Basis of Architectural and Urban Planning Formation of Scientific and Educational Complexes

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Abstract. A modern university becomes a place for the formation of human intellect in all its diversity: in the form of knowledge, innovations, competencies, and at the same time remains a special territory: a space for meeting and joint work of researchers, professors and students. Such task creates additional special requirements for the qualities of the architectural space of university complexes. This article discusses the architectural and urban principles of creating new facilities and complexes for educational, scientific and technological needs. We analyzed effective centers from the town-planning scale up to the level of local architectural objects. The main goal is to develop the theoretical foundations for the architectural design of scientific, educational and research facilities that correspond to modern educational and scientific technologies in the context of innovative economy.

1. Introduction

1.1. Problem
Now leading universities in all countries (as catalysts for economic growth based on innovation) are becoming centers of social and cultural life of the region, connecting elements between the city’s society, government and business community. The combination of research and educational activities in university complexes provides competitive advantages for educational technologies compared to traditional universities (1, p. 50). In this strategy, educational institutions become regional centers of the new social economic policy.

New educational technologies require new spaces and architectural forms for functioning. To understand the spatial structure and development prospects in typology of university spatial forms, firstly it is necessary to understand the global trends, as well as to formulate the main perspective spatial models for the development of higher education institutions.

1.2. Context
Initially, scientific and educational objects did not imply a certain unified space, but in process of growth and integration, complication, special typological properties of space for scientific, educational and research activities were established. The architectural qualities of the integrated learning space (which includes the research component) focused in the unity of time and action. The most famous theoretical concepts in this area are the concepts of “post-industrial society” (R. Aron, D. Bell), “information society” (M. Castells, F. Mahlup), “knowledge-based economy” (P. Drucker, B.A.
Lundvall, R. Nelson). In this work, we rely on the thesis that the “production” of knowledge (as a product of science and education) requires a special environment, virtual and physical, including architectural and urban space, which called “academic environment”. The connection between urban planning and architectural structures of society and its spatial “identity”, supports social and cultural identity (theories of K. Levy-Strauss, Yu.M. Lotman, H. Mutanyola-Tornberg, P. Pellegrino).  

1.3. Hypothesis
According to the latest studies of the World Bank (4, p. 70), universities and research institutes are becoming the main engine of scientific and technological progress and the basis of regional capitalization. The features of the new education could characterized by several basic trends. Firstly, it is global educational space. Secondly, according to modern educational policy, the most important part of tertiary education is academic environment, which we discussed above. The academic environment includes not only the “virtual” world of research, but also its architectural embodiment in spaces for study and work, public spaces of the university and places for comfortable living. A world university is impossible without creating an academic environment for the interaction of high-class specialists, without an upscale space and infrastructure. The signs of space of the “world-class university” could be considered as followings: academic freedom, campus with necessary equipment for the educational process and scientific research, high quality of social and public life. Moreover, the architectural and urban planning position of the space of the scientific and educational complex cannot be separated from the city fabric, the university’s contribution to social and urban development (at the city’s level, or region and country levels) serves as a new indicator in determining the university position in modern rating systems. Thus, the complex spatial organization of the territory, the internal spatial environment of objects (interior) and the unique architectural appearance (exterior) are important factors in the formation of the academic environment.

2. Method
The production, transfer and creation of knowledge historically have been the main functions of scientific and educational institutions. Today, the main goal of university, research and experimental complexes is not only the formation of knowledge and competencies, but also research breakthroughs, as well as cultural foundations of social personality. To carry out this work, research objects (scientific and educational complexes as architectural and urban systems) were divided on different groups. The methodological concepts integrate the research line: at the macro level, with the concept of innovative “growth zones” that concentrate human and financial resources, and at the micro level, with the concept of transformable “intellectual” objects in modern campus. According to the hypothesis, the process of “production” of knowledge linked with the qualities of academic environment, with the spatial qualities of objects and spaces (13). The planning organization of the new generation university complexes reflects the variety of functional and spatial schemes based on “technological units”: RECs. The Research and Educational Center (REC) is a new typological unit of the university complex. This is multifunctional structure, which includes various spaces, its combination gives a synergistic effect in the process of research.

3. Results
3.1. Urban planning level
In the past, we had two large groups of models for organizing the education process: the model of “unity of time and space” and distance model. If classical universities grew and developed evolutionarily, using models that grew out of religious space, new-generation university complexes use “technological units” that grew out of specially designed “programs” for education concepts. The university campus as an integral object, typological architectural and spatial unit, appeared in the 17th century, and according to modern definitions, the campus is a cluster complex that includes educational, scientific, laboratory, pilot production, social and recreational and residential objects on
isolated territory. In general, all education campuses can be divided into four main types: urban dispersed, urban local, suburban local (or actually "campus" type), mixed type, a mixture of the structure of the donor city and the university complex that forms the urban environment (example: Harvard) (18).

Table 1. World class universities: some examples of various modern campuses.

| Situation | Name of the campus | Type of function | Type of structure | Area, ha | Density persons/ha | Total surface, sq.m. | Density index |
|-----------|--------------------|------------------|-------------------|---------|-------------------|---------------------|--------------|
| Country   | City               |                  |                   |         |                   |                     |              |
| USA       | Cambridge          | Harvard          | research          | 238.9   | 32                | 300                 | 1.5          |
| USA       | Cambridge (Boston) | Massachusetts    | research          | 68      | 14                | 300                 | 1.5          |
| USA       | Berkeley           | University of California | research | 500 | 2200 | 111 | * | 1.3 |
| England   | Oxford             | University of Oxford | research | * | * | 95 | * | 1.6 |
| France    | Sorbonne           | University Paris V | Research, classic research | ≈27 | * | 1400 | 253 190 | 0.9 |
| China     | Beijing            | Tsinghua University | Research, technical research | 392 | 15 | 123 | 1 980 000 | 0.5 |
| China     | Guanzhou           | Jinan University | Research, technical research | 169.5 | - | ≈500 | 1 004 400 | 0.6 |
| Russia    | Moscow             | Moscow university | Research, technical research | 205.7 | 12 | 322 | 1 000 000 | 0.5 |

In terms of scale and size (or number of students), university complexes could be several types:

1. Microcampus in urban environment: concentration of a complex in one facility (as Business school Skolkovo, Moscow).

2. The mini-campus of classical universities, new universities or campuses - satellites (consists of 1 university, up to 2000-5000 students), characterized by “college spatial type” (perimeter buildings, with courtyard).
The following spatial principles are usual for micro- and minicampuses: high density (or high-density carpet building structure with minimal spaces), main space, as a "communicator" and place of social interactions.

3. The classic historical campus with system of “malls” and “colleges” (some modern universities recreate this model).

4. Macro campus with a high density complex structure.

5. Megacampus - consists of several universities (from 2 to 10) with a common social, engineering and transport infrastructure (Megacampus of Guangzhou, China). The basic architectural and urban principles: fractal structure (6),

   common infrastructure (transport, social and engineering), spatial diversity (Table 1, 15).

As the result, we see that modern complexes were created with the goal of further growth and transformation embedded in their program. Schemes of the main spatial and functional composition of campuses can be classified as follows:

1. Monoblock campuses (based on blocked RECs, consisting of several functional elements). Typical for dense urban development, or for special climate conditions (Skolkovo Business School, Moscow, Jussieu, University of Hong Kong),

2. One-center: concentrated (as Mason Institute, USA). Spatial cores uniting technological units compose the main technological zone of the REC (as in Singapore Nanyang University).

3. Linear campuses (developing along communication and compositional axis), this could be analogue of a “linear city” or “city façade” (Berkeley, USA).

4. Quarters (Jinan, for example), or with system of malls and colleges, as in classical universities (9).

5. Forming the urban environment, which characterized by large territories (10) (as MIT and Harvard, who created Cambridge, USA, Masdar, UAE).

   Public space in the structure of the university complex is one of the most important key element that unites objects and creates a unique architectural environment, spatial image. Spaces of "rest", park recreational spaces are necessary for recreation and activities, are necessary for the balance of its development (17). The structure of the university involves a network of park spaces filled with public functions (8). Basing on the history analysis of the development of research universities, it is possible to formulate principles for organizing space of university campuses:

   1. First of all, the defining feature of a successful complex is the presence of a strong idea of education, a concept and a program for its development (“code” and “identity”) that attract students and professors in “academic environment” (12).

   2. Autonomy and self-organization, which means the existence of a separate territory, and the existence of reserve territories for all future construction phases.

   3. Engineering communications system, that consist of an internal and external network.

   4. Natural environment, concept of a green campus. This concept uses eco-buildings, zero-emission buildings and green areas (4).

   5. Compact territory, not divided by streets and roads and provide access control and security of the internal space, 6. Human scale is necessary to create comfortable architectural environment for the campus.

   7. High quality architecture and attractiveness of spatial environment, which meets the requirements for the quality of life and study.

   8. “Public zone” for the formation of public entrance space of the campus and connection with the city (7).

   9. Social infrastructure of the campus, which includes sports facilities (open areas for various sports, and indoor halls, pools and stadiums), cultural centers and recreational facilities.

   9. Security of the territory, both technical and social, and ensuring social comfort. Creating an atmosphere without aggression and with a tolerant attitude based on the cultural identity and the formation of university cultural tradition (12).
3.2. Object level
Modern scientific and educational centers and other key objects of universities correspond to the new paradigm of education, which is shifting to individuality. The main objects of the modern university complex (elements of campus systems) include the following:

- RECs (research-educational centers, basic technological units),
- media libraries, libraries, information centers, ITC (information technology centers, business incubators),
- housing - dormitories, faculty, visiting professor units,
- social infrastructure - sports, leisure, food, etc.,
- engineering facilities (infrastructure and technology parks).

The technological unit of the modern university complex (REC) is made on the basis of the technological program (the “technology” of the educational process based on technology of the production process) (19). This is the scientific and educational centers of new generation universities. RECs are forming the internal structure of the modern university campus. In many cases, non-core functions are outsourced to a separate social zone, and RECs (even technologically and spatially independent) form the main research and educational zone of the campus. The principal components of a scientific and educational center, or functional groups of spaces, are the follows:

1. Learning spaces that take into account specifics of the educational process and technologies.
2. Spaces for scientific activity.
3. Spaces for congress activities.
4. Administrative facilities. A separate group includes others: food facilities (restaurants, buffets, canteens, cafes, with their service premises), rooms for cultural and communication events and so on (3).

In addition to these basic functional units of research and educational center, its structure requires halls, communication and recreational spaces such as indoor courtyards, spaces of internal gardens as well as facilities for organizing outdoor activities for teachers and students, sports facilities. In an effective center it is necessary to provide recreational and communication central space, unifying center of architectural composition (11).

At the same time, it is possible to divide these rooms into blocks, and to mix them according to levels. The layout and compositional scheme of the scientific and education center can be determined by education technology, and also be a “three-dimensional box” where main functional rooms are linked using additional communication spaces. Transformable spaces and free plan for most parts involve the using of a post-beam system and structure of spatial frame. Such spatial principles make possible to change the quantity, capacity and structure of spaces. The principle “each floor has its own function” in new research and education centers is increasingly replacing the principle of “each block has its own function”, since functional levels are more effective in terms of communication and connections between rooms of different functions (20).

In accordance with the complex space of modern university and its internal structure, the building of REC is perceived from different sides: so, the central facade often does not exist. The reserves for development of university complexes are very important, and research and educational center is not only a building but simultaneously changing educational program and technologies, and in the future, when they will be transformed, new premises and new territories will be required (14). RECs - “mixes” combine different disciplines in one spatial block. This kind of mixing of functions leads to synergy in research programs and creates new technologies in perspective areas. This meets the basic principle of the REC, - complexity, combining scientific education spaces, with the possibility of transforming the program for using these spaces, all of these give freedom in the educational and scientific processes (1).

3.3. Orestad College - “free plan”
Orestad College is an educational institution in Denmark designed, built and opened as part of national education reform in the 21st century. The goal of this reform is to increase the general level of
education through the implementation of advanced education technologies in the field of educational organizations, including architectural means. The college building consists of four levels, each of which contains from 4 to 10 educational “spaces”. On each floor there are areas not only for learning, but also for interactive communication, as well as for independent and group work of students, the concept of the absence of classrooms was applied. Each floor is a platform; this decision provides the ability to view the entire interior of the building from anywhere inside. The center of student life has become the area around the main staircase, the most “lively” and active place that used for independent work of students in small groups.

3.4. Spitsker school of architecture
On a similar principle, the concept of the interior space of the Spitzer School of Architecture on the campus of New York City College was built. An internal staircase, with a complex climbing scenario, passes through the entire building and leads to the roof, where there is amphitheater for independent student activity, and for public lectures focused on Manhattan (2).

4. Discussion
In the process of research, the issues of creating the public space as the main catalyst for social processes and social interactions, public and residential space and their construction principles to ensure social comfort are considered. But it should be understood that there are some dangers and threats to the development of the university lie in unpopular strategic decisions, such as placing the university campus in social “ghetto”, high building density of the campus space, the lack of a high-quality internal natural and cultural environment, the separation of a single territory by streets and roads, excessive remoteness from the city and lack of common space with the city, the lack of “representative face”. The issues of interaction between campus space and urban space were also analyzed, and the basic principles of the “green campus strategy” were formulated as a concept of sustainable development of the university’s urban area inside a system with the environment of the city and nature (5).

Along with the identification of the principles of RECs, innovative principles we also formulated for the creation of information centers, social and cultural centers, residential facilities of university complexes: a modern building is a complex engineering structure, including formation of comfortable space. Further development of the topic may be related to the deepening of the share of distance learning while maintaining the importance of the typological and technological core and the space of the “academic environment”, as well as new information technologies in the process of training.

5. Summary
As a result, we can formulate criteria for design and formation of university campuses and objects. University complexes of leading modern higher educational institutions are developing urban spatial structures. University complexes, historically created as conglomerates of objects focused or dispersed in the urban environment, are eventually forced to create new campuses of the third type (according to the classification given in the introduction), in the form of new urban clusters with significant territorial reserves for their development, and closely connected with the city structure - social and spatial. All this becomes possible with the proper organization of space, the availability of capacities and information systems for the organization of technical and teaching processes.

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