Flow-line production method in the residential construction: analysis of the state, problems and development trends

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Abstract: Methods in the modern residential construction must meet the requirements for the effective use of material and labor resources. Today, three methods are used in construction: successive, parallel, and flow-line methods. The most progressive and providing a rhythmic output of construction products and an even use of resources is the flow-line method. The article considers the use of the flow-line method of the residential construction both in high-rise multi-storey construction and in low-rise construction of suburban settlements (micro-districts). In the work, we analyze the problems and prospects of using the flow-line method of construction in the Irkutsk Region. We discuss main advantages and disadvantages of the most common technological and constructive solutions of the flow-line method in the residential construction. The paper analyzes possible combinations of methods in the residential construction. It has been found that when using the parallel-flow method, the duration of construction is reduced by an average of 20%, and labor productivity increases by about 10%. The economic efficiency of the flow-line (parallel-flow) method is manifested in the reduction of construction time, reduction of downtime of resources and (or) individual spreads of work, increasing labor productivity and the profitability of the residential construction.

The problem of the residential construction is currently quite acute and widespread, both throughout Russia and the Irkutsk Region, in particular. The construction industry in the region is characterized by mixed trends. If we turn to the statistical data, we will see that for 3 years the residential construction market of the Irkutsk Region has been showing an extreme degree of stability: 974 thousand square meters were commissioned in 2017, 987 thousand - in 2018, and 977 thousand - in 2019. The volume of the commissioned “squares” differs from year to year seemingly insignificantly. These figures allow us to conclude that, in general, the construction industry in the region is developing quite steadily. However, as the heads of construction organizations note, since 2018, the share of the individual residential construction (IRC) has significantly increased in the residential construction market of the Angara region. In 2017, the population commissioned 323 thousand sq.m, in 2018 already 588 thousand sq.m, and in 2019 - 586 thousand sq.m. Last year, the population built 60% of the total volume of housing. Hence, it follows that the construction of apartment buildings in the Irkutsk Region is noticeably sagging. Since 2019, the regional program “Affordable Housing” began to operate in the Angara region, which included the following indicators for the commissioning of housing in the Irkutsk Region (Table 1) [1].

Analysis of housing commissioning data shows that 6,430 thousand m² of housing should be commissioned from 2020 to 2024. In 2024, 34% more square meters should be commissioned than in
2020, or 59.9% more than in 2015. Representatives of the region's construction industry are skeptical about these numbers. According to most analysts, there are various problems in the residential construction that destabilize it; this is the lack of infrastructure projects, issues of the competitive environment in the construction and production of building materials, etc [2]. Experts also include the issue of improving methods in the residential construction.

**Table 1.** Actual and planned commissioning of housing in the Irkutsk Region until 2024.

| Year | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|------|------|------|------|------|------|------|------|------|------|------|
| m² (thousand) | 922.3 | 912.6 | 974.8 | 987.5 | 977.3 | 1100.0 | 1200.0 | 1278.0 | 1377.0 | 1475.0 |

**Figure 1.** Schedule of housing commissioning in the Irkutsk Region.

Foreign and Russian experience has revealed two key issues in the construction of housing, namely construction time and economic efficiency. In other words, for all participants in the construction, the issue of shortening the production time without increasing the cost of the final product is urgent. Therefore, the choice of a method for organizing construction becomes relevant. The residential construction uses three methods: successive, parallel, and flow-line methods.

The construction of several identical buildings, such as residential buildings in neighborhoods, can be carried using successive and parallel construction methods.

With the successive method, the total construction period of all buildings is equal to the total construction period of these buildings [4]. The resource consumption is minimal. Each type of resources is consumed for a short time with certain cycles and frequency. There is a possibility of interruptions (even long ones) in the work of teams, machines and mechanisms, supply and consumption of materials and structures.

With the parallel method, the construction period is minimal and equal to the construction period of one building [5]. The consumption of resources per unit of time increases several times. At the same time, the type of resources changes depending on the construction period.

However, the modern level of construction production and organization, when construction and installation work is mainly carried out by high-capacity contracting general construction organizations, excludes the use of successive and parallel construction methods in their pure form. This is primarily due to the need for an even use of resources (machines, work teams, etc.), as well as the limited availability of these resources.

For example, during the construction of any object, as the work is performed in a certain technological sequence, mechanisms and teams that have completed the work of a certain stage become available. So, first, earthmoving equipment becomes available, then teams of assemblers, assembly
cranes, etc. In order for these capacities not to stand idle, they must be switched over to the construction of another object. Thus, certain work begins on the second object as it ends on the first object, etc.

When performing work on many objects at the same time in certain periods, the need for homogeneous resources can significantly exceed their actual availability. Therefore, as work is completed on one object, these resources will be successively transferred to another one, etc.\[6\]

Today, the flow-line method is the most appropriate. The flow-line method, while retaining the respective advantages of the successive and parallel methods, avoids their disadvantages. With the flow-line method, the work on the construction of each of the houses is divided into several processes, the execution of which takes the same time. In a complex consisting of N number of houses, homogeneous processes are performed successively one after another, and heterogeneous processes - in parallel. The duration of the construction of the N number of buildings, divided into several processes, will be longer than with the parallel method, but shorter than with the successive method. The intensity of resource consumption here will also be higher than with the successive method, but less than with the parallel one \[5,7\].

The flow-line method was first applied in the USSR in 1931-1932 in Moscow. A number of experts give an example of the flow-line method in the construction of houses on Bolshaya Kaluzhskaya Street in Moscow in 1938, which made it possible to reduce the labor intensity of construction to one and a half man-days per 1 m³ of a finished building versus two and a half man-days at other construction sites.

Some authors consider it expedient to improve the flow-line method of construction by developing calendar schedules with the optimal sequence of work development, maximum use of production resources, and the use of software for operational management of work progress. Features of this production method allow for the simultaneous construction of several objects, including large and technologically complex ones \[8\]. The flow-line method ensures a rhythmic release of construction products and an even use of labor resources.

There is an opinion about the expediency of using the flow-line method in the residential construction only for high-rise multi-storey construction. However, this method is successfully used in the United States for the low-rise suburban construction \[9\]. Some Russian experts are inclined to believe that the construction of low-rise housing by the flow-line method is not practiced in Russia \[10\]. Others associate the flow-line method only with the presence of factory conveyors that produce finished construction products. Let us disagree with these conclusions. Indeed, in the Irkutsk Region, when organizing the construction of low-rise housing, successive, and more often parallel, methods are used. However, during the construction of the “Crystal Park” micro-district, the flow-line method is used. This is a low-rise settlement; the project provides for two-storey houses and apartments from 40 to 52 square meters in quadruplex houses, from 60 to 141 square meters in duplexes, as well as townhouses with an area of 120-166 square meters (Figure 2).
Construction began in 2019. In 2020, 22 houses were commissioned: townhouses, duplexes, and quadruplex houses. Fifteen residential quarters and two kindergartens are planned in the “Crystal Park” micro-district. The project includes a general education school, an art school with an assembly hall, a site for a shopping center has been allocated. In the forest areas, there are three stages of the “Residence XV” quarter: cottages on individual plots. It is possible to organize the construction of such an object and commission it as soon as possible only by applying the flow-line method of construction, since other methods will significantly increase the construction time, which is unprofitable for the developer. Figure 3 shows the stages of construction of the Czech Quarter in the “Crystal Park”, where you can see the speed of construction of duplexes and quadruplex houses.

Despite the fact that low-rise buildings have a number of specific features, the use of the flow-line method can significantly reduce the construction period of these objects.

It is planned to commission the entire facility in 2021. A municipal art school will be commissioned at the same time.

**Figure 2.** Plan of the “Crystal Park” micro-district.

**Figure 3.** Stages of construction of the Czech Quarter.

![Czech Quarter, June 2020](image1.jpg)  
![Czech Quarter, July 2020](image2.jpg)
It can be concluded that the use of the flow-line method for the low-rise construction is a necessary condition for the development of the residential construction in the Irkutsk Region. Of course, the presence of factory lines or plants for the production of prefabricated structures will enable a wider application of the flow-line method in the construction of low-rise buildings.

At the present stage of development of the construction industry in the Irkutsk Region, it can be effective to use combined methods of construction, in particular, parallel-flow and fast flow-line methods.

In Irkutsk, the “Sovremennik 1” micro-district was erected in the shortest possible time using the parallel-flow method, 90 thousand m² were commissioned in two years (2014-2016) (Figure 4).

The essence of the parallel-flow method is to divide the process of construction into separate construction flows [11]. The transition of specialized teams from one separate spread of work to another occurs in a coordinated rhythm. Certain volumes of products are manufactured at regular intervals. The entire construction process is divided into work zones. In each zone, work is performed by a complex of brigades or specialized construction teams. Brigades and teams move from one site to another in a strictly defined order provided for by construction technological processes, evenly moving from one work zone to another. These types of work must be strictly combined in time, keeping the pace of construction and installation work. Ensuring the uniform movement of workers from one work zone to another may be feasible only if the work zones are equal in labor intensity, and the number of workers in the teams remains the same. Each team, having completed work on its work zone, prepares the site for the next cycle of work, which will be carried out by the next construction team. Consumption of material and labor resources will be continuous and even. This method of construction makes it possible to achieve the set goal - to minimize costs, increase the profitability of construction, and provide labor resources with continuous work.

It is empirically determined that when using the parallel-flow method, the duration of construction is reduced by an average of 20%, and labor productivity increases by about 10% [12].

According to experts, this method is well combined with modern industrialization of production, when the process of erecting objects turns into the process of assembling buildings and structures from individual parts, i.e. prefabricated structures. Today, the residential construction in the Irkutsk Region uses mainly monolithic reinforced concrete structures [13]. Although, as representatives of the Union of Builders of the Irkutsk Region note, monolithic reinforced concrete structures for mass construction have practically exhausted their technological and economic capabilities. A lot of technical solutions and materials have appeared that make it possible to solve almost any problems of the residential construction, one of which is precast reinforced concrete. With the use of precast reinforced concrete, it is possible to decrease the cost of construction by significantly reducing the labor intensity of work at the construction site, and the volume of “wet” processes by 90% compared to the monolithic construction (excluding foundations). Accordingly, energy consumption at the construction site is reduced by 80% in winter. The work is carried out all year round and round the clock. The quality of the structures manufactured in the factory is high. In general, the cost of construction is reduced by at least 20%, the construction time is reduced by more than 2 times, the consumption of reinforcement is reduced by up to 20%, and the consumption of concrete is reduced by up to 30%. Reinforced concrete structures and many complex construction operations are carried out under stationary conditions by the flow-line method with post-operational quality control. Installation and concreting of joints of structures is carried out at the construction site. When switching to this type of the residential construction, it is necessary to improve the parallel-flow method, since other methods in this case will be inapplicable or ineffective.

Many authors distinguish the fast flow-line method of construction, however, with a detailed analysis, we can rather talk about the very same parallel-flow method. The main characteristics of the fast flow-line method in the residential construction distinguished by experts are, as a rule, a rhythmic consumption of labor and material resources, a guarantee of the shortest terms of work, and the release of construction products with minimal resource consumption [14]. China's construction industry is cited as an argument in favor of the fast flow-line method. China is now the world leader in high-speed
construction, when 95% of the work associated with the construction of buildings is carried out in the factory. Even installation is not carried out at the construction site, but only the assembly of ready-made modules. However, these characteristics are also inherent in the flow-line (parallel-flow) method. Therefore, from our point of view, there is no need to distinguish the fast flow-line method of construction.

The modern organization of construction production allows for various methods of construction. Important indicators in determining the method suitable for the construction of a particular object or series of objects are the duration of construction, characteristics of labor productivity and the profitability of construction in general.

As noted in the studies of a number of authors [3,15], the use of the flow-line method allows:
- Reducing losses of working time by about 23%;
- Improving operating conditions for construction machines - 19%;
- Reducing construction costs - 15%;
- Increasing labor productivity - 40%;
- Reducing construction time by about 1.8 times.

The economic efficiency of the flow-line construction method results from the reduction in construction time due to an increase in the productivity of workers and a decrease in production losses of working time; the improved use of new production spreads and working capital as a result of an increase in the rhythm of construction production; an increase in the quality of construction due to the specialization of teams participating in the flow in certain types of work and the improvement of labor methods.

References
[1] Decree on the approval of the state program of the Irkutsk Region “Affordable Housing” for 2019 - 2024 and invalidation of certain decrees of the Government of the Irkutsk Region: Decree of the Government of the Irkutsk Region 780
[2] Berlizeva A E 2017 Analysis of the construction industry in the Irkutsk Region Issue of Science and Education 6(7) pp 73-77
[3] Zhadanovsky B V and Erizhokova E S 2018 Flow-line method as a method of organizing construction System Technologies 28 pp 136-140
[4] Astashenkov V P 1989-2004 Improving the operational management of the flow-line construction of residential complexes: abstract of candidate degree dissertation p 26
[5] Afanasyev A V 1990 Flow-line organization of construction p 302
[6] Alenicheva E V 2004 Organization of construction by the flow-line method: Textbook p 80
[7] Afanasyev A V 2011 Parallel-flow organization of work Bulletin of Military Construction 3 pp. 36-38
[8] Siverikova A I and Velichkin V Z 2015 Parallel flow method of construction Construction of Unique Buildings and Structures 4 p 31
[9] Kazansky Yu N, Nemchin A M, Nikeshin S I 1995 Construction in the USA and Russia. Economics, Organization and Management p 438
[10] Sazonova T V, Kazakov D S 2014 Low-rise construction: problems and solutions Bulletin of Ufa State University of Economics and Service. Series: Economics 1(7) pp 194-198
[11] Bovteev S V 2000 Development of the theory and practice in forming and optimizing parallel-flow organization of work Abstract of candidate degree dissertation Bovteev S V St. Petersburg p. 24.
[12] Drapeko V G 2010 Reduction of the total duration of work types with their parallel-flow organization Organization, Planning and Construction Management. Saint Petersburg: Leningrad Civil Engineering Institute pp 15-23
[13] Drobysheva T V 2011 Analysis of trends in the development of the residential construction in the Irkutsk Region Bulletin of the Irkutsk State Technical University 10(57) pp 94-97
[14] Gainetdinova Yu I 2017 Organization of flow-line development of residential complexes Young
[15] Chashchin D V 2017 Flow-line method of construction production *Eurasian Scientific Journal. Kursk: Publishing house: Distance Learning Center Limited Liability Company* pp 290-291

[16] Skolubovich A Yu and Matveeva M V 2019 Development of a methodology for assessing the readiness of enterprises for public-private partnership in the field of public water supply *Proceedings of Universities. Investment. Construction. Real estate* 9 pp 274–283 DOI: 10.21285/2227-2917-2019-2-274-283