

## Information-Analytical System for Managing Cities of Perm Region Spatial Development

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### 1 ABSTRACT

To date, the practice of urban planning and design in Russia is based on the principles of the Soviet planned economy, while the current economic conditions require new approaches.

Perm National Research Polytechnic University together with JSC «PROGNOZ», with the financial support of the Perm Region Government during the year of 2013 is developing an integrated spatial development IT-model, which allows the bringing together of socio-economic statistics, real estate state cadastre data, mathematical, statistical and adaptive methods library integrated with GIS under one platform.

The main purpose of the system is the improvement of validity of decisions taken in different urban planning types, design improvements of Land Use and Development Regulations and prioritization of the municipal budget allocation.

Decision support system is based on the Prognoz Platform (PP) - a next-generation BI platform for building high-tech business applications on a turnkey basis. PP allows to visualize and analyze operational data model and forecast processes. It has its own data warehouse designer which helps to build full-featured industrial BI systems based on the Prognoz Platform. PP Integration with the state information system for urban planning allows consideration of established local and federal law requirements for the quality of the urban environment, the prevailing land use and capabilities of municipal budgets.

Model is to be used for the following tasks:

- Analysis of the effects of the changes in the administrative-territorial division of the region;
- Optimization of social facilities, taking into account standards of security, transport availability, etc. on the territory;
- Analysis of the current and future needs of transport infrastructure development, resource security of the region;
- Justification of the area choice for investment projects, etc.

In the first phase the analogs of software that are used to solve problems of this kind, were identified.

In the second phase of the model development typology and classification of simulation objects were studied, a list of necessary calculation and performance indicators/indicative indexes were determined, an algorithm providing integration with GIS and a prototype system were created. Prototype testing was conducted for the following tasks:

- Optimization of social facilities, taking into account federal regulations and budgetary constraints: selection of the site for the construction of a new school in the city;
- Justification of the energy infrastructure development scenario by combining mining settlements of Kizelovskoe and Gremyachinskoe municipal districts of Perm Region;
- Land Use Plan development for new residential area in New Lyady, Perm
- The next step of the analysis implies specifically housing and social infrastructure development challenges arising at the local government level, for the solution of which it is expedient to use the created model.

## **2 URBAN PLANNING PROBLEMS IN RUSSIA, OBJECTIVES AND TASKS**

To date, the practice of urban planning and design in Russia significantly differs from other market economy countries, thus is based on the principles of the Soviet planned economy, while the current economic conditions require new approaches.

Due to resource limitations municipalities cannot provide required amount of experimental research for the development and assessment of variable scenarios of socio-economic development, thus cannot define priorities in construction financing of objects of social, transportation and engineering infrastructure.

At present there are no practical technologies that allow the improvement of validity of spatial planning and decreasing the amount ineffective budget expenditure associated with implementation of urban planning policies.

Implementation of Western urban planning technologies seems to be impossible due to condition of Russian urban planning system, which is still undergoing the formation stage, whereas, the development of cities goes either spontaneously or according to short term planning.

The complexity of spatial planning of any urban objects lies, primarily, in variability of settlement typologies and the necessity of large amount of input data processing (from climate and geographical to political) and decisions, taken at different levels of administrative management.

The research objective is the decision support system development based on a complex model of spatial development, containing general socio-analytical statistics, federal real estate state cadastre data, mathematical, statistical and adaptive methods library integrated with GIS considering established by the legislation level of availability of different types of services, opportunities municipal budgets, prevailing urban conditions.

## **3 GENERAL CHARACTERISTICS OF TASKS SOLVED WITH THE IT-MODEL OF INFORMATION-ANALYTICAL SYSTEM**

The decision support system is based on the IT-model of spatial development. It allows the bringing together of socio-economic statistics, real estate state cadastre data, mathematical, statistical and adaptive methods library integrated with GIS - under one platform. The model allows consideration of established local and federal law requirements for the quality of the urban environment, the prevailing land use and capabilities of municipal budgets.

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## **4 OVERVIEW OF THE EXISTING ANALOGS**

In the first phase the analogs of software that are used to solve problems of this kind based on following criteria were identified:

- Conducting research of spatial data possibility;
- Availability of tools of geospace modelling;
- Data visualization (presentation of data in user-friendly format);
- The completeness of the software (does not need installation of or plug-ins primary or secondary programs);
- Users accessibility (possibility to download the software without conducting any additional commitments or agreements).

Name	Developer	Operation system	Access	Purpose	Defining features
ArcGIS	Esri <a href="http://www.esri.com/">http://www.esri.com/</a>	Linux, Windows, Unix, iOS, Android, Windows Phone	Limited (платные версии)	Create, visualize, manage, analyze spatial data	Has a special application for the PC, mobile phone; Visualizes large volumes of geo-referenced statistical information; Maps of all scales: from the plans of plots to world map; Toolkit for analyzing spatial information
Agstats	Dr. Kevin McGarigal - University of Massachusetts <a href="http://www.umass.edu/landeco/research/fragstats/fragstats.html">http://www.umass.edu/landeco/research/fragstats/fragstats.html</a>	Windows	Free	Landscape metrics for different types of models	The ability to use the characteristics such as the area, density, physical parameters
Erpy	RiSE group (@gmail:rise.group.eafit), Dr. Juan C. Duque and Boris Dev <a href="http://www.rise-group.org/section/Software/clusterPy/">http://www.rise-group.org/section/Software/clusterPy/</a>	Linux, MAC OS, Windows	Free	Spatial clusterization	A collection of algorithms, combined in groups for regions
Groupier	<a href="http://www.rise-group.org/section/Software/clusterPy/">http://www.rise-group.org/section/Software/clusterPy/</a>				
Eodaspace	GeoDa Center for Geospatial analysis and Computation <a href="https://geodacenter.asu.edu/software">https://geodacenter.asu.edu/software</a>	MAC OS, Windows	Free	Spatial econometrics	Spatial models built using GMM, IV and spatial HAC
Google earth	Google <a href="http://earth.google.com/">http://earth.google.com/</a>	Linux, MAC OS, Windows	Free/400\$ extended version	3D visualization	Has a special application for the PC, mobile phone; Automatically updates the data through the Internet; Contains current and historical maps; You can create a small visual elements correlated with internet
Grass	GRASS Development Team <a href="http://grass.osgeo.org/">http://grass.osgeo.org/</a>	Linux, MAC OS, Windows	Free	Environment visualization	Extensive set of tools for GIS raster and vector data, SQL, visualization
Legacy GeoDa	GeoDa Center <a href="http://geodacenter.asu.edu/geodasum">http://geodacenter.asu.edu/geodasum</a>	Windows	Free	Analysis of spatial data	Visualization, ESDA, contains territorial regression; interactive exploratory analysis, the basic spatial possibilities of recourse
PySAL	GeoDa Center <a href="http://www.pysal.org/">http://www.pysal.org/</a>	Linux, MAC OS, Windows	Free	Analysis of spatial data	Modules for computational geometry, spatial weights, mobility and spatial econometrics
Quantum GIS	QGIS Development Team <a href="http://www.qgis.org/">http://www.qgis.org/</a>	Linux, MAC OS, Windows	Free	Environment visualization	Has broad functionality, additional plugin capability, includes elements of geoprocessing
R-Analysis of Spatial Data	Roger Bivand <a href="http://cran.r-project.org/view=Spatial">http://cran.r-project.org/view=Spatial</a>	Linux, MAC OS, Windows	Free	Analysis of spatial data	Integration of spatial data: classification, processing, reading and writing spatial data, graphical representation, environmental analysis, spatial regression
SAGA	Institute of Geography at the University of Hamburg, Germany <a href="http://www.saga-gis.org/en/index.html">http://www.saga-gis.org/en/index.html</a>	Windows, Linux	Free	GIS, space analysis	Surface analysis, geostatistics, terrain analysis, hydrology modeling, various TIN tools

Table 1: The results of software analogs analysis.

One of the defining criteria was the presence of functional of geospace modelling. Basic characteristics of analyzed software are summarized in Table 1.

There were 12 systems analyzed, most suitable for a variety of analytical tasks of spatial planning are – ArcGIS, SAGA, PySAL, providing special tools to meet the challenges of spatial planning.

The algorithm and prototype of the model based on the research conducted was created.

## **5 KEY PARAMETERS AND TARGET FUNCTIONS OF THE MODEL**

In the second phase of the model development typology and classification of simulation objects were studied, that allowed to determine a list of necessary calculation and performance indicative indexes of providing favourable living conditions on different territories. The existing standards are analyzed for the provision of social services by the example of the Perm edge areas to determine necessity of establishment of certain restrictions. The main theoretical approaches to modeling spatial location problem of social facilities, the objective functions and the basic relations used in the analysis of urban development in the Russian Federation have been outlined in the research work of A.V. Golovin [4].

Set of key parameters for the prediction of target functions that characterize urban planning situation and used for the verification of the model include:

The number and size of households (people), the number of students and preschool (% of population), estimated housing security, FAR (the ratio of floor space to land area), a planning factor (the ratio of the living area to the total area), the ratio of land development, % , water consumption (liter/person a day), stories of buildings.

These parameters are determined using the specific indicators to be defined by the plan of the municipality, Land Use and Development Regulations or SP 42-13330. 2011 "Urban Planning. Planning and construction of urban and rural settlements", or set on the basis of demographic and urban research.

The target functions which are determined by the calculation formulas for the forecast period (years) include: the predicted increase in population, students and preschool, required land area of residential development, community facilities, water and energy consumption, the need for new development in public transport and projected level of motorization, forecast maximum area of commercial real estate and other parameters of the territory.

This information is included in the attribute information of model geodatabase.

## **6 ALGORITHM AND PROTOTYPE OF THE MODEL**

The main components of IT-model as the basis of i decision support system of strategic decision-making in the field of spatial planning are three major subsystems: 1) data storage, 2) tools for working with maps and 3) modeling and forecasting tool. For this purpose they are integrated on a single platform.

Data repository must contain:

- Socio-economic statistics,
- Forecasts for the development of territories,
- Information system for urban planning,
- Legal and regulatory framework of urban planning,
- Other sources of data used in the practice of urban planning.

Tools for working with the maps will be borrowed from the geographic information systems considered in the table above.

Prognoz Platform is used as a tool for modeling and forecasting. It is a next-generation BI platform for building high-tech business applications on a turnkey basis. Prognoz Platform supports the development of software solutions on the desktop, web, and mobile devices for visualization and online analytical processing (or OLAP), reporting, and modeling and forecasting of business processes.

Application of Prognoz Platform and its analytical tools will help to find solutions of multiobjective optimization problems of spatial distribution of various objects (housing, civil, industrial etc.) in urban areas and analyze long-term scenarios for the development of cities.

The logic of the system taking into account selected components and the use of this system to solve practical problems is presented in Figure 1.

Modeling and forecasting tool is designed to make data researches, create different econometric models and analytical calculations implementation based on them. The possibility of visual design models and algorithms of arbitrary complexity, a rich library of mathematical and statistical techniques (more than 300 units.) as well as automatic generation of reports with the analysis results, are its main advantages.

Modeling and forecasting tool is widely used in the development of economic and mathematical models in many countries and regions, including USA, Brazil, China, Kazakhstan, Russia.

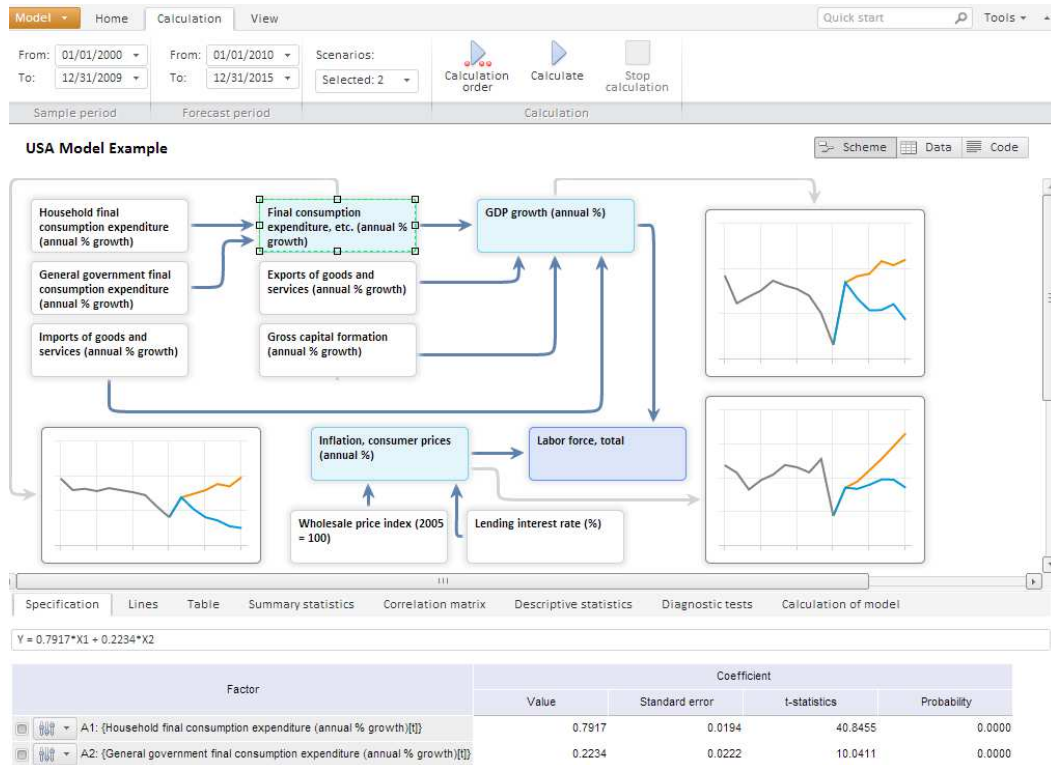


Figure 1. Example of the USA macro model implemented using PrognozPlatform - modeling and forecasting tool.

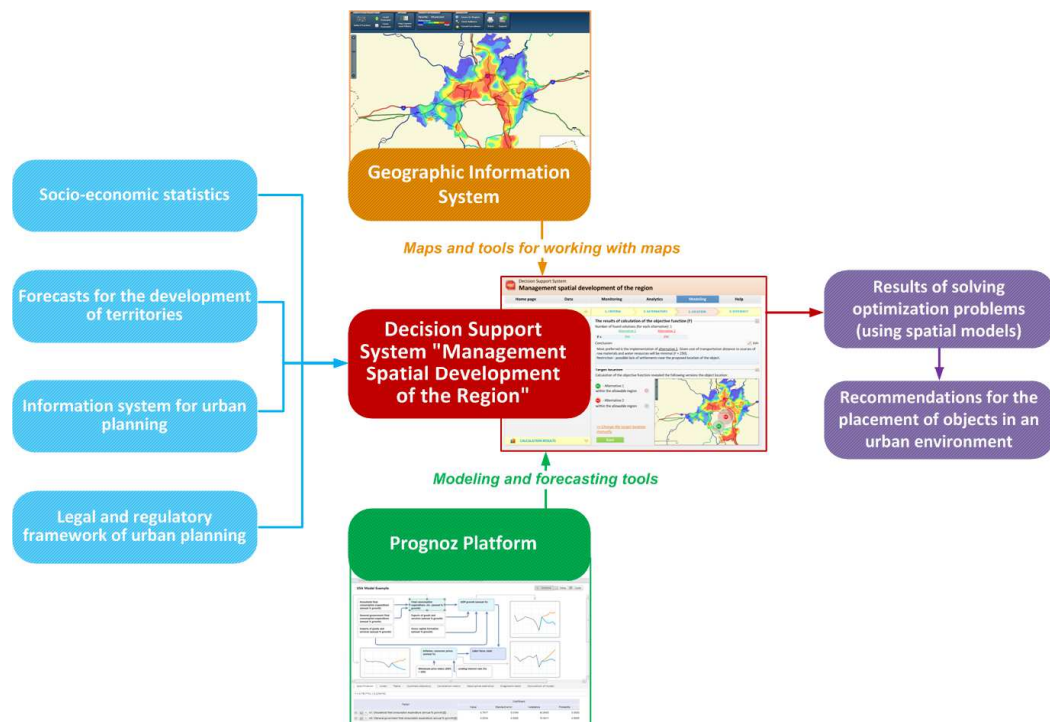


Figure 2. IT-model structure.

## 7 PRACTICAL RESULTS

The following problems in developing the model using its prototype were solved:

- Location optimization of social facilities subject to federal regulations and budgetary constraints: selection of the plot for the construction of a new school in the city;
- Land Use Plan in the development / utilization of new residential development area of Lyady Perm.

Demo application on Figure 3 shows a prototype model for the solution of plot choice.

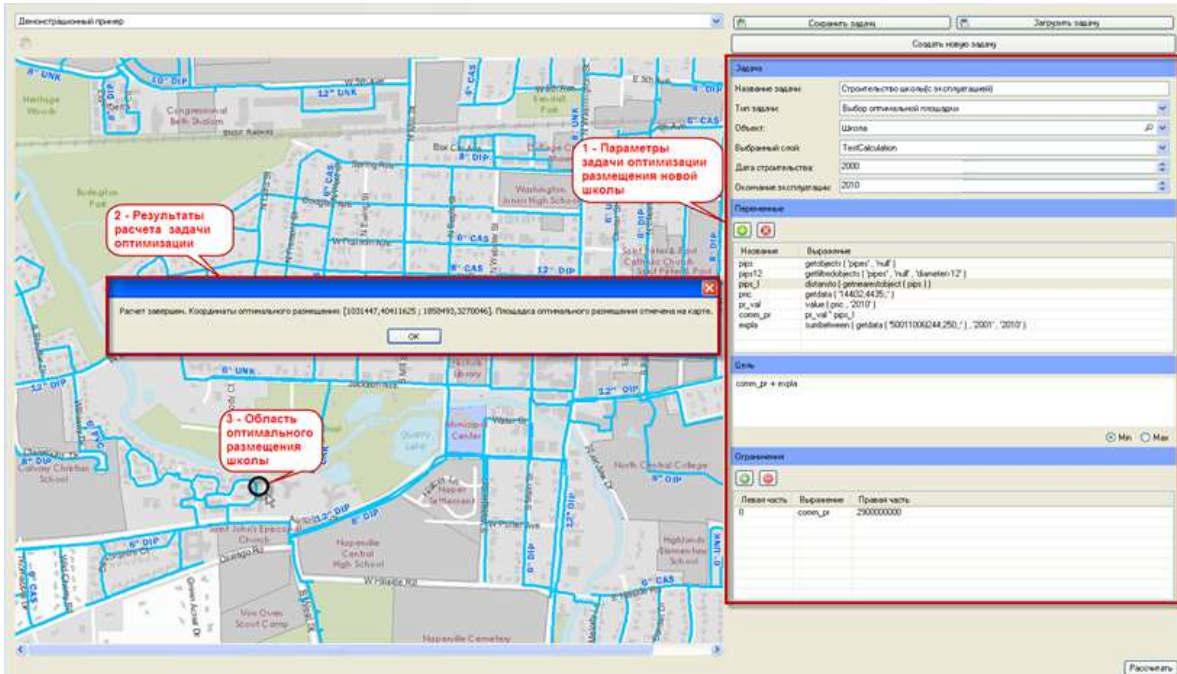


Figure 3. The task of Social objects location optimization interface.

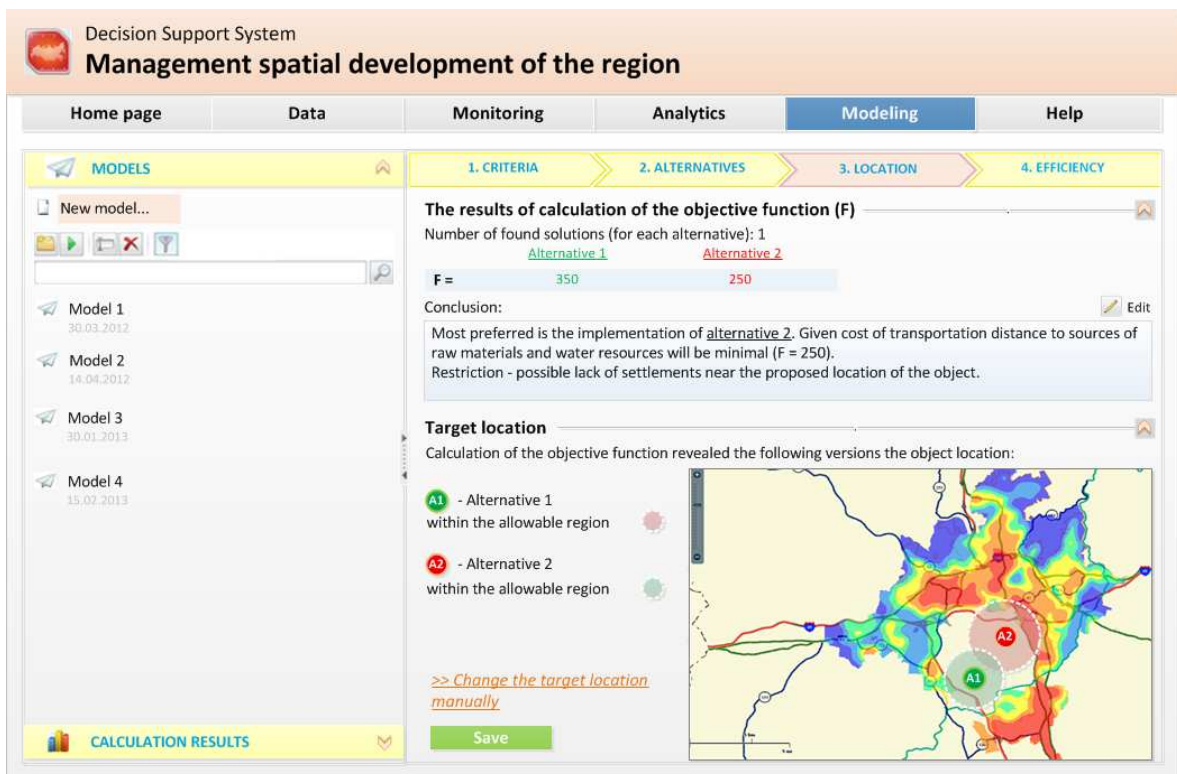


Figure 4: The interface of strategy development of Novye Lyady.

To date OAO PROTON, one of the largest enterprises of the aero-space sphere, implements the Program of Territory Cluster Development «Technopolis Novyi Zvezdnyi», which is based on the expansion of production by 3,000 new jobs.

The implementation plans of the enterprise is directly dependent on solving the problem of housing new employees, development of transportation and engineering infrastructure of the New Lyady District in Perm.

Calculations conducted using the prototype model show that New Lyady have sufficient land resources to accommodate new residential buildings within existing boundaries and the additional land outside the existing boundaries, is not required. During the first stage of production up to 2016 (opening up to 600 jobs) the existing social infrastructure (kindergartens, schools) is sufficient. The reconstruction of the school building and enlargement of its capacity will not be required until the year 2020. Budget expenditures for the first stage of development until 2016 should be directed to the reconstruction of utilities and road Perm – New Lyady reconstruction.

## 8 CONCLUSION

The first stage of system development is finished:

- basic optimization algorithms developed;
- a software tool that allows the system to use analytical and GIS spatial data simultaneously developed;
- socio-economic statistics and state real estate cadastre data repository formed.

The next step of the analysis assumes specific development challenges of housing and social infrastructure arising at the local government level; testing the model in the development of land use regulations and development and prioritization in the municipal budget allocation.

## 9 REFERENCES

- ALEKSEEV YURIY V., SOMOV G.Y. Urban planning of settlements. The evolution of planning. Moscow, 2003.
- MAGUIRE D.J., GOODCHILD, MICHAEL F., BATTY. M. GIS, Spatial Analysis, and Modeling. ESRI Press,
- MONTRONE S., PERCHINUNNO P. Statistical Methods for Spatial Planning and Monitoring (Contributions to Statistics). Springer, 2012.
- GOLOVIN ANDREY.V. Modeling for decision-making in urban planning at the example of the network of municipal educational institutions. In: Bulletin of the Perm national research polytechnic university 'Urbanity', Vol. 2 (10), pp.6-31. Perm, 2013.
- ZAVIALOV A.LEKSEY, MAKSIMOVA SVETLANA.,SHULTZ DMITRII., MIKUSHIN PIOTR., LORENZ PIOTR. Integrated model of development as basis for the urban planning. In: Bulletin of the Perm national research polytechnic university 'Urbanity'. Vol.4 (12), pp.10-20. Perm, 2013.
- VANCUTSEM DIDIER L., LYUBIMOV ALEXANDR., MAXIMOVA SVETLANA., MELTCOVA EKATERINA. Summary of spatial development concept for settlement of Novye Lyady based on industrial cluster 'Technopolis 'Novyi Zvezdnyi'. In: Bulletin of the Perm national research polytechnic university 'Urbanity'. Vol.4 (12), pp.21-30, Perm, 2013