Reconstruction of industrial building with nonstandard space-planning decisions

Natalia Braila, Petr Iatsinevich¹, Marina Korenevskaya, Sergey Erzakov and Tatiana Simankina

¹Peter the Great St. Petersburg Polytechnic University, Polytechnicheskaya st., 29, St.Petersburg, 195251, Russia

E-mail: ¹yatsinevich@mail.ru

Abstract. The article is devoted to the selection of the optimal organizational and technological solution for the reconstruction of non-operated industrial buildings with different volume-planning structure. Lately there is a tendency to move most of the large industrial enterprises outside of the city in order to improve the environmental background and to release highly-sought investment land. Thus to date many of the industrial buildings are not operated for decades, which leads to an accelerated accumulation of physical deterioration of structures. Reconstruction with a change in the functional purpose of buildings can save on expensive demolition and new construction, and at the same time, it is possible to competently use investment-profitable large areas of factories and research institutes for multi-functional facilities. The article analyses the domestic and international experience of reconstruction of similar facilities with a change in functional purpose, identifies the main problems and risks arising from the implementation of such projects. Also, specific solutions are proposed for the reconstruction of an industrial building located at: St. Petersburg, the hallmark of which is an area of about 30 thousand square meters, nonstandard space-planning decisions, as well as location in the investment attractive part of the city. Conclusions were made about the necessity of creation a multifunctional environment for reconstructed buildings, based on the location of the facility, the economic efficiency of the reconstruction process and people’s demand.

1. Introduction
Since the 1990s due to economical perturbations and natural processes of urban development in Russia many of industrial facilities, research institutes were closed and still functioning plants were moved to the city outskirts. Many of these buildings have not been used for decades now, which leads to accelerated accumulation of physical deterioration of structures, as well as aggravation of the problem of depressiveness of the territories they occupy [1-5]. There are two possible solutions for these objects: demolition followed by construction of a new facility or reconstruction while changing the functional purpose and technical and economic indicators of the building. Reconstruction, implying minimal interference in the volumetric spatial characteristics of a building [6], is usually the most profitable solution.

Especially interesting is the world experience in the reconstruction of industrial facilities. Recently, the number of reconstructed objects in the world has increased, this is due to the global introduction of BIM-technologies in reconstruction projects [7, 8]. For Example, authors present us the state of the art of scanning tools and methods used to represent a very complex architecture and propose a
methodology and assess it in a large experiment carried out on the most complex building of a 1300-megawatt power plant, an 11-floor reactor building [9]. However, reconstruction issues are relevant not only for industrial zones, but also for ordinary public buildings. In particular, in Kuala Lumpur Sustainable Building Assessment of Colonial Shophouses after Adaptive Reuse was conducted on the example of the building performance of heritage shophouses that were adapted into budget hotels [10], the article concluded, that adaptive reuse is very important in Malaysia as it helps to save heritage buildings from being demolished to satisfy modern needs. However, there are many examples of the reconstruction of industrial facilities and a change in functional purpose. New functional purpose of buildings varies from hostel to amusement park.

For example, the London coal-fired power plant Battersea closed in 1983 will soon acquire a new function. It is planned to open its base a theme amusement park, dedicated to the history of the industry of England. The main object of this complex will be an unusual rollercoaster passing through all levels of the building, as well as inside it (figure 1). In Italy, in the city Lainate the old caramel plant was transformed after reconstruction into a modern office center, which is a real architecture masterpiece (figure 2).

![Figure 1. Amusement park in the territory of the coal power station Battersea, London](image1)

![Figure 2. Office center in the building of the former caramel factory, Leynat](image2)

In the reconstruction of industrial buildings with a change in functional purpose, special attention should be paid to energy efficiency. At present, the requirements for energy efficiency of buildings are getting higher and higher. The European Parliament adopted the Near Zero-Energy Building (nZEB) as the energy efficiency paradigm through Directive 2010/31/EU, but a common technical and legislative framework for energy renovations is yet to be established [11]. Buildings currently play a fundamental role for the achievement of the sustainable development goals, as they are responsible for several environmental, social, and economic impacts. Energy renovation projects of existing buildings can support the reduction of environmental impacts by leading, at the same time, to economic and social advantages [12]. Most of the industrial facilities in the world were built after the Second World War, to restore the economic strength of countries. Buildings built at this time have high energy consumption and inadequate thermal comfort, especially in summer conditions, largely attributable to the high transmittance of windows, lack of effective shading devices [13] and insufficient heat transfer resistance of enclosing structures [14]. It is especially important because higher requirements for energy efficiency are imposed on buildings with a long-term presence of people (residential buildings, hotels, business centers).

Tendency to increase non-exploited industrial facilities in European countries are associated with the increase in China's industrial power, where in the main industrial buildings are being reconstructed without changing the functional purpose [15]. But there are also unusual reconstruction projects there, for example, in Guangzhou, one of the largest plants has already been shut down and has been convert
into a multifunctional complex Xintiandi Factory, combining a shopping center, as well as office and hotel spaces. Moreover, according to the concept of renovation, most machines and production machines in it will remain in their place as entourage (figure 3).

![Figure 3. Xintiandi Factory, Guangzhou, China](image)

In Russian Federation, speaking of reconstruction of empty industrial objects, there is a tendency to create art spaces as there are no strict requirements established for where them to be placed: there is a possibility to locate them in a small apartment as well as in a large unexploited industrial facility [16]. For example, the building of the plant "Red Triangle" in St. Petersburg is planned to be reconstructed into an art object and thus to turn the industrial zone into the underground center.

There are no doubts that such projects do not require large expenses, because almost any building or premises can be adapted to the art space with little amount of modifications. However, the profitability of this concept is a disputed issue because the market is rapidly filling with rivals [17,18].

Based on this, the issue of choosing the most effective way of the reconstruction of the industrial building remains relevant.

2. Purposes and objectives of the research

The purpose of this work is to propose rational use of an industrial building for public and business purposes:

- development of the concept of functional zoning, taking into account the need to create a comfortable environment in each part of the building and volume-planning solutions;
- valuation of the efficiency of the building part’s reconstruction for a hotel.

3. Description of the research

The building under reconstruction is located at the address: St.-Petersburg, Krasnogvardeyskaya square, 3. The building consists of three structures: the letters E, E1, E2. Letter E previously was used as a test room and it occupies most of the building. Letter E1 – two-storey building with different types of planning. Letter E2 is a four-storey building with corridor type layout. A separate space is the volume of the tower, where currently the test stand is installed, elevation point – 47 m (figures 4 and 5).
The building was built in 1972. Initial technical survey showed that the total wear is in the range of 30-35%, while the percentage of wear of load-bearing elements does not exceed 15%.

The main load-bearing elements of the building are reinforced concrete columns of rectangular and I-beam section, which is optimal for reconstruction, because you can freely plan the layout of premises, floor slabs are mass reinforced concrete, precast concrete walls. In warehouse and industrial buildings metal frame is used.

The main feature of the Eastern part of the building, lit. E, is the production room, which has a span of more than 20 m and height 19 m. Previously this space was intended for equipment testing under conditions simulating the operation of nuclear reactor. The concept proposes the separation of this space in height on several floors, for an optimal use and economic efficiency of the reconstruction project.

Good condition of bearing construction elements allows to build-up additional floors to extent useful space [19,20]. The project provides for the superstructure of one floor 4 meters high in letter E2, 6 meters high in the Eastern part of the building and in the southern part of 4.5 meters high respectively. In addition, it is planned to build floor structures in the space of the tower and Eastern part of the building, as well as to shift the fire lane in the southern part.

Superstructure of additional floors is provided with further strengthening of existing structural elements. Materials and structures for additional floors are selected so to provide sufficient load-carrying capacity of the elements, fire safety, no need for lifting equipment and at the same time create the least dead load on existing structures. Thus, a modern effective decision was made on the use of metal columns, on which a reinforced concrete monolithic slab is laid over the corrugated steel deck. The construction scheme is shown in figure 6:
4. The concept of functional zoning of an object after reconstruction

According to the rules of land use and development of St. Petersburg, the facility is located in the territory of TD1-1_1 - a public and business sub-zone of multifunctional public and business buildings and residential buildings located in the historically developed areas of St. Petersburg with the inclusion of engineering infrastructure facilities (figure 7).

![Figure 7. Scheme of land use and development](image1)
![Figure 8. Existing surrounding buildings](image2)

To determine the most effective use of the existing industrial building, an analysis of the existing surrounding buildings was carried out along with other examinations. An illustrated fragment of the study is shown in figure 8.

Taking into account the results of the structural survey, legal examination, as well as the analysis of the market and the competitive environment, a decision was made to reconstruct the facility into multifunctional complex, including hotel, restaurant and business center, as well as a large cultural and leisure center. The model of the functional zoning of the object is presented in figure 9, explanations are given below.

![Figure 9. Model of the functional zoning](image3)
1. 4 * hotel complex with 211 rooms, occupying the western and northern part of the E2 building, with rooms of different categories, two restaurants and bars, and a separate restaurant for the residents of the hotel. The hotel rooms fit optimally into the existing corridor-type layout. The reconstruction project was carried out in full compliance with the requirements of the RMD on 31-03-2008. The administrative and service rooms of the hotel are located on the 1st floor, the rooms start from the 2nd floor (figures 10 and 13);

2. sports and fitness center in the western and southern part of the building (on the second and third floors, which are separated and unproductive) detached from the hotel, but providing its guests with individual access (with a multitude of gyms, individual halls, a tennis court, a children's playground and adult swimming pools), figure 11;

![Figure 10. Plan of the 2nd floor of the hotel](image)

![Figure 11. Sports complex plan](image)

3. spa center on the first and second floors of the southern part and on the second floor of the western part, divided into three zones - dry (wrapping rooms, peelings, massages), beauty (beauty salon) and wet area (bathrooms and shower procedures, large baths complexes, saunas, mini-aqua park, swimming pools, etc.);

![Figure 12. Entertainment center plan](image)
4. Entertainment center on the fourth floor of the eastern and southern part (slot machines, rollerdrom, bowling, cinemas), figure 12;
5. Business center on the fourth and fifth floors in the tower space (conference rooms, office rooms, meeting rooms, banquet hall on the roof);
6. Bar and panoramic restaurant on the last floor of the tower.

According to the accepted space-planning decisions, the first floor of the building is a passageway. Through the front door you can get to the restaurant located on the territory of the tower, as well as the entrance to the sports and entertainment center (figure 13).

![Figure 13. Scheme of the first floor](image)

The main entrance ceremonial groups to the buildings are envisioned from the side of Krasnogvardeiskaya Square (the hotel entrance) and from the south side (from the space of the sports and entertainment center) - the entrance to the leisure area. The general view of the building after reconstruction is shown in figure 14.

![Figure 14. 3d model of reconstruction results](image)
4.1 Technical-and-economic indexes of the project are presented in Table 1.

Table 1. Technical-and-economic indexes of the object before and after reconstruction

| Letter | Area, m² | Number of storeys | Functional purpose | Area, m² | Number of storeys | Functional purpose |
|--------|----------|-------------------|-------------------|----------|-------------------|-------------------|
| Tower  | 1667.5   | Mezzanine         | Test stand        | 4423.3*  | 7                 | Restaurant Business center |
| E      | 6426.9   | 1-3               | Industrial, warehousing, administrative and amenity | 15828*  | 1-4               | Sports and entertainment complex |
| E1     | 3763.3   | 2                 | Administrative and amenity, warehousing | 5462.9  | 3                 | Sports Complex Spa complex |
| E2     | 16305.4  | 4                 | Administrative and amenity | 19082   | 5                 | Hotel |
|        | Basement |                   |                   |              |                   |                   |
| Total  | 28974.2  |                   |                   | 45607.3    |                   |                   |

*a* The reconstruction project provides for dividing the height of the tower space by 7 floors, the one-story part of the building of the letter E into 3 floors.

5. Calculating the efficiency of investment in reconstruction for a hotel function with the associated areas of public catering (restaurant) and trade

After reconstruction, the object will be a compound polyfunctional complex. There is a high probability that implementation of the project will require the involvement of several investors. Thus, it is advisable to consider the efficiency of investment in each of the letters separately.

As an example of grounds for the economic viability of capital investments in reconstruction, the calculation of the cash flow for reconstruction and operation for the hotel function (letter E) with the accompanying zones of public catering (restaurant) and trade (part of the 1st floor and the Tower) is considered. The main technical-and-economic indexes of the considered part of the project are presented in Table 2.

Table 2. Technical-and-economic indexes to assess the efficiency of investment

| Total area, m² | 21 164.4 | Rentable area, m² | 10 931.0 |
|----------------|----------|-------------------|----------|
| Restaurant area, m² | 3 091.0 | Area of the shopping space at the hotel, m² | 500.0 |
| Guest room inventory, m², including: | 7 340.0 | Without regard to administrative and ancillary facilities |
| single room first category | 35 pc. | A total of 211 rooms ranging from 17 to 102 sq.m |
| double room first category | 155 pc. | | |
| studio number | 11 pc. | | |
| Luxury suit + luxury apartments | 10 pc. | | |
The forecasted period is 9 years, of which 2 years are spent for the reconstruction and preparation of the facility for operation (including furniture and equipment of the hotel, restaurant and trade zone) and 7 years for the analysis of cash flow for the return of the facility to profitability and constant cash flow, also the cost of a conditional sale at the end of the forecast period (terminal value) is calculated. All parameters (the cost of renting rooms, restaurant premises and the trade zone, underload, operating costs, etc.) are calculated on the basis of market data on the main competitors.

Total indicators of the project:
- aggregate investments amount to about 2 billion rubles, including VAT;
- the income is formed from the rental of a room fund (about 87% of income), a restaurant and commercial premises (about 13%);
- discount rate – 20%, IRR – 25%;
- net operating income after reaching a constant cash flow - about 550 million rubles. in year;
- NPV is about 450 million rubles;
- simple payback period - about 6 years, discounted - about 9 years.

Thus, the project is estimated as cost-effective.

6. Conclusion

It can be concluded that the reconstruction of industrial buildings for public and business purposes is a promising way for development of industrial microdistricts of the city. This is due to the fact that large areas of factories and research institutes can be competently used for multifunctional objects. The reconstruction project is more investment-attractive than new construction after the demolition of existing facilities, since most of the load-bearing structures and the three-dimensional characteristics of the building are preserved. However, such economically burdening factors as the unsatisfactory condition of the building, the placement of harmful production in it, and so on can limit the economic feasibility. Therefore, the advantage of reconstruction along with the change of the functional purpose before demolition and subsequent construction can be said for sure only after the feasibility study of the project is completed.

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