p_i/gdp_i \quad (5)$$

The main definitions of elements in formulas 4 and 5:

- the share of the country's population in the total world population $m_i = M_i/M$

where: M_i - population of the i country, M - population of the world;

- the share of the country's useful power in the total world: $p_i = P_i/P$

where: P_i - useful power of the i country; P - useful power of the world;

- the share of the GDP of the country in the GDP of the world as a whole: $gdp_i = GDP_i/GDP$

where: $GDP_i - GDP$ of the i country, $GDP - GDP$ in the world.

Tier 3: The designed Object in relation to the internal environment

For the purpose of assessing the Object in relation to the internal environment, there are several additional parameters explained in Table 3.

Table 3

Parameters of the internal environment of the designed Object

N	Indicators	Designations	Units	Source
1	Industry (including construction) part of GDP	IND	%	Official Database
2	Agriculture, forestry, and fishing part of GDP	AG	%	Official Database
3	Services and transport part of GDP	ST	%	Official Database
4	Population employed in the economy	LM	capita	Official Database
5	Population unemployed in the economy	ALM	capita	Official Database

Source: authors' construction.

It follows from the theory of sustainable development that a correctly formulated goal must link the dynamics of the main social, economic and environmental parameters that determine the sustainability of changes in the capabilities of socioeconomic systems. These parameters mainly include six parameters (Table 4). The analysis and recognition of the situation of the object (country) takes place in the period of time from the 1st level and further up to the 6th level.

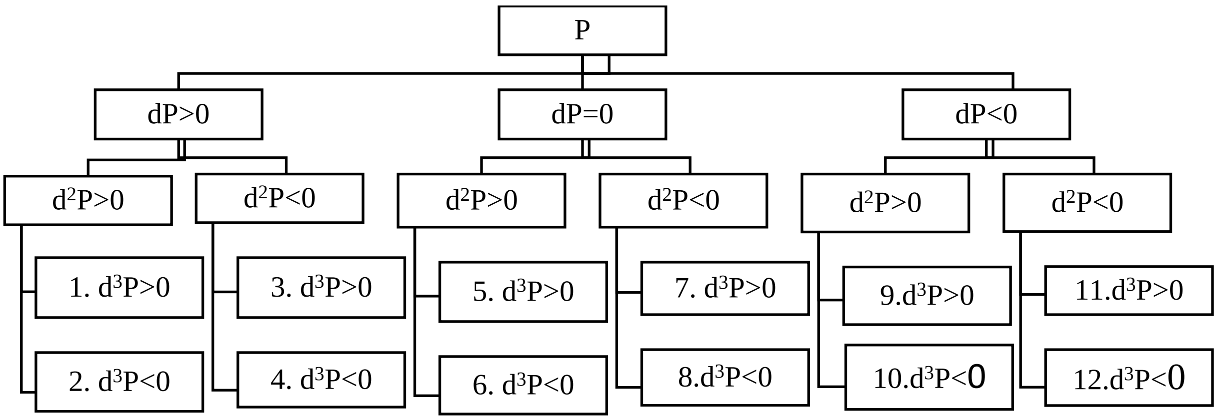
Table 4

Main parameters for building a classifier of logically possible types of goals

N	level	Indicators	Designations	changes	velocity of changes	acceleration of changes
1	level	Population	M	dM	d^2M	d^3M
2	level	Useful power	P	dP	d^2P	d^3P
3	level	Full power	N	dN	d^2N	d^3N
4	level	Standard of life	U	dU	d^2U	d^3U
5	level	Quality of environment	q	dq	d^2q	d^3q
6	level	Technological excellence	f	df	d^2f	d^3f

Source: authors' construction

In the first iteration, the selected parameter change can take one of three values: 1) "+" does not decrease; 2) "-" decreases; 3) "0" constant value. In the second iteration, the rate of change of the parameter is additionally analysed and the position of the system is refined.



Source: authors' construction

Fig. 3. **Object's useful power changes diagram**

Each type of useful power change in accordance with the Figure 3 defines a certain change in the opportunities of the system and influence the development scenario.

Table 5

Description of opportunities of the system in accordance with Figure 3

N	Opportunities of system	N	Opportunities of system
1	**sustainable growth over time**	**2**	rapidly growth, but unsustainable
3	growth with a sustainably decrease in the growth rate	**4**	growth with a decrease in speed and stability
5	opportunity remains with the prospect of transition to sustainably growth	**6**	opportunity remains with the prospect of accelerated but unsustainable growth
7	opportunity remains with the prospect of growth with a sustainable decrease in speed	**8**	opportunity remains, but an accelerated and sustainable decline is expected in the future
9	opportunity is currently decreasing, but there is a prospect of moving towards accelerated and sustainable growth	**10**	opportunity is decreasing, but accelerated but unstable growth is expected in the future
11	opportunity is decreasing, but growth is expected in the future with a sustainably decrease in speed	**12**	**ability sustainably and rapidly decreases - degrades**

Source: authors' construction

In a similar way, changes are decomposed in all parameters of sustainable development management M, N, U, q, f (Table 4). Thus, we have a system of indicators of sustainable development with the invariant

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power, which characterizes the technological, economic, environmental, social and other opportunities and needs of the regional socioeconomic system. The obtained values of the parameters make it possible to identify the target state and then calculate the required state and needs of the regional object. The description of various development scenarios (submitted selectively) are presented in Table 6.

Table 6

Formalized description of various scenarios (submitted selectively)

N	trends	dM	dP	dN	dU	dq	df	d2N	d2P
1	Extensive growth	< 0	> 0	> 0	≥ 0	> 0	= 0	> 0	> 0
2	Development (intensive growth)	> 0	> 0	> 0	> 0	> 0	> 0	> 0	> 0
3	Sustainable development	> 0	> 0	= 0	> 0	< 0	> 0	= 0	> 0
4	Degradation	< 0	< 0	< 0	< 0	> 0	= 0	< 0	< 0
5	Stagnation	< 0	= 0	< 0	≤ 0	> 0	< 0	= 0	= 0

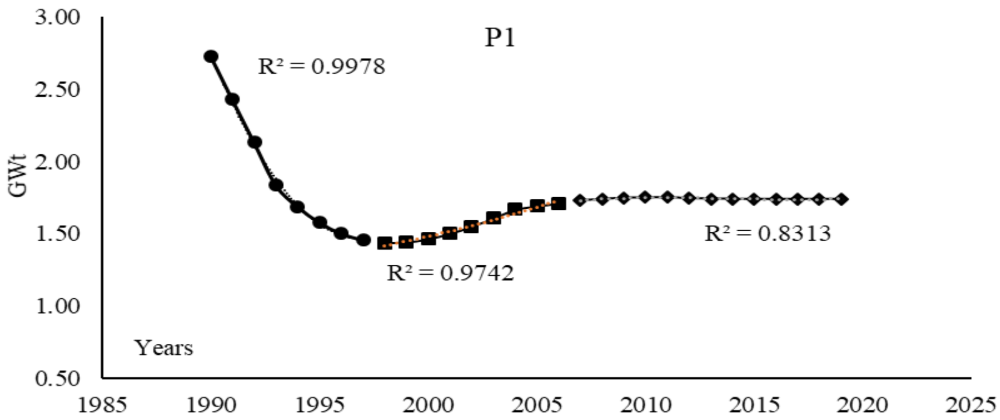
Source: authors' construction

Each type of goal corresponds to a certain state of the socioeconomic object. To establish a correspondence between the target type and the current state of the object, it is necessary to calculate the values of the target parameters for a given time and correlate the obtained result with the classifier of possible target types. As a result, we get an answer to the question: what type of goals corresponds to the existing state of the object.

The next stage is the formulation of the strategic goal for all the selected six parameters and in accordance with the classifier. All types of goals can be used as analysis options according to the procedures. This procedure includes the inverse effects of the implementation of the given parameters. Possible target parameters can be used as initial settings: non-decreasing population; doubling production; doubling the standard of living of the population; improving the quality of life. Natural scientific management tools are new ideas, projects, technologies (innovations), divided into three classes: 1) class of innovations associated with new energy carriers (N); 2) class of innovations associated with an increase in the generalized coefficient of technology perfection (f); 3) class of innovations related to improving the quality of planning (coefficient of presence (absence) of a consumer) (ε).

Research results and discussion

Based on the results of the calculations, figures of trends of useful power dynamic helped to identify Latvia's development for three periods: the 1st period 1990-1999; the 2nd period 2000-2007; the 3rd period 2008-2019 (Figure 5). For assessment, tree points (years) were selected: 2000, 2008, 2019.



Source: authors' construction

Fig. 4. **Dynamic of useful power changes P(t) of Latvia in period 1990-2019, GWt**

Based on the considered indicators, an integral assessment of Latvia in points 1990, 2000, 2008 and 2019 was made. The evaluation results are presented in Table 7.

Table 7

Indicators of socioeconomic and sustainable development for Latvia in 1990, 2000, 2008, 2019

Years	M(t)	TA(t)	GDP	PX	N(t)	P(t)	G(t)	U(t)	q(t)	QoL	f	E	PHP
	10^6 cap.	years	10^9 euro	10^3 euro	GWt	GWt	GWt	GWt/cap.	x	kWt/cap.	%	%	kWt/cap
	1	2	3	4	5	6	7	8	9	10	11	12	13
1990	2.7	70.2	3.6	1.6	9.1	2.7	6.4	1.0	1.0	0.7	31	11	1.5
2000	2.3	70.2	9.0	3.6	5.0	1.5	3.5	0.6	1.1	0.4	31	11	1.6
2008	2.2	72.1	17.8	11.2	5.5	1.7	3.8	0.8	1.1	0.6	33	14	1.7
2019	1.9	75.7	29.9	16.0	5.5	1.7	3.8	0.9	1.0	0.7	33	14	2.0

Source: official database data and authors' calculations

In order to assess the Object in relation to the external environment, three indicators were calculated in 2008 and 2019 in selected countries and the EU as one region: energy imports (EIMP) as part (%) of energy use in the Object; relative weight of a country's useful power normalized by world population (WM); relative weight of a country's useful power normalized by world gross domestic product (WP) (Table 8). According to the calculated data in Table 8, the relative weight of Latvia in terms of WM is within the values of the Baltic Sea region countries and the EU. The United States has the highest values, indicating higher per capita productivity. The weight of Latvia in terms of BP is in the nature of a decrease and in 2019 is the world average. This parameter has a high value for China, which indicates the excess of the economy in production terms over monetary terms. The share of energy imports tends to decrease for Latvia, as well as for the USA. During the same period, China doubled the value of this indicator.

Table 8

Energy export part (EIMP), relative weight of country's useful power normalized by world population (WM) and world gross domestic product (WP) in 2008 and 2019

No	Country/region	Abbrev.	EIMP		WM		WP	
			2008	2019	2008	2019	2008	2019
			%	%	x	x	x	x
1	Latvia	LV	61	45	1.4	1.5	1.6	1.0
2	Lithuania	LT	58	75	1.1	1.4	1.3	0.9
3	Estonia	EE	23	0	1.7	1.7	1.5	0.9
4	European Union	EU	55	55	1.9	1.6	0.5	0.5
5	USA	USA	25	7	4.5	4.3	0.7	0.8
6	China	CH	8	15	0.7	1.2	2.9	1.4
7	World	WR	x	x	1.0	1.0	1.0	1.0

Source: official database data and authors' calculations

The internal structure of the Object is estimated using GDP indicators and the structure of the part of the population employed in the economy. The following indicators were used for Latvia in 2000, 2007, 2019: industry (including construction) value added as a part of GDP (IND); agriculture, forestry, and fishing value added as part of GDP (AG); services (including transport) value added as part of GDP (ST); population employed in the economy (LM); population unemployed in the economy (ALM).

Table 9

Internal structure parameters of Latvia in 2000, 2008, 2019 (%)

Year	IND	AG	ST	LM	ALM
2000	24	4	72	27	15
2008	22	3	75	29	8
2019	19	4	77	24	7

Source: data from the World bank database

The state of Latvia in 2019 was definition based on the calculated and determined parameters at all assessment tiers, as well as using the dynamics of useful power changes for the period from 1990 to 2019 (Fig. 4). The main assessment parameters are presented in Table 10.

Table 10

Development scenario of Latvia for the period 1990-2019

N	period	scenario	dM	dP	dN	dU	dq	df	d^2N	d^2P
1	1990-1999	Degradation	< 0	< 0	< 0	< 0	> 0	= 0	< 0	< 0
2	2000-2007	Extension growth	< 0	> 0	> 0	≥ 0	> 0	= 0	> 0	> 0
3	2008-2019	Zero growth, stagnation	< 0	= 0	= 0	≤ 0	> 0	= 0	= 0	= 0

Source: authors' calculations

The obtained target parameter values make it possible to identify Latvia's situation in the 2008-2019 period as unsustainable development, i.e. the possibility of development remains, but in the future an accelerated and sustainable recession, a decrease in consumption, a deterioration in the quality of life and a decrease in the population are expected. If the current version of Latvia's development continues, it means long-term stagnation and further degradation. Unfortunately, the first serious signals in the form of population decline are already happening.

Formulating a future positive development scenario requires the following goals: maintaining or increasing the population (M); maintaining or increasing the total consumption of energy resources in power units (N); maintaining or increasing the total final product in power units (P); increase in the generalized technology perfection coefficient (f); improving the quality of the natural environment (q); raising the standard of living and level (U).

Conclusions

The analysis of the research results allows formulating the main requirements for designing and managing sustainable development.

1) In the design and management of sustainable development of systems, natural science meters and units of measurement, reduced to a single unit of measurement, should be used for systems open to constant energy flows.
2) The proposed design methodology makes it possible to formalize the task at different stages and levels of the system, based on the formalized principles and criteria of sustainable development, to determine the parameters of the system's current and target state, and to determine the size of the system, problems and predict the consequences.
3) Latvia's situation in the period 2008-2019 can be characterized as unsustainable development, and if it continues, it would mean long-term stagnation and further degradation. Therefore, measures are urgently needed to evaluate the goals of sustainable development and to implement measures that would ensure further development of the country.

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