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Стратегии редевелопмента объектов серого пояса на основе нейронных сетей

Strategies for redevelopment of gray belt objects on the basis of neural networks

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КЛЮЧЕВЫЕ СЛОВА

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neural networks;
clusters;

KEYWORDS

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АННОТАЦИЯ

В статье исследуются подходы к редевелопменту объектов в сером поясе. Собрана и систематизирована информация о 45 объектах, расположенных в разных административных районах города. В качестве критериев для кластеризации объектов выбраны общие факторы (год постройки здания, восстановительная стоимость здания в базисных ценах 1969 года, действительная стоимость здания в ценах 1969 года, высота, объем, этажность, общая площадь застройки, группа капитальности, функциональное назначение) и факторы физического износа покрытия, перекрытий, стен, фундаментов, внутренней отделки, инженерных сетей, общий износ). В результате исследования созданы самоорганизующиеся карты с различными параметрами обучения. Показана возможность изменения и выбора необходимой стратегии редевелопмента для зон серого пояса в зависимости от параметров обучения самоорганизующихся карт и индивидуальных характеристик объектов, входящих в серый пояс.

ABSTRACT

The article considers the approaches for objects redevelopment in the gray belt. Information was collected about 45 objects located in different administrative districts of the city. As the criteria for clustering objects, general factors (year of construction of the building, cost of building restoration in prices of 1969, actual cost of building in prices of 1969, height, volume, number of stores, total building area, fundamental group, function) and factors on physical deterioration (wear of roof, floors, walls, foundation, finishing, MEP, total wear) were chosen. As a result of the study, SOMs with different learning parameters were created. As a result of the research, it was established how to change and select the desired redevelopment strategy for the zones of the gray belt, depending on the leaning parameters of the SOM and the individual characteristics of objects entering the gray belt.

Contents

1. Introduction

The question of the development of old industrial zones remains relevant for today. The reorganization of industrial buildings and their territories is capable of creating new places for attraction of tourists and locals of the city, thereby stimulating the economy, dispersing the tourist center and reducing the transport load [1-5]. Moreover, the rethinking of this territory will allow developing a network of polycentres with a developed horizontal specialization that contribute to the improvement of the quality of life through the reasonable and comfortable arrangement of the territory, creating an attractive, balanced and lively environment for labor, life and recreation of the population [6-8].

The industrial zone of St. Petersburg, or the "gray belt", is the largest reserve for urban development near the historic center of the city [9, 10]. The area of industrial buildings in St. Petersburg is about 50 million m^2. According to various estimates, this zone occupies about 40% of the total area of the city [11-15].

Industrial areas are located in 12 administrative districts of St. Petersburg. The gray belt was delineated by the coast of the Neva Bay, including the port complex in the southern part of the Kanonersky Island. This territory included steads of industrial and public-business buildings in the Kirov, Moscow, Frunzensky and Nevsky districts, within the territory between Obvodny Canal and Leninsky Prospekt, Tipanova Street and Slavy Prospekt. In addition, industrial buildings on the right bank of the Neva from Narodnaya street to Prospect Energetikov and in the southern part of the Krasnogvardeisky district remained in the borders of the belt.

According to specialists of the Committee for Economic Policy and Strategic Planning of St. Petersburg, the territory of "a gray belt" is socially unsuccessful, has undeveloped and outdated infrastructure, in particular transport. The most widespread problems of industrial zones – impurity of the territory, existence at industrial sites of a large number of the dot objects which are under protection of the state, separate structure of property. At the same time the industrial sites adjoining to the central city territories, undoubtedly have a great development potential [16].

At the moment development of "a gray belt" is fixed on regional and federal levels. In St. Petersburg such laws as the Resolution of the government of St. Petersburg from 3/28/2012 N 275 "About the Concept of social and economic development of St. Petersburg till 2020" and the Federal law from 7/21/2005 N 115-FZ (an edition from 7/29/2017) "About concession agreements" and also the Law of St. Petersburg No. 282-43 "About an order of granting the real estate objects which are owned by St. Petersburg for construction and reconstruction". This law regulates an order of participation in the auction, an order of investment into objects, depending on exposure of reconstruction by administrative regions of objects [16].

In recent years several offers on revitalization of "a gray belt" sounded: from student's projects prior to the international competition "A gray belt. Transformation". But any initiative hasn't been realized. Some buildings are recognized as monuments of architecture and demand laborious work on restoration. For such buildings it is difficult to find the investor who will undertake the project of such scale. Nevertheless, in the neighborhood of Obvodnyy Canal several new points of an attraction have already appeared: creative space "Tkachi", business complex "Obvodnyy dvor". In plans – opening of the Museum of the railroads and construction of Planetarium (which diameter of a dome has to become the biggest in the world). Also, residential buildings are actively built on the territory of the gray belt. According to experts from the company Colliers International [17], since the beginning of this year, the primary housing market, built on the territory of industrial zones, will be replenished by 919 thousand m^2 and will reach 5 million m^2. The dynamics of housing in the “gray belt” is shown in the Figure 1:

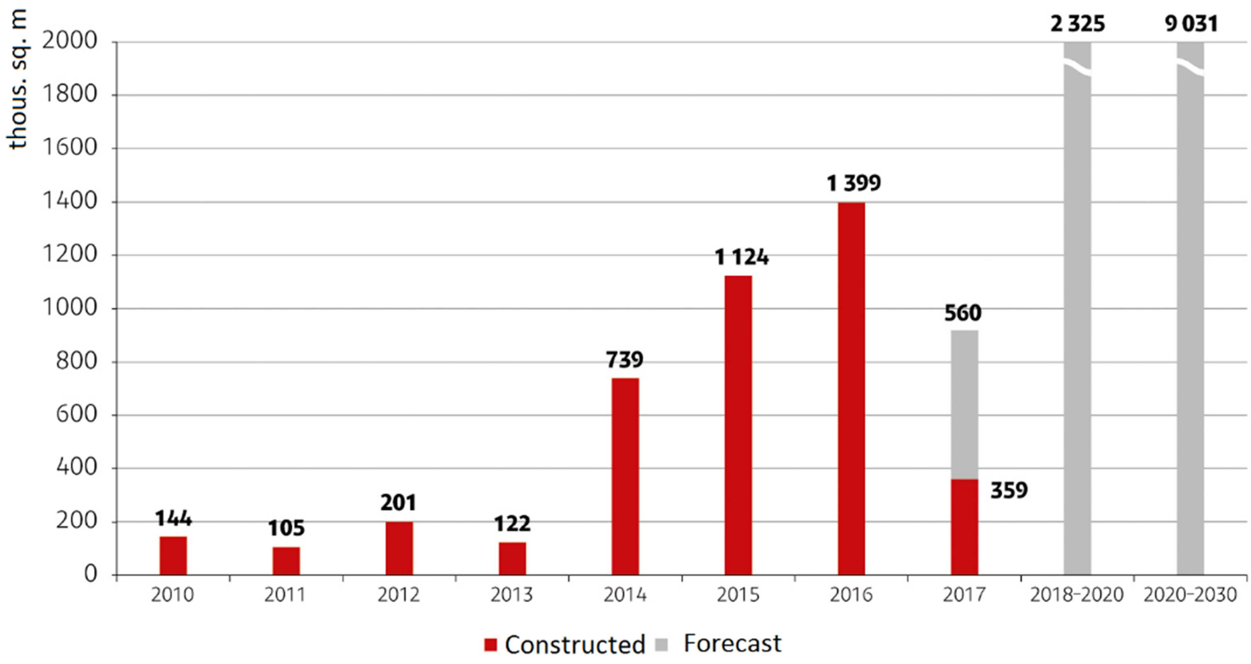

Figure 1. The dynamics of housing in the “gray belt”.

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2. Methods

To determine the effective strategy of redevelopment of gray belt objects, it is necessary to develop an approach for classifying objects included in these zones. In this paper, it is proposed to use self-organizing maps for clustering objects [18].

A self-organizing map (SOM) or self-organizing feature map (SOFM) is a type of artificial neural network (ANN) that is trained using unsupervised learning to produce a low-dimensional (typically two-dimensional), discretized representation of the input space of the training samples, called a map, and is therefore a method to do dimensionality reduction. They were developed in 1982 by Tuevo Kohonen, a professor emeritus of the Academy of Finland [19, 20]. Self-organizing map (SOM) is an efficient programming tool of neural network modeling for visualization and generalization of multidimensional data. It is suitable for solving complex problems as a process analysis, a machine perception, management and transferring of information [21, 22].

The Self-Organizing Map algorithm can be broken up into 6 steps [19, 20]:

1. Each node's weights are initialized.
2. A vector is chosen at random from the set of training data and presented to the network.
3. Every node in the network is examined to calculate which ones' weights are most like the input vector. The winning node is commonly known as the Best Matching Unit (further – BMU). (Equation 1).

$$DistFromInput^2 = \sum_{i=o}^{i=n} (I_i - W_i)^2 \quad (1)$$

where I – current input vector;
W – node's weight vector;
n – number of weights.

4. The radius of the neighborhood of the BMU is calculated. This value starts large. Typically it is set to be the radius of the network, diminishing each time-step. (Equations 2, 3).

$$\sigma(t) = \sigma_0 e^{(-t/\lambda)} \quad (2)$$

where t – current iteration;
λ – time constant (Equation 3);
σ_0 – radius of the map.

$$\lambda = numIterationsImapRadius \quad (3)$$

5. Any nodes found within the radius of the BMU, calculated in item 4, are adjusted to make them more like the input vector (Equations 4, 5). The closer a node is to the BMU, the more its' weights are altered (Equation 6).

$$W(t+1) = W(t) + \Theta(t)L(t)(I(t) - W(t)) \quad (4)$$

$$L(t) = L_0 e^{(-t/\lambda)} \quad (5)$$

$$\Theta(t) = e^{(-distFromBMU^2/(2\sigma^2(t)))} \quad (6)$$

where W – new weight of a node;
L(t) – learning rate;
Θ(t) – distance from BMU.

6. Repeat item 2 for N iterations.

As objects of research were selected 45 buildings of the gray belt, located in different parts of the city. About 4-5 objects for further researches have been chosen from each district. The distribution of the objects of research by districts is shown in the Figure 2.

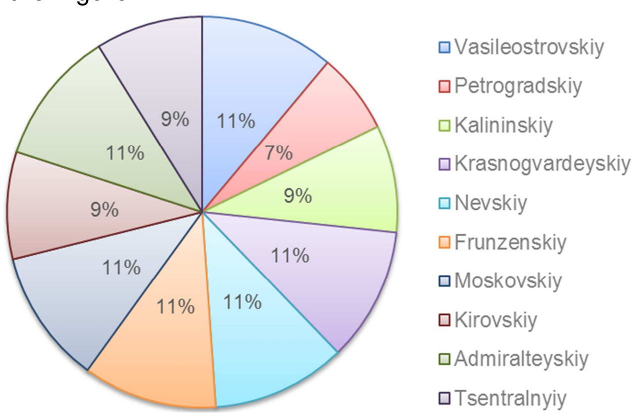

Figure 2. The distribution of the objects by districts.

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3. Results and Discussion

For each object, information was collected, divided into two categories:

1. *Additional information* (year of construction of the building, cost of building restoration in prices of 1969, cost of building restoration in prices of 1969, height, volume, number of stores, total building area, fundamental group, function). The data are presented in Tables 1a and 1b.
2. *Factors on physical deterioration* (wear of roof, floors, walls, foundation, finishing, engineering systems, total wear). The data are presented in Table 2.

Table 1a. Additional information

Symbol	Constructi on year	District criminality, number of crimes per year	District ecology	Status of committee for the state preservation of historical and cultural monuments	Stead cost, rub	Stead area, m^2	Fundamental group
V-1	1917	2106	5	+	35999263	8072	1
V-2	1917	2106	5	+	64610428	5449	1
V-3	1907	2106	5	-	14654117	2833	3
V-4	1985	2106	5	+	71700947	15543	2
V-5	1984	2106	5	-	2129502392	511891	2
P-1	1904	1584	7	-	478214956	6878	2
P-2	1867	1584	7	-	35941796	552	3
P-3	1898	1584	7	-	13295053	870	2
K-1	1913	5175	5	-	13796281	14362	2
K-2	1963	5175	5	-	13796281	14362	3
K-3	1934	5175	5	-	13796281	14362	1
K-4	1913	5175	5	-	2 653 579	1148	1
Kr-1	1992	3672	6	-	39592782	9499	2
Kr-2	1953	3672	6	-	13254558	3180	1
Kr-3	1953	3672	6	-	10724521	2573	1
Kr-4	1970	3672	6	-	21776619	4300	2
Kr-5	1930	3672	6	-	46768211	16367	2
N-1	1978	4996	7	-	11996582	5376	1
N-2	1976	4996	7	-	17939192	4509	1
N-3	1934	4996	7	-	48210196	11515	1
N-4	1978	4996	7	-	25520706	5999	1
N-5	1981	4996	7	-	245155675	49129	1
F-1	1980	3748	4	-	121762894	21113	1
F-2	1917	3748	4	-	23624643	4333	3
F-3	1986	3748	4	-	86123293	14537	1
F-4	1976	3748	4	-	12857044	2310	1
F-5	1905	3748	4	+	108097376	2463	1
M-1	1924	3756	8	-	13157510	15783	1
M-2	1914	3756	8	+	92942962	2242	2
M-3	1936	3756	8	-	31374545	6353	2
M-4	1981	3756	8	-	28478398	6860	1
M-5	1907	3756	8	+	10150100	2445	2
Kir-1	1962	3756	6	-	17939691	3735	1
Kir-2	1963	3756	6	-	59143928	4418	2
Kir-3	1982	3756	6	-	26117537	7436	2
Kir-4	1961	3756	6	-	27063021	7139	1
A-1	1864	2829	5	-	10210678	1902	3
A-2	1913	2829	5	+	12358034	2302	1
A-3	1913	2829	5	+	336637432	76132	1
A-4	1917	2829	5	+	10325157	1922	1
A-5	1903	2829	5	-	5398950	1005	2
T-1	1936	2842	6	-	26586007	1130	2
T-2	1969	2842	6	-	21115711	4144	1
T-3	1969	2842	6	-	21115711	4144	1
T-4	1907	2842	6	-	30403250	975	2

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Table 1b. Additional information

Symbol	Cost of building restoration in prices of 1969, rub	Actual cost of building in prices of 1969, rub	Height, m	Volume, m^3	Number of stores	Total building area, m^2	Function
V-1	431584	172634	5.1	53948	2	7 264	industry
V-2	657716	377467	4.1	46639	4	8262	administrative
V-3	53978	20512	5	3940	3	631	industry
V-4	1512172	1344446	4.6	65122	4	19809	industry
V-5	258418	222239	16.4	26641	4	4933	industry
P-1	1411656	762294	3.8	96031	7	19169	industry
P-2	55610	41900	2.5	8530	3	488	
P-3	118011	101489	3.5	4911	4	952	office
K-1	14166246	9228092	2.5	16014	4	114 213	industry
K-2	50844	29998	3.6	3345	2	709	checkpoint
K-3	3100078	1519038	4.3	487639	3	50 399	industry
K-4	125719	84231	2.6	6051	2	1 348	canteen
Kr-1	17431	14991	5.4	3058	1	567	storehouse
Kr-2	349908	209945	3	14864	4	2 872	accommodation
Kr-3	181795	99987	2.9	8286	4	1 799	accommodation
Kr-4	172352	124058	8.8	13338	2	2 393	industry
Kr-5	99883	45980	3.2	8480	1	2 278	storehouse
N-1	49818	390906	3.1	27338	4	5 970	office
N-2	470043	394836	10.9	44766	1	4 401	industry
N-3	724686	514527	8.9	60898	3	10 093	industry
N-4	15364	13213	6.3	5649	1	415	storehouse
N-5	829922	688835	3.3	21445	8	5 154	laboratory
F-1	342250	290649	3.4	996	1	3 682	industry
F-2	67629	39225	6.6	6739	2	6 739	industry
F-3	735813	625441	3.8	5252	3	8 349	administrative
F-4	1368738	1192875	4	16245	6	948	industry
F-5	270943	151843	3.5	12282	4	2 930	bathhouse
M-1	55283	36683	6.8	1124	2	552	car service
M-2	785149	49644	3	40788	7	7 976	accommodation
M-3	339348	232694	4	5958	4	3 301	administrative
M-4	1283962	1104208	6.3	75847	4	4 879	industry
M-5	261619	195061	3.45	11671	4	2 152	dormitory
Kir-1	271492	192759	4.05	11804	2	2 559	canteen
Kir-2	125861	72999	7.2	9989	1	1 268	industry
Kir-3	394169	311394	5.2	22078	3	4 881	storehouse
Kir-4	195544	152563	3.1	11073	4	1 195	boiler house
A-1	422571	228188	3	24887	4	4 668	accommodation
A-2	686720	412032	4.8	36723	1,3,5,6	2 302	industry
A-3	83991	42961	4.1	7499	2	1 365	industry
A-4	395972	241543	3.5	34826	5	1 921	accommodation
A-5	10333450	6602	3.15	17260	6	2 742	accommodation
T-1	151369	112013	7.3	7892	2	1 658	industry
T-2	122843	89675	4.75	7726	3	1 649	storehouse
T-3	64242	46897	3.5	3569	2	771	storehouse
T-4	194523	114768	3.3	11030	5	1 790	accommodation

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Table 2. Information on physical deterioration

Symbol	Wear of roof, %	Wear of floors, %	Wear of walls, %	Wear of foundation, %	Wear of finishing, %	Wear of MEP, %	Total wear, %
V-1	75	60	55	55	70	70	60
V-2	50	50	40	35	30	45	44
V-3	60	70	60	60	70	65	62
V-4	15	15	10	10	20	15	14
V-5	15	15	10	10	20	15	14
P-1	50	45	45	40	45	50	46
P-2	30	40	30	30	20	15	25
P-3	10	35	30	30	5	5	14
K-1	40	40	30	30	40	35	36
K-2	45	45	35	40	40	45	41
K-3	50	50	50	55	50	50	51
K-4	25	30	40	45	25	35	33
Kr-1	15	15	15	5	-	15	14
Kr-2	45	35	35	40	40	45	40
Kr-3	40	40	40	40	50	50	45
Kr-4	35	20	20	20	35	35	28
Kr-5	40	30	65	65	60	65	55
N-1	30	15	15	15	15	30	21
N-2	20	15	15	10	20	15	16
N-3	40	25	25	25	30	35	29
N-4	25	15	15	15	20	25	14
N-5	20	15	15	15	15	20	17
F-1	10	10	10	10	5	10	11
F-2	40	40	40	50	45	45	42.4
F-3	15	15	15	10	20	20	15
F-4	25	20	20	20	10	15	16
F-5	40	35	45	45	50	50	45
M-1	35	25	50	50	30	25	35
M-2	35	40	40	40	30	40	37
M-3	30	40	40	45	35	35	37
M-4	15	10	15	10	15	15	14
M-5	30	30	30	25	25	5	24
Kir-1	35	25	25	25	30	30	29
Kir-2	40	35	45	40	40	50	42
Kir-3	30	20	20	20	20	25	21
Kir-4	25	30	25	15	25	40	30
A-1	40	45	45	40	50	50	46
A-2	40	40	40	35	45	40	40
A-3	45	45	50	45	50	60	49
A-4	40	40	40	40	35	35	39
A-5	40	30	30	25	40	40	34
T-1	20	30	25	30	25	30	26
T-2	30	20	25	20	30	35	27
T-3	30	20	25	20	30	35	27
T-4	30	40	40	40	50	40	41

After pre-processing the data and assessing their quality in the program Deductor, the total sample of the investigated objects was 35 buildings. *Additional information* and *factors on physical deterioration* have been investigated for the presence of extreme values and emissions. Objects with extreme values were excluded from the studies. Based on results of the data processing 4 objects were identified as «out of data». It includes objects with value of one or several parameters is significantly out of range. The initial number of factors (21 pieces) was reduced to 16.

In the program Deductor *Factors on physical deterioration* (wear of floors, walls, foundation, MEP, total wear) was analyzed. The results of the analysis are shown in Figure 3. The x-axis shows the values of each test criterion. The total number of clusters was 8 (Table 3).

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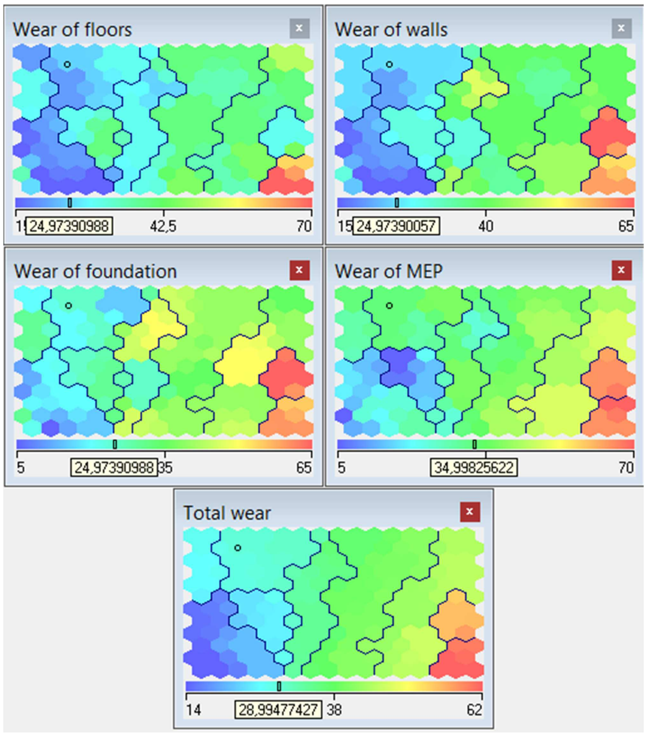

Figure 3. SOM of the physical deterioration factors.

Table 3. Clusters on physical deterioration

Cluster	Symbol	Wear of floors (average), %	Wear of walls (average), %	Wear of foundation (average), %	Wear of MEP (average), %	Total wear (average), %
1	V-1	65	57,5	57,5	67,5	61
	V-3					
2	Kr-5	30	65	65	65	55
3	V-2	41	42	42	42	44
	Kr-3					
	F-2					
	F-5					
	Kir-2					
	A-1					
4	K-2	39	39	40	40	41
	Kr-2					
	M-2					
	M-3					
	A-2					
	A-4					
	T-4					
5	K-4	28	30, 40, 50	25, 45, 50	34	34
	M-1					
	A-5					
6	Kr-4	25	24	22	35	29
	N-3					
	Kir-1					
	Kir-4					
7	P-2	28	27	25	24	26
	M-5					
	T-1					
	T-2					
	T-3					
8	P-3	20	19	17	20	17
	Kr-1					
	N-1					
	N-4					
	F-3					
	F-4					
	Kir-3					

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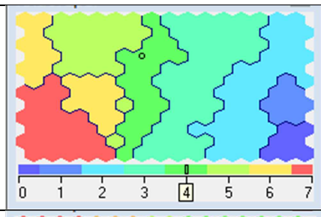
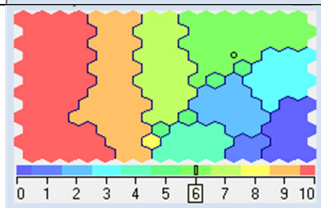
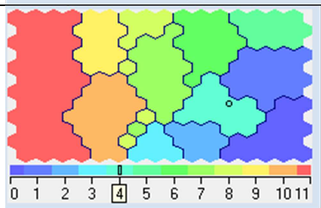
The map, which made it possible to obtain optimal clustering of a non-residential property in the gray belt in the quantity of 8 clusters, was created by the method of samples of various training parameters.

General factors were also studied. Using a variety of map learning parameters, such as the map initialization method, the number of learning epochs (iterations), the neighborhood function, you can get a different number of clusters (Table 4). It is also worth noting that to build a SOM of the physical deterioration factors, the Step function was used (line 1 in Table 4).

Table 4. SOM with different parameter

Version	Learning parameters		Number of clusters	SOM MAP
	Function	Iterations		
1	Step function	400	8	
2	Gaussian	500	11	
3	Gaussian	1000	12	

As a result of the study of several SOM of the general factors, it was revealed that the parameters that exert the greatest influence on the formation of clusters are: function of object, district ecology, construction year, district criminality, number of stores. An example of a SOM of the general factors is shown in the Figure 4.

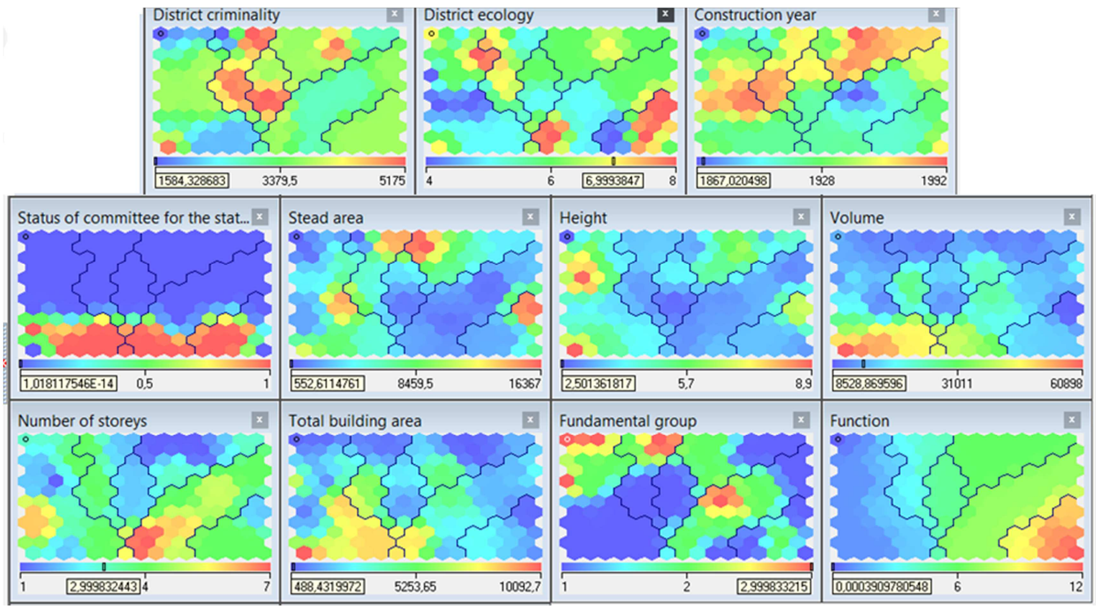


Fig. 4. SOM of general factors.

Studies in the field of clusterization were reflected in the works of Debock G., Kohonen T. "Analysis of financial data using self-organizing maps," Slepukhina I. "Formation of a regional management system by urban renovation", Popova O.N. "Method of scheduling of repair buildings on the basis of their structural analysis." This algoritm was first used by Popova O. N. for the clustering of buildings for reproduction purposes.

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Depending on the indicators of physical wear of structural elements of buildings, the program divided the objects into 8 clusters. As the ordinal number of the cluster increases, the indicators of physical wear decrease.

2 objects from the Vasileostrovskiy district got to the first, with the maximum physical depreciation rates at 62%. The objects of this cluster are in a pre-emergency condition according to their technical state.

The second cluster consists of one object located in the Krasnogvardeiskiy district, thereby breaking out from the general tendency of combining. This building has different indicators of physical wear, due to the difference between the indicators of the technical condition of separate structural elements. In particular, the wear of the floors is 30%, while the wear of the remaining constructive is 65% and 55%. The program could not determine the analog for this building and put it in a separate cluster.

The objects assigned to the fifth cluster are knocked out from the overall clustering. Objects with various wear of floors from 30 to 50%, as well as with different indicators of wall wear – from 25 to 50% got to it. But at the same time wear of other structural elements of the objects is the same. These wear indicators refer objects to the technical state to satisfactory and unsatisfactory.

The sixth cluster can be combined with the fifth, since it contains variations in the wear index. The wear of internal networks, equal to 35%, is not comparable with the wear of other designs, the average value of which reaches 25%. The sixth cluster can be classified according to its technical state as satisfactory.

According to the technical state, the objects of the third and fourth cluster are in an unsatisfactory state, the seventh and eighth in satisfactory condition.

SOM is the mathematical mechanism of clustering. It allows to combine objects with multidimensional characteristics (factors) into clusters. This in turn allows to unify the strategies for an individual cluster. This mechanism allows to reduce the labor costs for planning.

Depending on the SOM learning parameters, you can vary the number of clusters and, accordingly, the number of objects in them. The choice of the function, the number of iterations, lead to different results, giving the possibility of choosing different strategies for redevelopment of objects in the gray belt, in favor of the priority of certain factors. For example, in one of the cases considered, the priority criteria for a strategy of alternate redevelopment can be a function of object, district ecology. Under another strategy, the prevailing parameters are the year of construction and the number of floors of the building.

The uniqueness of the proposed method lies in the ability to vary and modify redevelopment strategies, based on priority parameters for specific conditions. Another undeniable advantage of the method is its functional ability to work with a huge amount of input data and obtain optimal results.

Clusters of physical deterioration obtained in the Deductor program can be narrowed, thereby reducing their number, based on its results some recommendations can be given for subsequent actions (table .5)

Table 5. Recommendations for clusters

Cluster	Symbol	Technical condition	Description	Recomedations
1	V-1	Emergency	Bearing and enclosing structures of the building (foundations, walls and floor slabs) are not able to perform its functions due to the high degree of damage. Load bearing capacity reduces of over 40 - 50 %	It is required to conduct security and support activities. This building is a cultural heritage site and needs to be renovated.
2	V-3			In this case, it is advisable to demolish building and construct the object, in accordance with the needs of the district.
	Kr-5			
3	V-2	Pre-emergency	Bearing and enclosing structures of the building (foundations, walls and floor slabs) have significant damage. Significant cracks of structures from non-uniform deformations appear. Displacement of floor slabs on supports is more than 1/10 of the anchorage depth. Reducing the load-bearing capacity of the structure up to 40-50 %	The buildings in this cluster belong to the objects of cultural heritage. It is required to conduct safety activities (unloading of structures, etc.). Building maintenance should be stopped during major repairs (reconstruction and restoration (strengthening) of damaged structures).
	F-5			
	M-2			
	A-2			
	A-4			
4	Kr-3			The two options should be economically compared: 1- reconstruction of the building with changing of functional purpose, 2 - demolition of the building and construction a new object to fill the infrastructure of the district.
	F-2			
	Kir-2			
	A-1			
	K-2			
	Kr-2			
	M-3			
	T-4			

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Cluster	Symbol	Technical condition	Description	Recomedations
5	K-4	Unsatisfactory	Bearing and enclosing structures (foundations, walls, floor slabs, partitions) have significant damage with limited distribution. The displacement of the floor slabs on supports is not more than 1/10 of the anchorage depth, but no more than 2 sm. There is a formation of a vertical crack between the longitudinal and transverse walls. Windows, door frames, roof, flooring, engineering equipment have significant problems. Bearing capacity of structures reduce up to 25 %.	It is required major repair with strengtheninig and restoing the bearing capacity of damaged structures to ensure normal building maintenance.
	M-1			
	A-5			
	Kr-4			
	N-3			
	Kir-1			
	Kir-4			
6	P-2	Satisfactory	Minor damage to bearing and enclosing structures. In some areas there are separate hollows, potholes, capilliform cracks. There are minor defects associated with uneven settlement of the building. There are no shifts and damae to ceilings, stairs, arches.	It is required maintenance with fixing local damage without strengthening the structure
	M-5			
	T-1			
	T-2			
	T-3			
	P-3			
	Kr-1			
	N-1			
	N-4			
	F-3			
	F-4			
	Kir-3			

4. Conclusion

The study showed that the redevelopment of the territories of the gray zone requires a comprehensive and integrated approach. Methods to redevelopment of territories from the point of view of dividing the zones of the gray belt into administrative regions are not justified.

It is necessary to work out a comprehensive redevelopment strategy based on a detailed consideration of the properties of each object – the building. The approach proposed in the article will help to reveal the hidden dependencies between objects located in different parts of the city, depending on their unique characteristics. The flexibility of the proposed approach, the possibility of changing the strategy by correcting the input parameters of the SOM, will allow taking into account the individual wishes of investors / customers, taking into account the features and uniqueness of each considered object included in the gray belt.

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