

## Determination of territorial compactness and analysis of optimization of energy-efficient characteristics of the university campus

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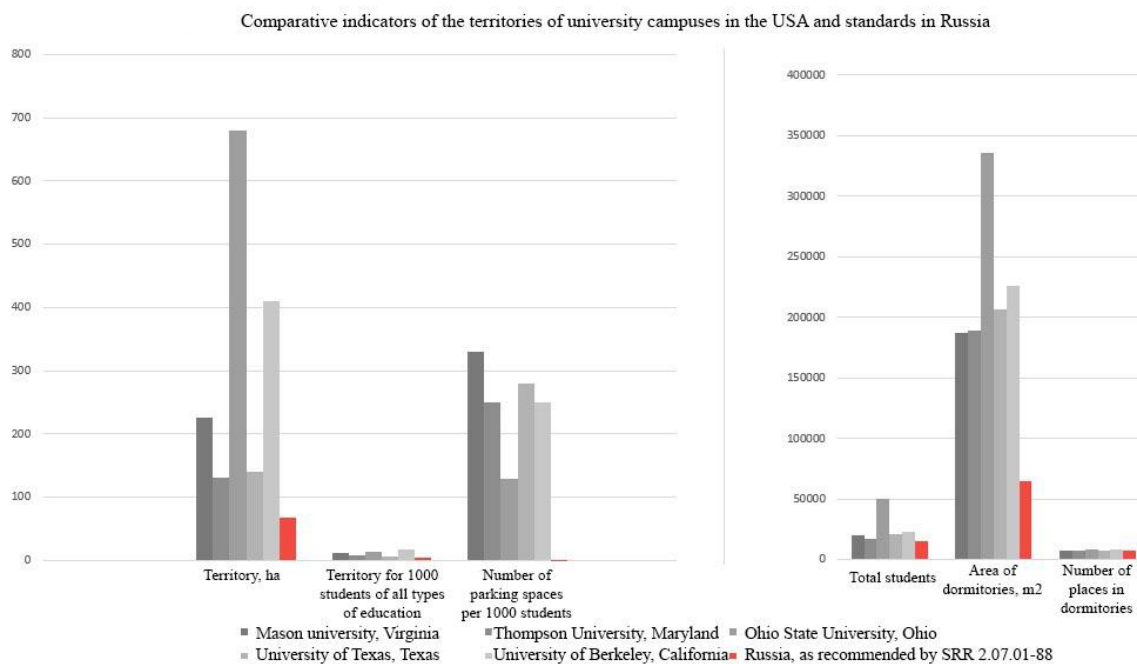
**Abstract.** This article provides an overview of the spatial structure of university campuses, taking into account its reasonable organization and improving the energy efficiency of buildings-obtaining the status of a "self-sufficient" university campus. The analysis of the compactness of pedestrian work on the territory of universities is carried out. Modern technologies based on "sustainable architecture" to improve the quality of architectural characteristics of domestic universities are considered. The aim of the work is to identify the most promising model for the development of the spatial structure of the campus and modern solutions to the problem in the field of architecture of low-energy efficient university campuses.

One of the factors in the development of scientific and educational activities is the architectural spatial environment of the university campus (campus). The main component of this structure is the complex architectonics of communication links between educational premises for lectures, research laboratories, residential premises for students, the library and many other premises that carry functions for full-fledged learning and professional skills of students.

The energy efficiency section of the campus is taken into consideration as this part is one of the fundamental factors in the design of the campus. Energy efficiency of the campus is widely used in the West, for example, reducing the energy efficiency of educational institutions due to facades - the cylindrical Kuggen building for the Chalmers Technical University in Gothenburg and the campus of the University of Southern Denmark in Kolding (Kolding Campus), built according to the project of Henning Larsen Architect's. [1]. domestic experience shows that a significant part of the operated university campuses were built at the end of the twentieth century, so most of these buildings need various kinds of restoration to improve their quality and energy efficiency. the problem is that the attempt to apply the Set of Rules approved by the ministry of regional development "SR 42.13330.2011. Planning and development of urban and rural settlements. the updated version of CRR 2.07.01-89\*" [2] can lead designers to design buildings and complexes in the middle and end of the last century. The set of rules, along with the concept of "university", continues to operate with the concepts of "technical universities; agricultural; medical, pharmaceutical; economic, pedagogical, culture, art, architecture" (appendix "G"), although almost all state higher education institutions have received the status of universities. In relation to general education schools, the rules operate with the concepts of schools of "I-III stages", which were relevant in the 50s of the XX century. And according to the standards for



dairy kitchens, factories-laundries and factories-dry cleaners, a rare subject of the federation can fulfill the recommendations of the Ministry of Regional Development established by these Sets of Rules. All this leads to the need for designers to independently develop approaches to the formation of principles for the construction of educational buildings and university campuses. Conclusion - in our time the rules of construction require adjustments based development technologies, using new materials and the development of design solutions for the twenty-first century, the comparative performance of university campuses of the USA and regulations in Russia (figure 1).



**Figure 1.** Comparative indicators of the territory of US university campuses and standards in Russia [6].

All this leads to the need for additional development of the principles of building higher education institutions, additional study of scientific literature on this topic.

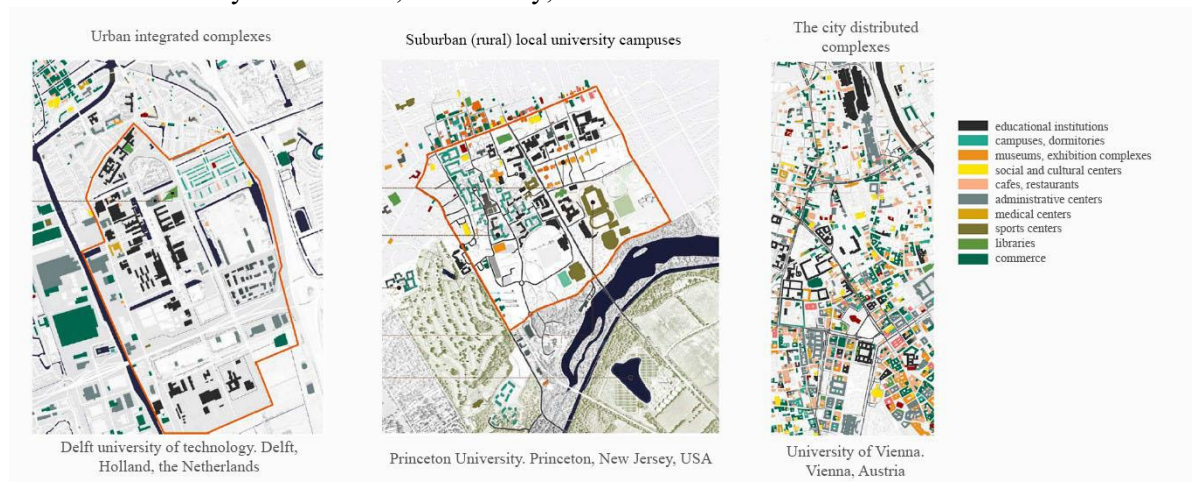
Consider the classification of universities, types of compositional architectural and urban planning solutions and on this basis analyze several higher education institutions in Russia and in the West with a similar climate. On the basis of the theoretical part, we will try to identify problems and, as a result, propose new approaches to the design of university campuses in this climatic environment.

Classification by urban features (picture 1), in particular by urban affiliation, allows you to divide all student campuses into three main types [3]:

1. Urban distributed complexes. They are a collection of university facilities dispersed in an urban environment. the type is effective and “works” exceptionally well only if the urban environment in which the university's facilities are located is of great value in the cultural and social sense of the word. At the same time, this type of complex has some problems with sustainable development and security. For example, the HSE campus in Moscow, Delft University of Technology in Delft, Holland, the Netherlands.

2. Urban integrated complexes. They are high-density campuses in urban development. The isolation of this type of territory creates problems with development and new construction, security (modern systems of restricting access and control to the campus are required), problems of social comfort and problems with the placement of additional structures that require separate and special zoning. It is effective, just like the first one, only in a socially comfortable urban environment of a large city. For example, the university of Vienna in Vienna, Austria.

3. Suburban (rural) local university campuses. They are located outside of dense urban development. This is the most up-to-date and recognized effective strategy of the university campus. For example, Princeton University in Princeton, New Jersey, USA.



**Figure 2.** Classification of campuses by urban features [4].

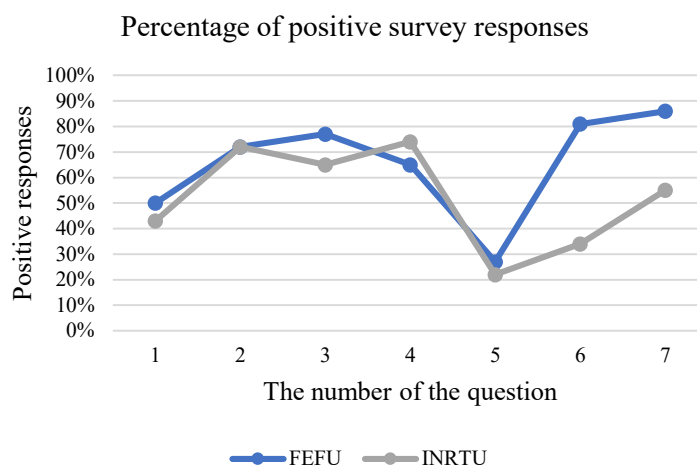
The first type has the most readable functional connections than the second or third, which allows you to freely navigate in the external and internal space, which can not be said about the other two. This is his only positive point. The distributed type of campus is the least promising of all the presented ones, as it is limited to urban development and does not have a legal basis for further territorial development. the most promising in this regard is the third type of development, which is located in the suburban (rural) zone and does not have serious restrictions on construction and territorial expansion. the first two types are most common in Russia, and attempts were made to design suburban-type campuses, but they were not implemented.

In the 50s and 60s, it was possible to build a complex for Moscow State University on the Leninsky (Vorobyov) Mountains and a university complex in Novosibirsk Akademgorodok. Attempts to build university campuses for Leningrad (now Saint Petersburg) [5] and Tomsk Universities have not yet been fully implemented.

One of the last examples of the construction of university campuses and FEFU in Vladivostok (Far Eastern Federal University entered the TOP 500 best universities in the world by QS in the TOP-30 best Russian universities according to Forbes and in the TOP 25 best universities in Russia according to the Agency RAEX [6]).

To understand the quality of planning decisions and their impact on the overall perception of the campus, a survey was conducted (Table 2) among students of architectural and design areas of the Irkutsk National Research Technical University (INRTU) and the Far Eastern Federal University (FEFU). It turned out that the survey participants answered almost equally positively to most of the questions, but in three aspects, students from the same university answered most positively. FEFU students rated the level of the educational cluster, the quality of the functional and spatial environment and the aesthetic component of the campus much higher than INRTU students. This suggests that the type of local development of the campus is really inferior in quality and needs to modernize the culture of spatial organization of universities.

1. Are you comfortable getting from your place of residence to your place of study?
2. Is it convenient for you to navigate the internal structure of the university campus?
3. Are you satisfied with the functional and spatial structure of the environment?
4. In your opinion, is there a unity in the composition of the three-dimensional and planning structures of the campus?



**Figure 3.** The results of a survey among students of the campuses of the INRTU and FEFU. The author of the survey - student of the INRTU, Potonova N. (gr. ARb-18-1), 2020.

The following classification (Figure 3) allows us to feel the diversity of the spatial organization of universities, which has developed over several centuries, starting from the formation of universities on the basis of monastic schools in the Middle Ages. Conventionally, there are 5 main models of the campus, which characterize the differences in spatial infrastructure, the degree of autonomy of the internal and external environment [7]:

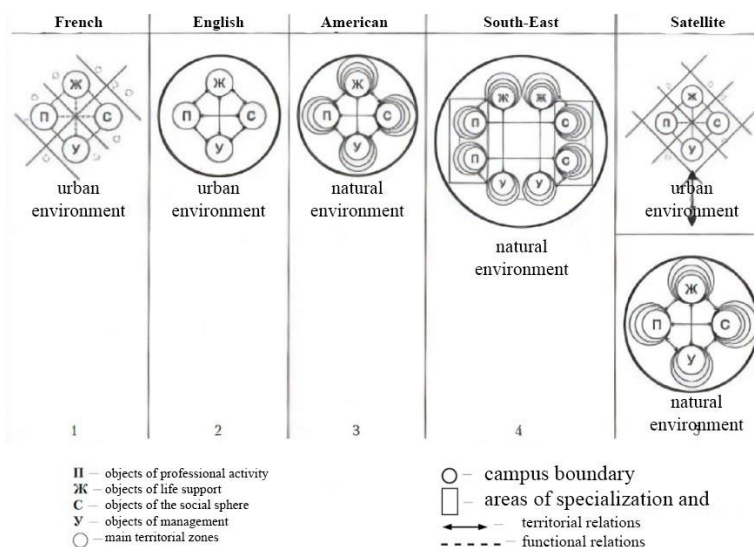
- the first model is a blurred type of campus without territorial boundaries and autonomy, without development reserves, with a motley population that is not related to the interests of the university community, high building density – up to 1.5 hectares per thousand people and above, intersections of urban transport, bustle and low environmental indicators of the environment characteristic of the centers of the largest cities. The only advantages are the low cost of construction and maintenance due to the use of existing social infrastructure in the city;

- the second model retains the territorial autonomy and boundaries of the campus, does not have many of the disadvantages of the first type of model, uses the advantages of urban infrastructure, but is limited in expansion, tends to increase the density of development and completely loses the natural environment;

- the third model is the most optimal in comparison with the previous ones, but it is inferior to mega-universities in terms of cooperation, specialization with neighboring universities and is more expensive;

- mega-universities of the fourth type are currently the most promising model, which has all the advantages compared to the rest;

- the satellite model of the fifth type is a forced step in the development and improvement of the competitiveness of old universities, it does not require large construction costs compared to the previous one, but it fully meets it in all other respects.

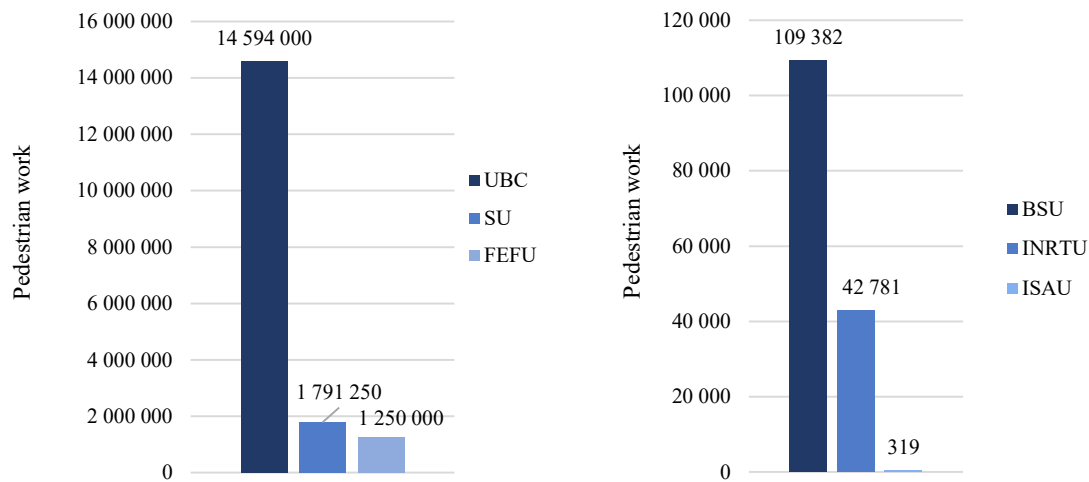


**Figure 4.** Basic models of spatial organization of campuses [6].

To assess the feasibility of spatial organization of university campuses, we will turn to more specific examples and conduct an analysis based on their transport and pedestrian schemes (figure 3). We offer to evaluate the compactness of the spatial location of the university. The matrix method will help us in this – we will make a matrix of departure points  $A_1, A_2, \dots, A_n$  (bus stops, student dormitories), write them in the top row of the table and destination points  $B_1, B_2, \dots, B_p$  (entrances to academic buildings), write them in the left column. In the table cell at the intersection of rows and columns, write down the distance that lies between the named points. The distance is measured by real paths on the map. Next, we find the determinant of the matrix, which is actually the sum of the distances from all locations of departure points to destination points. Next, you need to understand the degree of concentration/dispersion of the paths. To do this, divide the found determinant by the number of students studying at this university, and get a pedestrian job. In order to be able to compare the walking performance of students from different campuses, you need to take the same total number of students for calculations.

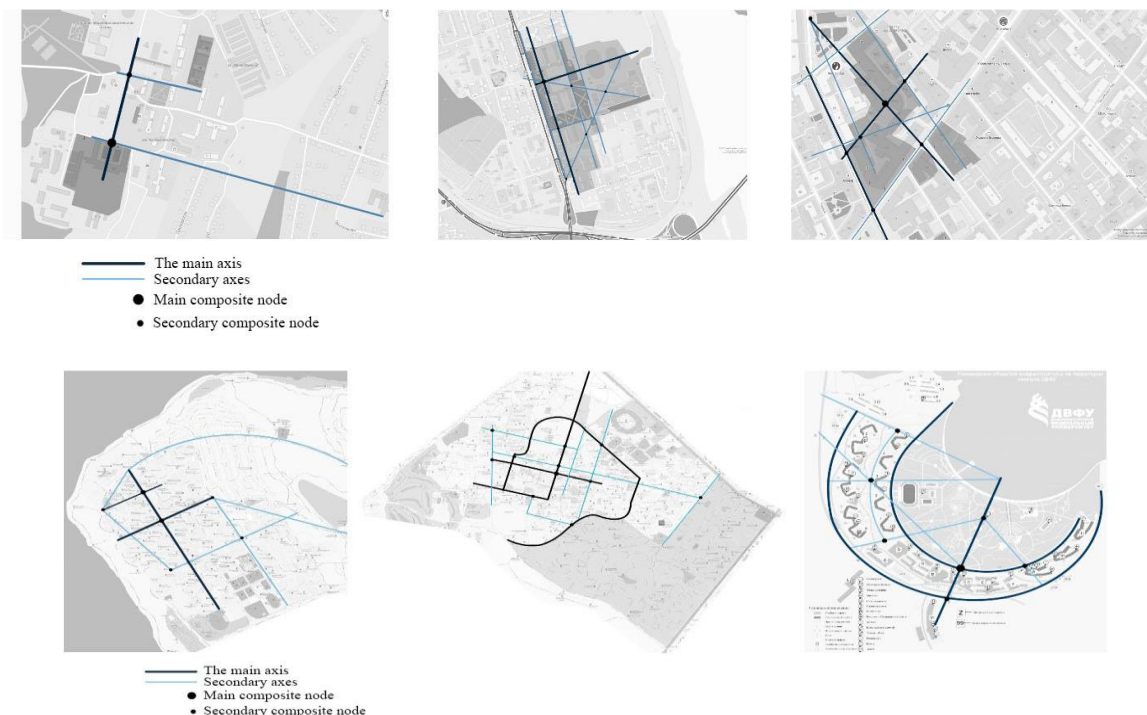
In this way, we will analyze the institutes of Irkutsk, Vladivostok, Canada and California. The climate in these areas is similar, moderate and sharply continental, i.e. the climatic conditions will be considered equal. To begin with, we will distinguish 2 groups of universities in terms of the number of students – INRTU, BSU, ISAU (pedestrian work for ISMU was calculated in the amount of 828 units of transport work per 5000 students, but the number of students is not commensurate with the universities represented, so we can not say that the transport scheme in ISAU, for example, is more logical than in ISMU) and pedestrian work in FEFU, UBC (The University of British Columbia), US (Stanford University). The analysis considers all 3 types of university campuses by urban planning features.

According to the results of calculations (figure 4), the most rational pedestrian work is performed in ISAU, despite the fact that this is a distributed type of development. This result is based on the simple and straightforward spatial structure of the campus. The dormitories and the entrance to the main building are almost on the same straight line and quite close to each other, with the exception of the G dorm, which is 8 km away from the main building, but does not add much pedestrian work. The second outcome of the analysis is the INRTU, which has a more complicated spatial structure but is not allocated for urban development. The most irrational and impractical solution to the pedestrian scheme is BSU, which has dormitories “scattered” in the city structure and students do a lot of pedestrian work every day.



**Figure 5.** “Results of a comparative analysis of the compactness of the spatial location of the university”. Author of the chart - student of the INRTU, Potonova N. (gr. ARb-18-1), 2020.

In FEFU, pedestrian work is performed 11 times less than at the university of British Columbia and 1.5 times less than at Stanford university (the calculation considered the campus area, not including bus stops). All 3 campuses have clearly defined borders, approximately comparable territory, and such results of pedestrian work units can only be justified by the structure of university campuses (Figure 6). They represent the framework of the spatial structure [16] of university campuses, consisting of the main and secondary pedestrian axes, and the nodes connecting them, you can clearly see how favorable conditions the campus provides to students and roughly assess the compactness of the spatial location of the university, but by the graphical method.



**Figure 6.** Framework of the spatial structure of university campuses. Author of schemes - student of the INRTU, Potonova N. (gr. ARb-18-1), 2020 [14].

In addition to the spatial organization of the campus, energy efficiency includes a huge variety of design solutions. Although the spatial organization of university campuses can be organized to improve energy efficiency, not only by logically solving the space of pedestrian links to create favorable conditions, but also, for example, by using warm corridors, it's the university of Waterloo [8] in Waterloo, Canada, where all the buildings on the campus permeate the transitions between buildings and exclude contact with the adverse environment to a minimum in planning solutions that meet the challenges of wind loads and create a cascade for shelter. These include the university of Toronto Scarborough [9]. In the first case, we observe a continuous main building that wraps around the forest and creates the same barrier against the wind. Considering the building of the NSU, it is impossible not to note the isolation of the main building, where again the fact of wind protection of the internal space can be traced [10].

Main design solutions used to preserve energy efficiency [11]:

- energy-saving technologies, such as solar panels, used on building facades. A vivid example of this is Stanford University;
- use of earth's heat for heating and cooling buildings;
- heat recovery of ventilation emissions, which consists in natural ventilation. For example, the arrangement of a botanical garden inside the campus of the National Research University of Singapore;
- maximum use of natural light and energy-saving artificial lighting with sensors for the presence of people in educational premises to reduce the cost of electricity for lighting, the use of reflections, reflections and reflected light to illuminate the interior is used in all modern universities., for example, a complex in downtown Phoenix, Arizona, USA;
- use of biofuels;
- automatic control and monitoring of energy consumption;
- the use of high-tech building materials, for example, bio-concrete, which was developed by the research group in the field of construction technologies of the Polytechnic University of Catalonia [12];
- the use of rainwater and a closed cycle of wastewater treatment. an example of this solution is the university of British Columbia in Vancouver, Canada, discussed above. In a sense this is manufactured nature, with each pool a bioswale that filters stormwater level by level to the bottom, where it flows into a cistern hidden beneath a seating deck. The official name of the procession is "stormwater terraces". The project's planning documents explain that it is meant to "showcase the university's sustainability goals". The cistern at the base holds only half of the possible runoff from the area which means that in the summer, the university switches to potable water to keep the "stormwater" flowing [13].

It is concluded that in order to attract students and create a favorable environment for the development of science within the walls of university campuses, more and more new ideas on the architectural solution of universities are being adopted every day. These ideas are mostly related to the Western experience of construction, and in Russian practice, the issues of the university environment, the culture of its organization, the use of "sustainable architecture" in construction for the design of self-sufficient buildings are not given enough attention. To solve the problem, it is proposed to pay attention to CRRs that do not correspond to the modern realities of the 21st century, and also to analyze the vast majority of university campus development in Russia, namely distributed and integrated, which do not provide prospects for further development and it is proposed to build a satellite campus (according to the type of qualification of the spatial organization model) to fill in the missing infrastructure elements or (not in such a global sense) to restore existing university campuses, taking into account the preservation of energy efficiency of the building.

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