

# Research institutes in the 21<sup>st</sup> century: opportunities for architects

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**Abstract.** Regarding the accelerated innovation in the 21<sup>st</sup> century, the article suggests modifying the spatial principles of Research Institutes as isolated institutions. The 21<sup>st</sup> century Research Institute should reflect the increasing levels of openness and security in modern information exchange methods. Thus, the Institute reveals invisible information processes in the physical urban environment, becoming the urban centre of innovation, a new workplace and leisure centre, as well as a catalyst for enhancing the city's sustainability. The article analyses the historical paradigm of effective methods for introducing innovation to the urban environment, as well as modern socio-economic needs of innovative research institutes in the city. As a result, a unique organizational structure and functional programme of a new Research Institute are suggested. The Institute directly participates in enhancing the urban environment and forming a new lifestyle of the city dwellers. New spatial principles of such buildings are also proposed, updating the architectural typology of Research Institutes in the 21<sup>st</sup> century. Due to the increased interaction with the urban environment, the Research Institute and the city are mutually transformed. This contributes both to increasing the Institute's efficiency and raising the city's economic potential and life quality.

**Keywords:** research institute, accelerated innovation, organizational structure, architectural space, urban environment, sustainable development, experience economy, open data, information exchange.

## 1 Introduction

Today, the urban environment is proved to shape people's mindset. Accelerated innovation processes in the modern city require a shift in the ways of organising work and leisure, demanding a creative approach, supported by research data. This is justified by the recent AIA Architecture Firm Survey Report [1], stating that, by 2020, 72 % of US architecture firms have been investing in research, databases, and their own libraries (with 66 % in 2017). These statistics reflect a steady growth in demand for research-based creativity in innovative urban development.

Therefore, it is necessary to find out how modern urban environment can contribute to research and innovation. The article suggests increasing efficiency of the research institutes

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in modern cities, by modifying the architecture of these institutions, which were previously developed as isolated organisations. Today, they should be directly involved in enhancing the urban environment, reflecting the increased levels of openness and security in modern information exchange methods.

The aim of the study is to propose a model of a 21<sup>st</sup> century research institute, where the time between innovation production and implementation is as short as possible. Therefore, the objectives include identifying architectural and technological means, which would link the new research institute to the urban environment. The institute should implement its innovations directly to the urban landscape and provide a new type of workplace and engaging leisure, provoking hands-on education in the city, ecological mindset, and new emotions. This reflects a gradual shift from the «consumer economy» towards the «experience economy» [2].

Among the recent studies on innovative urban development, many highlight the dialogue between the history of science and technologies and the paradigm of the urban environment evolution. They state that new knowledge and urban planning have influenced each other [3-5]. In particular, some researchers focus on the emergence of so-called Science cities and techno-clusters [6, 7], the relationship between technological development and urban economy, including related institutions [3, 8]. Other researchers study creative urban milieus, involving networks and organisations [9, 10], as well as sophisticated interactions between the city structures and the environment [8, 11, 12]. Hence, this research includes examining the methods for introducing innovations to the city and identifying future socio-economic needs of research institutes, which influenced the proposed architectural principles.

## 2 Materials and methods

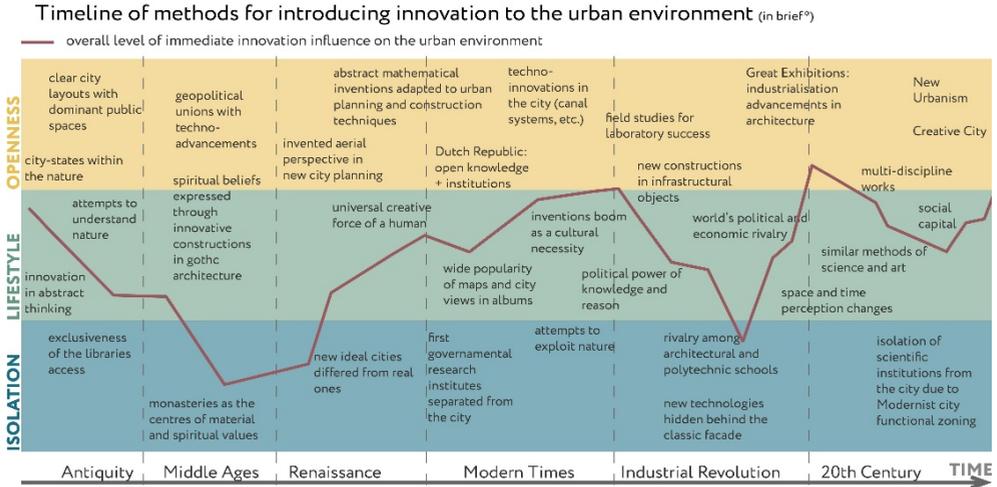
### 2.1 Historical paradigm of introducing innovations to the city

At the first stage of the research, a systematic analysis of the historical methods of introducing innovations to the city was conducted. The analysis, based on the methods of sociology of science [4, 13, 14], identified the level of innovations accessibility for the urban environment in different epochs; whether the inventions had an immediate influence on architecture and urban planning (Fig. 1).

The facts, gathered by the systematic analysis, are outlined in the diagram (Fig. 1) and are also listed below in more detail. These facts served as the materials for further analysis of modern needs of research institutes, as well as for further concept modelling. The systematic analysis proved that, historically, new knowledge was either open or isolated from the urban environment, which reflected periodical changes in people's culture and lifestyle.

In Antiquity, science and philosophy were intertwined, which led to innovations in abstract thinking methods. Together with empirical methods of physical science, they were aimed at increasing knowledge about nature, understanding it, but not changing or mastering it. Thus, the city-states, although surrounded by walls, existed within the nature, with no mental separation from it [15]. On the other hand, in Classical Greece and the Roman Empire, scientific and philosophical knowledge was centred in libraries and other public spaces, which were the prominent features of urban planning and architecture, yet not entirely accessible [15]. As Early Middle Ages faced a decay of urban environment, the centres of knowledge became more isolated, behind the walls of monasteries as strongholds of material and spiritual values [4]. Although not directly perceived in most cities' environment, technological innovations played an important role in forming prominent

geopolitical alliances of the epoch, like the Hanseatic League and the Republic of Venice [3]. Importantly, in medieval Gothic architecture, engineering innovations were perceived as a means of expressing the spiritual aspirations of the time [4].



**Fig. 1.** Diagram of the historical levels of immediate innovation influence on the cities' architecture and environment.

The invention of aerial perspective influenced the urban planning principles of the Renaissance and early Modern period, featuring a regular street grid with viewpoint axes, large squares, and elaborate front facades. These principles were implemented both in ideal city concepts (by G. Vasari, P. Cataneo, A. Durer, V. Scamozzi, etc.) and real urban planning, like the 16<sup>th</sup> century reconstruction of Rome, led by Pope Sixtus V and D. Fontana [4]. While the creative power of the Renaissance figures lied in developing a wide range of abilities, without specialising in a narrow field [4], the philosophical thoughts of the era implied that an ideal space can form an ideal society [16]. Hence, technological advancements, like earthwork techniques, were actively implemented to the urban environment. In the Baroque period, new discoveries, even the most abstract mathematic ones, immediately gained a reflection in the novelties of the emotional perception of architecture [4].

In the New Age city, the emerging scientific institutions were often isolated and ruled by state, like the Royal Society of London [8]. However, this contradiction was gradually levelled, and the royal libraries became truly scientific institutions. In addition to political and institutional transformations, the city representation has also changed, due to new mathematical and mechanical intellectual traditions. Thus, the maps and city views, collected in expensive atlases, became widespread among the elite and general public [8]. In the 17<sup>th</sup>-century Dutch Republic, accessible technological advancements fostered innovations in the city, like the Amsterdam canal system, in response to the population growth [3, 5]. Being at the forefront of institutional infrastructure and information technology development, the Dutch Republic had a de facto rule of technological knowledge openness, even to foreigners [3]. Useful knowledge was perceived a community matter; the expansion of infrastructure for storing and disseminating useful knowledge ensured its steady implementation [17]. With the flourishing machine industry in Europe by the 18<sup>th</sup> century, inventiveness was widespread among all population groups. The reasons for ingenuity and steady invention production were not in material gain, but in the epoch's cultural code [4]. The variety of inventions led to the industrialisation of almost every field of activity.

With Rationalism views heralding the era of Industrial Revolution, science and engineering achievements were aimed at «adapting» nature to serve the mankind [18]. This was reflected in the city concepts, like E. Howard's Garden city, and planning of regular parks and strict city grids. Scientific methods involved conducting experiments with nature according to a prepared plan, reversing the paradigm of empirical knowledge [19]. Instead, science gained increased political power and was developed in its practical application [4, 11]. Thus, the research on the factors of L. Pasteur's scientific laboratory success in the 19<sup>th</sup> century [13] states that the results of laboratory experiments gained political influence because they articulated their findings, justified by experiments and statistics. Hence, previously unclear matters, «invisible to the society», gained explanation and recognition in the «visible» physical reality [13]. Thus, a successful laboratory work is proved to involve a) parallel processes of field research and laboratory practice; b) effective equipment for a large number of experimental manipulations; c) scaling the general-specific problem; d) effective ways of recording, storing, and exchanging data; e) active use of statistics for the relevance proof [13]. These principles are key for the present research institutes, as well.

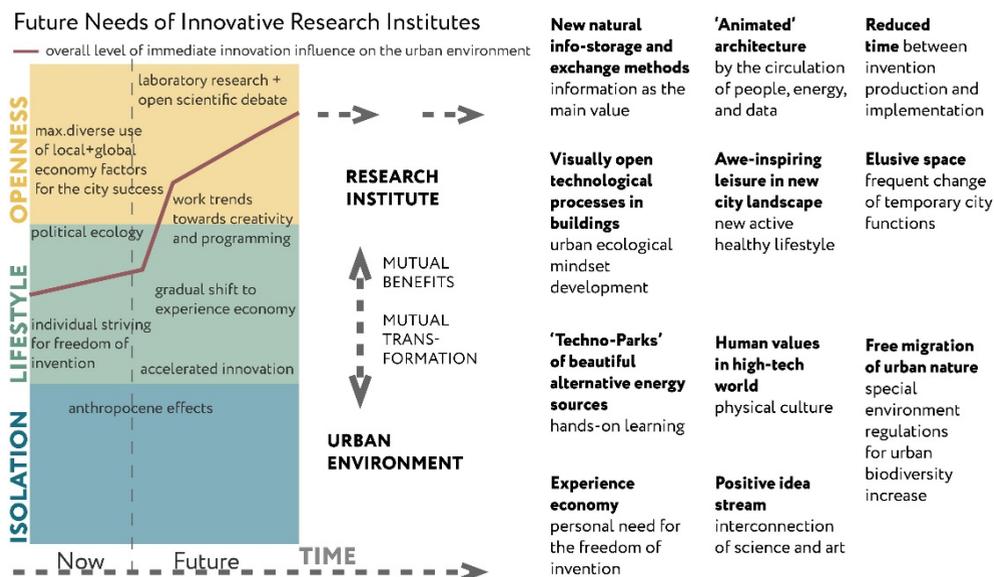
The general movement of inventions in the early 19<sup>th</sup> century almost did not affect the official public architecture, when new materials, like metal structures, were used only as a means of erecting neo-gothic and neoclassical facades. Meanwhile, new spatial possibilities were developed in technical and utilitarian structures, like bridges [4]. This contradiction reveals the gap between the architectural form and the building's construction, fostered by the early 19<sup>th</sup> century confrontation between architectural and polytechnic schools. Until scientific and technical achievements were organically perceived in artistic forms, the work of an architect and an engineer was rather isolated [4]. This trend changed in the era of Great Exhibitions, reflecting the worlds' new political and economic rivalry. New types of metal structures brought effective industrial production methods to construction and served the emerging innovative types of public buildings, like covered markets, department stores, and large exhibitions [4]. Thus, new industrial constructions reflected the trends of expanding trade and new 20<sup>th</sup> century perceptions of space and time, in architecture. Technological advancements were also aimed at solving topical issues in the immediate urban environment of the Industrial city. Thus, public transport, new water supply systems, electricity, industrial housing and high-rise buildings with new metal and reinforced concrete materials dealt with the consequences of urban population growth. Hence, new urban planning features were aimed to adapt former rural residents to the city, creating facilities for their new lifestyle [20, 21]. Moreover, Industrial city faced a simultaneous technological and moral changes, with a new perception of time. The demand for «free time» by the factory workers subconsciously reinforced the notion that working time belonged to the employer, thus turning abstract time into the object of trade [22].

By the 20<sup>th</sup> century, scientific methods developed in parallel with artistic investigation, forming a single culture with united science and art. Primary issues for the heads of scientific institutions involved common interdisciplinary approaches, comparing the findings in various fields, rather than popularising selected achievements in certain spheres, as it was in the 19<sup>th</sup> century [4]. With psychology, developing as an independent science [23], the architecture of education and research buildings of the 20<sup>th</sup> century was influenced by new methods of communication towards a more productive investigation. Thus, Modernist public research and education buildings, like the Carpenter Center at Harvard University (1963), included versatile spaces with flexible layouts, which ensured interdisciplinary studies, combining science and art [4]. Given the governments' priority of advanced science for a prosperous society, the 20<sup>th</sup> century scientific organisations were comparable to industrial enterprises, in terms of the number of employees and spatial solutions [6]. However, due to strict functional zoning of the Modernist city, research institutes, as well as so-called Science cities [6], were situated on the city periphery,

isolated from the immediate urban environment. By the end of the 20<sup>th</sup> century, sustainable urban development (1980) is measured, regarding the physical landscape, with objects and nature, and the social landscape, with communities and social practices [24], which together form the city’s economic, social, cultural, and natural capitals [25]. Thus, the human mind and creativity are the main resource of the city [10]. The Charter of the New Urbanism (1996) implies that urban space is formed by city dwellers, which is revealed in compact architectural planning with mixed functions. Plus, integration of alternative energy sources in architecture and landscape installations is also one of the modern methods of integrated scientific and creative research.

## 2.2 Modern socio-economic needs of innovative research institutes

Having analysed the key points of interrelation between innovations and urban environment in various epochs, it is important to identify how they are reflected in the modern trends. The next research stage involves the systematic analysis of modern research on urban economy and sociology, concerning research and innovation production (Fig. 2).



**Fig. 2.** Modern socio-economic needs of research institutes, affecting the proposed architectural principles.

The facts, listed in the diagram (Fig. 2), are the materials, justifying the historical paradigm, outlined before. Thus, two stages of our systematic analysis revealed the ongoing trends: 1) influence of scientific research on state policies and urban ecology (attitude to nature); 2) interdisciplinary approach, united science and art; 3) adaptation of city dwellers to a new lifestyle (work, consumption, and leisure) via the innovative urban environment; 4) scientific institutions as prominent public buildings in urban ensembles; 5) improvements of information exchange infrastructure for expanding common useful knowledge; 6) the epoch’s cultural beliefs, expressed through construction advancements. The 2-stage analysis enabled us to estimate modern socio-economic needs of innovative research institutes (Fig. 2), which affected the architectural principles for such institutes, formulated in further stages of the research.

The current gradual shift to the experience economy [2] can be justified by K. Groos's experiments of the play behaviour. They prove that natural human desire to invent or create

art, being the cause of something new, is the core feeling both for children's play and adults' work satisfaction [22]. Similarly, L. Mumford believed the airplane and the garden city to be the two greatest inventions of the early 20<sup>th</sup> century, as they gave humans freedom and a better living space [21]. Thus, modern research institutes should reflect the global trend of changing future workplace concepts that provide creative work processes with adaptive curriculum and active daytime leisure with accessible sports and green recreations. Plus, since technological advancements are frequently perceived as common heritage, some researchers argue that unconditional basic income in the future would foster creative processes, substituting other jobs with digitalisation. Adapted technological inventions can increase the low-skilled labour productivity, with the rise of high-skilled and creative workers' wages [26]. Meanwhile, digital programming has been adapted for research, when the algorithm solved an inventive problem and re-deduced Newton's laws, by very fast selection of variants in the process of «mutation», until an optimal solution is found [27].

The current epoch of digital humanism, uniting cultural heritage and technologies [28], has a side effect of excessively high knowledge production rates and the resulting fast data deterioration. Hence, urban environment today is spreading «wild knowledge» of successful practical tools among people *tete-a-tete*, which is more relevant and topical than many academic courses [29]. Thus, dense urban environment today is essential for the constant positive idea flow among people and companies in cultural clusters, in close proximity to the public facilities for work and leisure. According to other studies, future economic and social innovation has unpredictable combinations of favourable factors, so urban environment needs to be flexible and easily connected to global networks, in order to make use of the favourable conditions when they arise unpredictably [30]. Hence, stability of political economy development depends not only on large government-funded innovation organizations, but also on the support of private sector innovative companies, with a combination of employment structures, talent partnership, and interaction among scientific and industrial organisations [12, 31].

As the economy of a city or region is a set of activities that exist within its physical system, physical proximity of the city's institutions to each other and the effectiveness of its infrastructure are key to successful innovation processes and the city's productivity. Institutions also influence local economies and responses to external challenges [32]. This approach to dense physical urban environment reflects the natural methods of productive ecosystems, described in «The Nature of Economies». By maximizing the variety of ways to process the incoming energy, a natural ecosystem ensures its inner resource abundance [12]. Moreover, globalization and local interactions complement each other in innovation production. Cities and regions specialise in different technological fields, but use the universal language of mathematics and statistics, to create common knowledge. However, talented scholars and useful resources are clustered unevenly geographically, concentrated in a small number of locations [32]. For instance, digital technologies, which have transformed the service market and production logistics today, are based on rare metals, which can be found and processed in few places on Earth [33]. Although technologies become more accessible and elaborate, with cleaner production, the environmental impact of essential rare metals per kilogram is still large, due to the amount of chemicals and energy required to refine the metals [33]. Thus, in the current era of Anthropocene (1980s), humans are one of the acting components of the Technosphere, and therefore, they should ensure its continued existence [34, 35].

Finally, traditional laboratory research is now developed in parallel to open scientific debate [14]. Although the two kinds of sciences historically developed together, as it was outlined before, modern scientific dispute should be actively used to increase the number of technological advancements, directly implemented to the urban environment, as well as to

form an ecological mindset of the city dwellers by hands-on education, making obvious relationships between scientific methods and comfortable environment results. Thus, modern sociology of science proposes an innovative dual structure of scientific institutions, in order to divide their political and social influence between innovation production and its practical evaluation and implementation [14]. Hence, opposition between modern city and nature eliminates, as any neutral research data at the time of application becomes political and devoted to ecology. At the same time, political ecology inevitably concerns urban issues and, therefore, must be integrated in modern urban planning concepts, to solve environmental problems in the 21<sup>st</sup> century [11, 36].

Having summarised the ongoing socio-economic trends, concerning research and innovation in the modern city (Fig. 2), we proposed a new organizational structure of a 21<sup>st</sup> century research institute and new functional and architectural principles of such buildings, via the method of concept modelling. It was conducted with regard to the methods of sociology of architecture. According to these methods [21], in urban development, it is necessary to take into account the existing base code and technological innovations, examine their capabilities to enhance the community lifestyle, and finally develop a different system of relations, which is implemented in new urban planning and architecture principles. The results of these stages of the research are outlined below.

### 3 Results

#### 3.1 New organizational structure of a modern research institute

According to the results of the systematic analysis, modern cities face a new rise of openness to innovation. Hence, the effectiveness of innovation production may be increased if the research institute is linked to the urban environment by architectural and technological means, for beneficial interaction (Fig. 3).

New Organizational Structure of a Research Institute



**Fig. 3.** Proposed organizational structure of the 21-century Research Institute.

Such organizational model (Fig. 3) implies that the research institute conducts practical evaluation of inventions directly in the city space, as well as collects relevant data for new research. At the same time, the city dwellers have their immediate environment improved by the introduced innovations. As this organizational model requires a new level of openness to the urban environment, such research institute also becomes a new type of

workplace and leisure centre for the city dwellers, providing healthy daytime routine and hands-on education. This reflects the gradual shift towards the experience economy [2]. Traditional laboratory research should be developed in parallel to open scientific debate and practical evaluation, which together blur the line between urban ecology, society, and political agenda [11, 14].

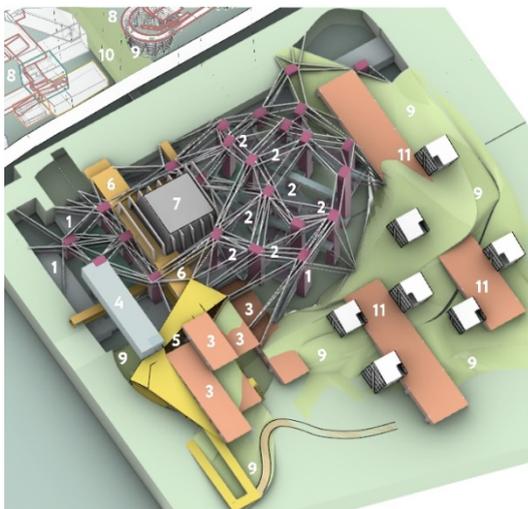
Modern research institute should reveal invisible information processes in the physical urban environment, becoming the urban centre of innovation and a catalyst for enhancing the city's sustainability. Thus, we propose an innovative organizational structure of a 21<sup>st</sup> century research institute, where innovations are directly introduced into the city (Fig. 3).

The global mission of this innovative research institute is to adapt a modern city dweller to the ongoing civilizational changes, which was proved by the historical paradigm analysis. To ensure effective innovation production, the new research institute should have strong interdisciplinary relationships on local and global levels. Thus, the institute's building is integrated into the public facilities area of major city districts, to create an accessible workplace with healthy recreation facilities, as well as a platform for open practical evaluations and hands-on education. The institute should be part of the city network of state and private scientific institutions for interdisciplinary cooperation. The institute should also benefit from the urban agglomeration resources, like the university campus or technological enterprises, so as to integrate young researchers into practice. On the regional level, the research institute cooperates with industrial producers, to ensure timely implementation of its innovations. This cooperation is supported by state initiatives, like national scientific projects [37], as it has a large political significance, according to the analysed historical paradigm. On the global level, it is connected with organisations, supporting sustainable urban development, like UN-Habitat. Thus, the new organizational model implies that the innovative research institute, directly involved in enhancing the urban environment, is a landmark of a successful city and region.

### 3.2 New functional and architectural principles of a modern research institute

To comply with its mission, the new research institute should have an innovative functional programme, proposed further (Fig. 4). It includes spaces of various accessibility, so as to provide safe spaces for its employees and visitors, as well as their interaction.

New Functional Model of a Research Institute



- EMPLOYEES ACCESS**
  - 1 LABORATORIES
  - 2 SCIENTISTS' SPACE
- COMMON INDOOR+EMPLOYEES ACCESS**
  - 3 ADMINISTRATION
  - 4 EXPERIMENTAL CLINIC
- COMMON INDOOR**
  - 5 FOYER-'SHOWROOM'
  - 6 LEISURE GALLERY (Medialibrary and Canteen)
  - 7 TRANSFORMABLE HALL
- COMMON OUTDOOR+COMMON INDOOR**
  - 8 CREATIVE CLUSTER
- COMMON OUTDOOR**
  - 9 SPORT AND STROLLING  
(New terrain and rooftop sportsgrounds)
  - 10 'TECHNO-ECOPARKS'  
(Techno-Installations, Experimental Urban Farm, and subsurface Techno-Channel)
- PRIVATE+EMPLOYEES ACCESS**
  - 11 SCIENTISTS' QUARTER (scenic apartments)

Fig. 4. Proposed functional model of the 21<sup>st</sup> century Research Institute

The spaces with employees' access include Laboratories and Scientists' Space. The Laboratories are isolated spaces for experiments that include: 1) (bio)chemical analysis, physical experiments, etc.; 2) data processing stations: heat maps, remote sensing, big data analysis, statistics and forecasts, the Institute's indoor environment data; 3) data storage and exchange infrastructure, namely, vertical storage along the staircases. This structure allows a gradual shift to new natural storage methods (like DNA storage).

The Scientists' Space is a work and rest zone without standard offices. It includes modular zones for individual and team work for 7 design departments: 1) Urban Planning Regulations (defining new standards); 2) Landscape Modification + Green Infrastructure (research, outdoor experiments, urban design projects coordination); 3) Thermal and Chemical Balance (urban environment monitoring); 4) Urban Grocery Farming (research, experimental vertical farming); 5) Sustainable Energy Supply (prototyping, supplying the «Techno-EcoPark» with new models); 6) Urban Nature and Biodiversity (monitoring, defining new means for maintaining it); 7) Machine Learning (research hard- and software development).

The spaces, where the employees and the visitors collaborate, include Experimental Clinic and Administration. The Experimental Clinic, linked to Laboratory blocks, provides urban health diagnostics and collects the users' data for research and statistics. It also controls experimental treatment with physiotherapy and physical education, connected with the healthy outdoor facilities. The Administration block is responsible for internal purposes, like the patent office and CEO management, as well as for external purposes. They include public affairs, like: 1) professional programmes for Young Researchers and further recruiting; 2) international, interregional, and inter-institutional partnership; 3) educational and cultural public programmes.

The common indoor spaces include Foyer-Showroom, Leisure Gallery, and Transformable Hall. The Foyer-Showroom includes a lobby for navigation of the employees and the visitors, with visual perspectives and panoramic views of the whole Institute's site. The Foyer also serves as a showroom, with an inspiring introduction to the Institute's research findings. The Leisure Gallery includes a media-library for the employees and the visitors, with a lecture hall, isolated reading and watching spaces, recreation sites, as well as an interactive gallery of the Institute's research. The Leisure Gallery also involves the Canteen and distributed Dining rooms, which provide healthy food, including the grocery from the Institute's neighbouring experimental urban farm. Thus, the Gallery spaces foster live information exchange. The Transformable Hall has a universal stage and movable seats. Thus, it is suitable for various programmes, like: 1) open practical experiments; 2) lectures and scientific conferences; 3) staff meetings; 4) performances and concerts; 5) rehearsal area for the neighbouring cultural cluster; 6) a recreation area, while not in use.

The Institute's neighbouring facilities include a Creative Cluster, Sports and Strolling facilities, the Scientists' Quarter, and «Techno-EcoPark». The Creative Cluster includes modular rental spaces for science-related creativity, like theatre workshops, publishing and printing house, galleries, start-ups, and unions of artists, writers, etc. The outdoor Science and Art green boulevard connects the Institute and the Cluster, for social interaction and idea stream. The Sports and Strolling facilities include modular multilevel rooftop sportsgrounds, for a healthy daytime routine of the employees and the visitors. The Institute's strolling facilities include its modified landscape, with an elevated green hill and a carved green canyon, which provide the microclimate control, greywater treatment, and active leisure spaces. The Scientists' Quarter includes private apartments with scenic views on the Institute's green hill. It provides safe living space for the Institute's employees, as well as open strolling paths on the green terrain, accessible for the city dwellers.

The neighbouring «Techno-EcoPark» is a strict grid of pedestrian alleys among the squares of innovative technical art installations, serving as alternative energy sources. Such technological landscape improves the city's ecology, maximising the benefits from its natural resources, as well as provides hands-on ecological education for the city dwellers. The neighbouring city park includes the Institute's elevated Experimental Vertical Farm, which supplies grocery to the Institute's Canteen. There is also a subsurface Central Techno-Channel, which includes energy supply and water treatment infrastructure, as well as goods delivery channels from the Transportation Hub. Above the infrastructure channel, there are only parks and squares, for easy service access.

The proposed Research Institute's innovative structure should be reflected in architecture. Thus, the 4 main architectural space principles, listed below, are proposed.

1. Maximum accessibility of the Institute's environment. This principle includes: a) sustainable Institute's building in the city ensemble, within the walking distance from residential areas; b) healthy recreation and sports facilities on the Institute's territory, accessible during the working day for the employees and the visitors; c) integration of people with reduced mobility as the Institute's visitors and workers.

2. Efficient use of environmental resources in urban planning and architectural solutions. This principle includes: a) elevated green terrain on the Institute's territory. New terrain is compiled of enriched soils, collected from the earthworks during the Institute's subsurface levels construction; b) alternative energy systems, integrated into the design as visually aesthetic and efficient installations. Diverse energy systems produce maximum energy from the territory's natural resources; c) increased autonomy and economic efficiency of the Institute, due to eco-materials and optimised construction process; d) interlinked comfortable indoor and outdoor environment, active daytime routine.

3. «Space Pluralism» in the Institute's architectural layout. This principle includes: a) simultaneous safe working process for the employees and fascinating educational leisure for the visitors; b) acceptable visual connections of working and leisure spaces for hands-on learning; c) the Institute's connectivity with the cultural cluster nearby for the constant idea stream.

4. «Animated Building» via the circulation of users, energy, and data. This principle includes: a) constant information exchange via the diverse users; b) real-time analysis of inner environment data for further research and the comfort increase; c) gradual shift towards more natural information storage and exchange methods, like DNA data storage.

## 4 Discussion

The proposal has been compared to existing progressive urban development institutions. The proposed organisational structure of a new research institute has similar features with the 4 organisations in Europe, USA, and Russia, which are aimed at integrating research, production, and social activities, namely: 1) Leibniz Institute of EURD (Dresden, Germany); 2) Urban Ecology Research Lab (Washington, USA); 3) OOO «Research and Development Institute of Ecology and the Sustainable Use of Natural Resources» (Tyumen, Russia); 4) Interregional scientific and educational centre «Advanced production technologies and materials» (Yekaterinburg, Russia) [37]. According to the comparison, the proposed model complies with existing trends in urban ecology research. However, the proposed model has a more variegated functional programme for interdisciplinary collaboration and immediate implementation of innovations in the urban environment. Hence, the proposed model has a potential for future implementation.

The proposed architectural principles include integration of alternative energy sources in architecture and landscape installations. A similar principle has been implemented in 2 institutions, namely: 1) National Renewable Energy Laboratory (Golden, USA); 2) Urban

Science Building (Newcastle, UK) [38]. In these research enterprises, eco-technological systems are integrated into architecture, for a comfortable working environment and climate data collection for further processing and research. Moreover, integration of alternative energy sources in landscape technological art installations has been justified by the case studies and open international architectural competitions, held by the Land Art Generator Initiative [39]. Hence, the proposed architectural principles for new research institutes comply with the modern methods of integrated scientific and creative research.

Finally, the principle of increased accessibility of the new research institute, integrating people with reduced mobility as its visitors and workers, has been justified by a recent case study [40]. Judging by the experience of the Soviet Union enterprises from the 1930s to the 1980s, people with limited mobility worked in consumer services, as well as in technical spheres, comprising up to 75 % of the enterprise's work force. Thus, adapting the architectural environment for people with reduced mobility gave a considerable economic effect. It is emphasised that if the working environment is adapted for people with reduced mobility, the environment of the research enterprise becomes more comfortable for all employees and visitors [40]. Thus, a productive research institute should be designed to meet the demands of its visitors and workers from various social groups living within the walking distance from the institute. As a result, a balanced environment provides physical and psychological comfort in the work space and a variety of healthy leisure.

## 5 Conclusions

The suggested organizational structure converts a modern research institute into the centre of technological innovation, which directly participates in enhancing the urban environment and forming a new lifestyle of the city dwellers. The proposed new spatial principles of such buildings update the architectural typology of research institutes in the 21<sup>st</sup> century. Given the increased interaction with urban environment, the research institute and the city are mutually transformed. This contributes both to increasing the Institute's innovation production efficiency and raising the city's economic potential and life quality.

The proposed functional and architectural principles of innovative research institutes are justified by the 2-stage systematic analysis, based on the methods of sociology of science [13, 14] and sociology of architecture [4, 21]. The analysis involved identifying the historical paradigm of effective methods for introducing innovations to the urban environment, as well as determining current and future socio-economic needs of innovative research institutes in the city.

The proposed organizational structure of a new research institute has been compared to existing progressive institutions in the field of sustainable urban development, as well as to relevant case studies, justifying the possibility of implementation of the proposed architectural principles. The comparison proved the proposed model's novelty in integrating multiple fields for effective innovation production. Being related to the current trends in urban development, the model has a potential for future implementation.

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