Application of new architectural and planning solutions to create an ecological city (on the example of Shanghai, China)

Shanshan Van1, Alexey Cheremisin2, Alexey Glinushkin2, Victor Krasnoshchekov1, Roman Davydov1,* and Victoria Yushkova3

1Peter the Great St.Petersburg Polytechnic University, 195251, Saint Petersburg, Russia
2All Russian Research Institute of Phytopathology, 143050, Moscow Region, Russia
3Saint Petersburg University of Management Technologies and Economics, 190109, Saint Petersburg, Russia

Abstract. This article represents the results of research on improvement of the Shanghai micro-district with the use of selected eco-friendly architectural and planning solutions and identification of the main ways to solve the problem of eco-urban development in Shanghai which are the following: land management, population management, clean energy sources and "green" consumption. Research is based on analysis and calculations on main trends of the theory and practical experience of construction of ecological cities in China and in the world.

1 Introduction

The Chinese and world experience in the development and implementation of architectural and planning solutions aimed at environmental modernization and reconstruction of the urban environment. Possibilities and prospects of development of cities to improve living conditions of people, enhance the quality of the environment, harmonization of relations between the city and nature are considered. This concerns the planning of urban areas, the creation of an environmentally balanced infrastructure that helps to meet the multifaceted needs of residents and to develop economic and environmental measures. For example, the city of Shanghai considers the strategic goal of the development as ecological city. It includes the measures for reasonable planning of territories, the establishment and maintenance of green areas, a high level of biodiversity, promoting the use of environmentally friendly sources of energy, optimizing the transport structure, protection of spiritual and cultural values, historic heritage, control of the population.

The one of the most important elements in the development of the territories of former industrial zones is the monitoring of quality of soil, water resources, air and other objects to determine ways of further land use [1-4]. The highest priority in control of environmental quality is given to express methods [5-12]. In some cases, the projecting and construction of hydraulic structures is necessary for the development of these territories [13-16]. It should also be noted that solar energy (along with another renewable energy sources) is a one of the great prospect for providing electricity for municipal needs of territories under reconstruction and modernization in such countries as China [17]. All these aspects should be taken into account at innovative development of territories under environmentally reconstruction from different points of view including the economy and the construction business [18-27]. An important factor in the development of such territories is solar energy [28-39]. This is especially true for China.

2 The objects of the research and their features, novelty of results and discussion

The scientific novelty consists in development of the methodology of environmental assessment of regional land use with application of the method of multi-criteria analysis and calculation of key parameters on the example of a particular district of Shanghai. The authors developed the criteria and determined the content of the assessment with the choice of formulas for calculating the coefficients of the significance of the basic parameters taking into account the environmental (ecological) potential of the territory, factors of economic activity, natural conditions. The method of the imposed analysis of factors is applied, the planning structure of sites is proved. Based on carried out calculations, the project of improvement of the Shanghai micro-district was justified and developed using the selected environmentally friendly architectural and planning solutions and identifying the main ways to solve the problem of eco-urban development in Shanghai: land management,
population management, environmentally friendly energy sources and "green" consumption [17].

On the base of analysis of current situation with "green" technologies in Shanghai, it was revealed that the rapid and environmentally unfriendly development of the economy has also led to serious environmental problems in the city, especially in the industrial zone of Shanghai. Currently, it is in the phase of post-industrial transformation at the late stage of industrialization. With the development of urbanization and the adjustment of the structure of industry, the old industrial areas of China and the city are gradually disappearing, due to many remnants of the past which are incompatible with the modernity. Former industries are gradually giving way to new, higher technological level. It is necessary to continue research and organize development in accordance with the conditions of urban planning. Against this background, Taopu district needs to be transformed into a modern industrial zone, and the environment needs to be restored. At the same time, this district is one of the few in the outer ring of Shanghai, and excellent opportunities for development are provided [40, 41]. Taopu district was chosen as the main area of this planning. First, regional functional units and roads are analyzed. The methods of analysis, calculation, modeling, forecasting and comparison are used to assess the degree of contamination and ecological potential of the land. Calculated ecological capacity of the land should promote to ascertain the possibility of their redevelopment, to estimate and nominate new solutions for the implementation of the ecological concept, through the planning of the industrial zone Taopu that help to increase the value of land and to develop the surrounding land use, and to provide residents recreational space. The process of transforming the image of the city and the image in the urban industry is expected to be positive. The economic and environmental benefits of urban renewal of large industrial areas such as Wusong and Gaohua are based on an ecological concept for 15% of the land used to promote regional functional transformation, which will open up great opportunities for the city with a wide choice of open spaces. Adhering to the concept of sustainable development, an advanced incubator of new technologies is being created in Shanghai.

2. Belonging to a particular industry. Transport accessibility, well-established communications and availability of resources. Such conditions as distance from the metro, connection with the city center, water supply and sewage system are taken into account. The high cost of land can be due to the abundant resources of the environment and excellent transport conditions. These features are easily captured by the market, and the value of reuse in this case increases.

2.1.2 Choosing an assessment model

At present, the environmental potential assessment methods are usually based on qualitative and quantitative analysis of baseline data with further identification of significant factors of environmental impact, choice of suitable environmental indicators and calculation of parameters under assessment. Using geographic information systems (GIS) with spatial database in this case is much recommended. The main environmental potential assessment methods are analytical and numerical which use the data of environmental monitoring with application of express methods in situ and in lab-scale conditions. This is very important whether it is an assessment of the suitability of urban land for any economic activity or a potential assessment of the adjustment of industrial land use. The final available capacity is estimated by weighing the factors that affect the ultimate goal. On the base of analysis of different conditions, data and parameters of the former industrial zone of Taopu authors of this article have found that for environmental potential assessment could be most reliable the methods based on spatial decisions for industrial land management [41], which combine the characteristics of the sites and the content of the environmental potential, as well as possibilities of its partial modification. From this point of view various assessment criteria and factors should be determined including the contamination coefficients. The decisive role of the environmental potential of industrial heritage reuse is established after contamination exceeds a certain level. The following assessment model is used:

\[ Y = P \cdot (r_1 \cdot w_1 + r_2 \cdot w_2 + r_3 \cdot w_3 + r_n \cdot w_n) \]  \hspace{1cm} (1)

where \( Y \) is a value of environmental potential; \( P \) is a contamination degree coefficient (in a range that can be changed in the near future, the contamination degree is 1 and the contamination level is much higher than the norm; the norm is if the level of contamination degree is 0); \( r_1,...,r_n \) are rank correlation coefficients for assessment criteria with numbers 1,...,n; \( w_1 \) to \( w_n \) are weighting coefficients.

2.1.3 Determination of weighting factors

In the course of this study it is assumed that the number of factors assessed is small and these factors are relatively similar in importance. For this purpose equal weight division is accepted. The weights (significance levels) of the nine assessment factors, such as
environmental contamination, land use, industrial land use, development intensity, historical and cultural value and so on (see Table 1), are 1/9.

2.1.4 Normalization of indicators

Normalization of indicators is a process of transforming the database to the form corresponding to the normal (reduced) forms includes normalization of the forward indicator and normalization of the reverse index. For the forward indicator, the formula looks like:

\[ X_{ij} = \frac{R_{ij} - R_{j}^{\min}}{R_{j}^{\max} - R_{j}^{\min}} \]  

\[ (2) \]

where \( X_{ij} \) is \( j \)-th unit element of assessment of normalized value coefficient of \( i \)-th object; \( R_{ij} \) is the actual value of the \( j \)-th individual element, which allows to determine the coefficient of the \( i \)-th object; \( R_{j}^{\max} \) is the maximum actual value of the assessment factor of the \( j \)-th individual element; \( R_{j}^{\min} \) is the minimum of the actual values.

2.1.5 Assessment criteria

The assessment criteria are given in Table 1.

Table 1. Table of factors for assessing the environmental potential of industrial heritage reuse

| Number of assessment criterion (1…n) | Classification of content | The assessment criteria | The weighting factor | - |
|-------------------------------------|---------------------------|-------------------------|---------------------|--|
| 1                                   | The contamination status  | Determination of contamination status based on relevant research results | 1/9 | ↑ |
| 2                                   | Scale of industrial land use | Belonging to the industrial heritage zone | 1/9 | ↑ |
| 3                                   | The status of industrial operation | Total abandonment, partial abandonment, inefficient operation, efficient operation | 1/9 | ↓ |
| 4                                   | Intensity of development | Ratio of plots with different levels of industrial and economic development | 1/9 | ↓ |
| 5                                   | Historical and cultural value | Presence or absence of protected objects of historical and cultural heritage | 1/9 | ↑ |
| 6                                   | External influence | Structuring and status of the territory (character of administrative and territorial structure) | Division of a city or district into territorial entities caused by natural, political, economic, ethnic, national and other factors, taking into account status of different territories and character of interrelations between them | 1/9 | ↑ |
| 7                                   | Attraction to the city center | Distance from city center | 1/9 | ↓ |
| 8                                   | Impact of transport transit (including railway transit) | Distance from transport transit ways, stops, including metro stations, surface railway transit stations | | ↓ |
| 9                                   | Influence of the river system | Distance from the river system | | ↓ |

↑ Positive indicator  ↓ The reverse index

The current status of each site depends mainly on the nature of the land, the degree of contamination, the state of industrial operation, the distance from transport stops, the distance from the river system and elements of historical and cultural value. The final results are shown in Table 2.

By analyzing the superposition of each factor, it can be found that the site No 2 is currently heavily contaminated as a result of intensive industrial activity and the contamination assessment coefficient is 1.0 i.e. it is not suitable for any use in the near future and can first be observed by monitoring tools with preliminary contamination assessment, landscaping indicator and planning of appropriate protection measures in the short term.

The comparison shows that the overall level of contamination on the Eastern side is relatively low, while the sub-blocks of the Central sector, such as No. 10, No. 11, No. 21-24, have some controlled
contamination, and the sections No. 21-25 are due to environmental factors. As can be seen from the assessment, the environmental potential for reuse is very high. From the current situation, it has really gotten outstripping development, and the reuse feature is mainly recommended for office space organization.

Table 2. Statistics of environmental potential assessment elements for reuse in the former industrial zone of Taopu

| Number of land plot | The status of contamination | The industrial scale of land use | The status of industrial operation | Intensity of development | Historical and cultural value | Distance from river system |
|---------------------|----------------------------|---------------------------------|------------------------------------|--------------------------|-------------------------------|--------------------------|
| 1                   | 0.20                       | 0.36                            | 0.3                                | 0.5                      | 0                             | 0.26                     | 0.89                     |
| 2                   | 0.00                       | 0.82                            | 0.6                                | 0.5                      | 0.5                           | 0.31                     | 0.88                     |
| 3                   | 0.80                       | 0.41                            | 0.5                                | 0                        | 0.14                          | 0.01                     | 0.42                     |
| 4                   | 0.20                       | 0.19                            | 0.3                                | 0                        | 0                             | 0.00                     | 0.32                     |
| 5                   | 0.20                       | 0.00                            | 0.3                                | 0                        | 0                             | 0.01                     | 0.42                     |
| 6                   | 0.80                       | 0.29                            | 0.3                                | 1.0                      | 0                             | 0.51                     | 0.81                     |
| 7                   | 0.20                       | 0.44                            | 0.3                                | 0                        | 0                             | 0.52                     | 0.93                     |
| 8                   | 0.20                       | 0.38                            | 0.5                                | 0                        | 0                             | 0.76                     | 0.94                     |
| 9                   | 0.20                       | 0.30                            | 0.3                                | 0                        | 0                             | 0.57                     | 0.88                     |
| 10                  | 0.60                       | 0.27                            | 0.6                                | 0.5                      | 1.0                           | 0.50                     | 0.72                     |
| 11                  | 0.60                       | 0.29                            | 0.3                                | 0.5                      | 0                             | 0.37                     | 0.58                     |
| 12                  | 0.20                       | 0.39                            | 0.3                                | 0.2                      | 0                             | 0.26                     | 0.42                     |
| 13                  | 0.20                       | 0.26                            | 0.3                                | 0.5                      | 0                             | 0.81                     | 0.88                     |
| 14                  | 0.20                       | 0.28                            | 0.6                                | 0.5                      | 0                             | 0.70                     | 0.73                     |
| 15                  | 0.20                       | 0.29                            | 0.6                                | 0.5                      | 0                             | 0.53                     | 0.57                     |
| 16                  | 0.20                       | 0.36                            | 0.3                                | 0.2                      | 0                             | 0.53                     | 0.41                     |
| 17                  | 0.20                       | 0.34                            | 0.3                                | 0.5                      | 0                             | 0.45                     | 0.27                     |
| 18                  | 0.20                       | 0.09                            | 0.3                                | 1.0                      | 0                             | 0.48                     | 0.21                     |
| 19                  | 0.20                       | 0.07                            | 0.3                                | 1.0                      | 0                             | 0.77                     | 0.93                     |
| 20                  | 0.60                       | 0.78                            | 0.3                                | 0.5                      | 0                             | 0.97                     | 0.94                     |
| 21                  | 0.60                       | 0.59                            | 0.6                                | 0.5                      | 0                             | 0.92                     | 0.81                     |
| 22                  | 0.60                       | 0.44                            | 0.6                                | 0.5                      | 0                             | 0.86                     | 0.75                     |
| 23                  | 0.60                       | 0.27                            | 0.3                                | 0.5                      | 0                             | 0.65                     | 0.58                     |
| 24                  | 0.60                       | 0.28                            | 0.3                                | 0.5                      | 0                             | 0.80                     | 0.56                     |
| 25                  | 0.60                       | 0.30                            | 1.0                                | 1.0                      | 0.5                           | 0.78                     | 0.41                     |
| 26                  | 0.20                       | 0.33                            | 0.3                                | 0.5                      | 1.0                           | 1.00                     | 0.41                     |
| 27                  | 0.20                       | 0.72                            | 0.3                                | 0.5                      | 1.0                           | 0.91                     | 0.24                     |
| 28                  | 0.20                       | 0.27                            | 0.3                                | 0.5                      | 0                             | 0.79                     | 0.12                     |
| 29                  | 0.20                       | 0.00                            | 0.3                                | 0.5                      | 0                             | 0.71                     | 0.91                     |
| 30                  | 0.20                       | 1.00                            | 0.3                                | 0.5                      | 0                             | 0.85                     | 0.96                     |
| 31                  | 0.20                       | 0.44                            | 0.3                                | 0.5                      | 0                             | 0.64                     | 0.70                     |
| 32                  | 0.20                       | 0.19                            | 0.3                                | 0.5                      | 0                             | 0.79                     | 0.54                     |
| 33                  | 0.20                       | 0.21                            | 1.0                                | 0.5                      | 0                             | 0.96                     | 0.39                     |
| 34                  | 0.20                       | 0.44                            | 0.3                                | 0.8                      | 0                             | 0.91                     | 0.19                     |

2.1.6 Overlay analysis of factors of assessment of the local plots

Each plot is numbered based on an analysis of current land use. As an indicator of the assessment corresponds to the degree of contamination, the scale of industrial heritage, the intensity of development, cultural value, location conditions and other features.
2.1.7. Planning areas on the basis of an assessment of environmental potential.

The area was redeveloped based on the results of an assessment of the environmental potential of the urban areas of the former industrial zone of Taopu (see Figure 2).
2.2 The results of the research

In the course of this research, the following tasks were solved.
1. The basic preconditions and tendencies of construction of eco-cities in China taking into account local features (social, cultural, economic, geographical, ecological) and world tendencies were revealed.
2. It is analyzed the current situation of green building in Shanghai, as one of the largest cities in China. Regional features of territorial planning were considered.
3. Based on the analysis of the status of land use in a particular area of Shanghai, an environmental assessment of regional land use was made.
4. There were developed the criteria and determined the content of the assessment with the choice of formulas for calculation of coefficients of significance of the parameters taking into account the ecological potential of the territory, factors of the environmental contamination and impacts of the various forms of land use and economic activities depending on functional zones of the territory, divided into sections: industrial buildings, residential buildings, green areas, transportation (road network), objects of culture.
5. Based on the overlay analysis of factors of assessment of the local block planning structure of the plots were justified with their schemes.
6. It was developed the elements of project of improvement of the Shanghai microdistrict with the use of selected eco-friendly architectural and planning solutions and identification of the main ways to solve the problem of eco-urban development in Shanghai: land management, population management, clean energy sources and "green" consumption.

3 Conclusion

The results of this research are of practical importance in the field of ecological territorial and architectural planning, taking into account the historical, cultural, geographical, social, economic and environmental trends in the development of megacities on the example of Shanghai and could be used in the development of new projects and solutions for environmental reconstruction and modernization of the urban environment in megacities all round the world with taking into account a range of features of different countries including Russia.

References

1. N.M. Grebenikova, K.J. Smirnov, V.V. Davydov, V.Yu. Rud, V.V. Artemiev, Journal of Physics: Conference Series, 1135(1) 012055 (2018)
2. N.M. Grebenikova, K.J. Smirnov, V.V. Davydov, V.Y. Rud, Journal of Physics: Conference Series, 1124(4) 041011 (2018)
3. N.M. Grebenikova, N.S. Myazin, V.Yu. Rud, R.V. Davydov, Proceedings of the 2018 IEEE International Conference on Electrical Engineering and Photonics, EExPolytech 2018, 8564409 295-297 (2018)
4. E.V. Rykin, A.V. Moroz, K.J. Smirnov, V.V. Davydov, V.V. Yushkova, MATEC Web of Conference, 245 12002 (2018)
5. V.V. Davydov, S.V. Kruzhakov, N.M. Grebenikova, K.J. Smirnov, Measurement Techniques, 61(4) 365-372 (2018)
6. N.S. Myazin, V.V. Davydov, V.V. Yushkova, V.Yu. Rud, Journal of Physics: Conference Series, 1038(1) 012088 (2018)
7. N.S. Myazin, V.V. Davydov, V.V. Yushkova, T.I. Davydova, V.Yu. Rud, Journal of Physics: Conference Series, 917(4) 042017 (2017)
8. N.S. Myazin, V.V. Davydov, V.V. Yushkova, V.Yu. Rud, Journal of Physics: Conference Series, 1038(1) 012088 (2018)
9. R.V. Davydov, V.I. Antonov, V.V. Yushkova, N.M. Grebenikova, V.I. Dudkin, Journal of Physics: Conference Series, 1236(1) 012079 (2018)
10. N.S. Myazin, S.E. Logunov, V.V. Davydov, V.Yu. Rud, N.M. Grebenikova, V.V. Yushkova, Journal of Physics: Conference Series 929 (1) 012064 (2017)
11. V.V. Davydov, Russian Physics Journal, 42(9) 822-825 (1999)
12. V.V. Davydov, E.N. Velichko, N.S. Myazin, V.Yu. Rud’, Instruments and Experimental Techniques, 61 116–122 (2018)
13. R. Davydov, V. Antonov, D. Molodtsov, A. Trebukhin, Advances in Intelligent Systems and Computing, 692 915–920 (2018)
14. R. Davydov, V. Antonov, D. Molodtsov, A. Cheremisin, V. Korablev, MATEC Web of Conference, 245 15002 (2018)
15. R.V. Davydov, V.I. Antonov, D.V. Molodtsov, Journal of Physics: Conference Series, 1135(1) 012088 (2018)
16. R.V. Davydov, V.I. Antonov, A. V. Moroz, Proceedings of the 2018 IEEE International Conference on Electrical Engineering and Photonics, EExPolytech 2018, 8564378 236-239 (2018)
17. V.A. Lyapishev, V.Yu. Rud, M.S. Sokolov, A.V. Cheremisin, Proceedings of the 2018 IEEE International Conference on Electrical Engineering and Photonics, EExPolytech 2018, 8564387 292-294 (2018)
18. D. Tarasova, A. Staritsyna, D. Nemova, K. Andreev, MATEC Web of Conferences, 53 01007 (2016)
19. V. Maslak, N. Nasonkina, V. Sakhnoskaya, S. Antonenko, D. Nemova, Procedia Engineering, 117(1) 985-994 (2015)
20. V. Mushchanov, V. Sievka, A. Veshnevska, D. Nemova, Procedia Engineering, 117(1) 1018-1026 (2015)
21. M. Petrichenko, N. Vatin, D. Nemova, N. Kharkov, A. Staritcyna, Applied Mechanics and Materials, 627 297-303 (2014)
22. T. Fejling, E. Torosyan, O. Tsukanova, O. Kalinina, IOP Conference Series: Materials Science and Engineering, 497(1) 012027 (2019)
23. V. Vilken, O. Kalinina, S. Barykin, E. Zolotova, IOP Conference Series: Materials Science and Engineering, 497(1) 012037 (2019)
24. O. Kalinina, E. Balchik, S. Barykin, MATEC Web of Conference, 239 04021 (2018)
25. V. Vilken, O. Kalinina, A. Dubgorn, E35 Web of Conference, 33 03012 (2018)
26. A. Bril, O. Kalinina, A. Levina, E35 Web of Conference, 33 03004 (2018)
27. R. Davydov, M. Sokolov, W. Hogland, A. Glimushkin, A. Markaryan, MATEC Web of Conference, 245 10003 (2018)
28. I.A. Zharikov, R.V. Davydov, V.A. Lyapishev, V.Yu. Rud, Yu.V. Rud, A.P. Glinushkin, Journal of Physics: Conference Series, 917(5) 052011 (2017)
29. I.S. Kudryashova, V.Yu. Rud, V.C. Shpunt, Yu.V. Rud, A.P Glinushkin, Journal of Physics: Conference Series, 741(1) 012106 (2016)
30. V. B. Fadeenko, V. Yu. Rud, Yu.V. Rud, A.P Glinushkin, V.C. Shpunt, W. Hogland, Journal of Physics: Conference Series, 1038(1) 012030 (2018)
31. N. Mahmoud, W. Hogland, M. Sokolov, V. Rud, N. Myazin, MATEC Web of Conference, 245 06012 (2018)
32. J. Stenis, W. Hogland, M. Sokolov, V. Rud, R. Davydov, IOP Conference Series: Materials Science and Engineering, 497(1) 012061 (2019)
33. R.V. Davydov, V.Yu. Rud, Yu.V. Rud, E.I. Terukov, Journal of Physics: Conference Series, 1124(8) 081039 (2018)
34. A.V. Moroz, V.V. Davydov, V.Yu. Rud, Yu.V. Rud, V.C. Shpunt, A.P. Glinushkin, Journal of Physics: Conference Series, 1135(1) 012060 (2018)
35. I.V. Bondar, V.Yu. Rud, Yu.V. Rud, D.V. Lozhkin, Semiconductors, 45(7) 912-916 (2011)
36. V.F. Gremenok, V.Yu. Rud, Yu.V. Rud, S.A. Bashkirov, V.A. Ivanov, Semiconductors, 45(8) 1053-1058 (2011)
37. V.Yu. Rud, Yu.V. Rud, V.F. Gremenok, E.I. Terukov, B.K. Barinov, Y.W. Song, Semiconductors, 46(2) 221-224 (2012)
38. N.S. Myazin, K.J. Smirnov, V.V. Davydov, S.E. Logunov, Journal of Physics: Conference Series, 929(1) 012080 (2017)
39. K.J. Smirnov, V.I. Medzakovskiy, V.V. Davydov, M.G. Vysockzy, S.F. Glagolev, Journal of Physics: Conference Series, 917(6) 062019 (2017)
40. X. Li, W. Liu. Status Quo, Urban Planning Journal, 4 23-29 (2011)
41. Y. Zhang. Urban Planning Journal, 5 1-8 (2012)