The place of virtual structures in design of engineer process

Anastasiia Slavina, Diana Tereshenko, Anastasiia Fomina and Ekaterina Rukosueva

Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, Russia

E-mail: SlavinaAY@mgsu.ru

Abstract. In this article the content and essence of the remote work in design of engineer processes is discussed. Design is one of the key stages of life cycle of construction, so it defines the most important parameters of personnel work. Virtual structures in project production have the role of structural units formed by the developed methods, which strive to complete the maximum number of qualitative projects in the shortest time. This method contributes to the empowerment of all independent members, united by a single goal in a working group, what improves the result and quality of the final product. Such progress is due to the improvement of working conditions, because with the creation of virtual structures, it became possible to perform assigned tasks outside the workplace.

1. Introduction
The appearance of Computer-aided design (CAD) is one of the most important steps of design of engineering processes developing. CAD allowed to facilitate the design process, reduce the initial design cost with annual improvement of final product quality [1,2].

Building Information Modeling (BIM) became the modern developing of CAD technology, which reassure the information support on all steps of life cycle of the object [3]. The principles of BIM technology were formulated in 1986 by R. Eysh. In our days the technology is extremely relevant and concerns the field of engineering study [4,2]. BIM technology is a software complex, which uses a three-dimensional information model of building. Such model is a new form of design and it has many advantages, including the ability of work with the specific object by several groups of specialists at the same time.

2. Materials and Methods
Information model can be applied not only to building object, which may be building or construction, it also can be transmitted to the product. The conception of the PLM (Product Lifecycle Management) makes a single information base, which describes the components and connection between them. The perspectives of Relational Generative Design also connected with the usage of BIM. With these technologies, work occurs with a virtual model of an object. The support of “virtual” presentation of information models and processes for all building life cycle steps and sub-systems is based on application of instrumental resources PLM/PDM [5].
Technical Data Management System is used for information flows management. It is intended for work with electronic documentation, technical and graphic data, and links information about object together.

The CAD technologies, used by project organizations, are fundamental. They provide the joint work of specialists in shared data environment, ability of making corrects and comments to the model and allows design participants to plan the work processes throughout all stages of the construction life cycle.

3. Results
The project organization optimizes functions due to CAD, remote access, cloud technologies, special software, dispersing their distribution. Geographically distributed work group can be organized by means of the virtual structures. Researchers note the positive experience of remote work in Russian and foreign organizations. Joint research by “1C-Bitrix” and Json & Partners Consulting companies shows than even today the economical effect of remote work is about 94 billions of rubles per year nationwide. The foreign experience of remote work is more successful. The leader in this field is USA, where each fifth employee performs his duties out of office. According to results of joint research of recruiting company “Hays” and communicative agency “Comunica”, more than half of employers (63%) use the service of remote employees [6,7].

The necessity of being directly on the workplace on territory of company or organization is connected with access to means of labor. Also presence of all employees on single territory makes planning, control and operative problem solving easier. Such order of things has formed historically and it started in the era of manual labor and the development of large industrial companies. Due to development of information technologies the necessity of permanent presence on workplace became less important. The concept of “workplace” has changed. The labor productivity comes to the forefront, regardless of where the specialist is at the time of performing his duties.

The practice of telecommuting networks functioning has shown that the “virtual” and “real” can exist separately from each other, but in synthesis they create the objective picture of surrounding reality. Virtual structure is some kind of merger of technical, information, social and human resources [8].

Quite detail scientometric research of “virtuality” concept was made by such authors as S.N. Bol'shakov, Kh. Vyutrikh, A.V. Kataev et al. The virtual structure combines the network of independent participants with the aim of mutual and voluntary usage of the resource base created by them with help of contemporary informative systems. It contributes the expand of capabilities of all structure participants and minimizes costs. The characteristic feature of virtual process is territorial disunity of the workflow participants. The system of work is designed in such a way that there is no need to perform work duties specifically at one workplace [9,10].

The analyses of different points of view on the base and functionality of virtual organization shows that despite the use of information technologies, the virtual organization is not effective enough for a range of activities [11, 12, 13]. Considering the construction production and dividing it into stages, it must be necessary to acknowledge that the remote work is possible only on some steps of preparation and implementation of a construction project. The final result of building production is the finished object, which remote constructing is impossible. In turn, design is such a stage of construction production, in which remote activity is possible.

There are already developed typologies of virtual enterprises in scientific literature [14, 15, 10, 16], which include web-oriented organizations, corporations, various virtual associations, offices, etc. The single sign of such typology is the association of several disparate and initially unrelated elements, which can be individual employees, and organizations in general.

The appearance of conception of virtual enterprise, first of all connected with publication of monograph “Virtual corporation” by U.Davido and M.Melouna. Enterpises or organizations created with the aim of long-term activities to implement market demands are the most attractive from a business point of view [17]. One of the most important stages in the study of virtual structures in
construction became the research made by S.N. Bol’shakov in 2013. The author offers system engineering model of virtual organization structures of building complex enterprises, which which “produces a process approach to production activities and mutually links separate organizations operating within the industry into a single network module” [18].

S.V. Bondarenko in scientific work “Social structure virtual network communities” (2004) emphasizes that virtual network communities have many foundations for formation, different internal structures, and they use various ways to expand their composition” [19]. The practical use of virtual elements is increasingly found in world practice. For determination of the virtual structures place in the design of engineer processes, existing virtual variants of associations were researched (Table 1).

| №  | The variant of association | Description                                                                 |
|----|-----------------------------|-----------------------------------------------------------------------------|
| 1  | Virtual enterprise          | Virtual enterprise is a cooperative network, which acts on an interim basis, combined to fulfill a market order and based on single information system. The participants of virtual enterprise have core competencies. |
| 2  | Virtual organizations       | It is a network of interactions of the main organization with the external environment on the basis of business cooperation and through information technology and telecommunications. Participants in business processes relate to external environment. |
| 3  | Virtual project office      | Technically, the office work is based on corporate project management technology. The advantage is convenient access to data, flexible joint work of design teams. The server allows to store all projects centrally and ensures single settings for all projects. |
| 4  | Virtual network community   | A virtual network community means a set of participants (users) of telecommunication networks. This participants have social norms, defined roles and formed a system of values. Also characteristics are: access to resources, the use of appropriate hardware and software artifacts. |
| 5  | Virtual organizational structure | This structure is based on single information field, it has interim form of enterprises association. Each enterprise (organization, partner) has feature competencies, which allows to fulfill the market order in a best way. |

4. Discussion

Based on the presented variants of work virtualization, the following functional characteristics variants can be distinguished for all options:

- voluntary association of participants through the use of information technologies;
- a combination of key technologies and competencies that allows to reach the best results at the lowest cost;
- the presence of a stationary center (one or several) with employees working according to the traditional system, while part of the employees works virtually;
- the creation of new areas in information technology, allowing to combine in one information field the participants of various groups and keep a record of data;
- improving the management apparatus in order to effectively organize the work processes a common goal and view on the final result, the implementation of one-time cooperation between the structural elements [20,21,17,22,23,24,25,10,26,27,28].

A common characteristic for all the presented options is the time limited existence. This characteristic is a distinctive feature of virtual organizations and fits into the general concept of adaptive and network structures [25, 29] (Figure 1).
Design of engineer process has ample opportunities for virtual activity, because the result of design engineers work is information, which presented in different form. Based on the earlier hypothesis, this section is devoted to the analysis of virtual structures in the design of engineer process.

There are intra-organizational and inter-organizational virtual forms of activity organization [30]. This article discusses intra-organizational, the basis for which is the design organization in engineering.

In order to offer to design organization the virtual structure as an instrument of improving the efficiency, it is necessary to form complete picture of its capabilities. Strengths and weaknesses of the internal environment of the organization determine its successful existence [31]. The analysis of the capabilities of virtual structures is presented in table 2.

| Point of view | Strengths | Weaknesses |
|---------------|-----------|------------|
| point of view of the state | - expansion of the geography of the construction design market; - attracting people with disabilities to work activities; - reducing the cost of maintaining public transport and reducing congestion of traffic; - attracting specialists from the regions, which affects the overall regions economy. | - lack of documents fully regulating the activities of virtual employees; - increasing the requests from virtual staff; - the risk of reduced demand for work connected with physical labor; - the risk of reduced demand for work with an obligatory stay in the workplace. |
| point of view of the design organization | - development of a culture of mutual trust; - the ability to choose the most suitable specialists; - the ability to reduce the cost of maintaining | - preferential choice of specialists with a narrow focus; - dependence on staff and its posting; - in some cases, coverage of expenses for Internet |
Point of view | Strengths | Weaknesses
--- | --- | ---
workplaces of employees and the entire organization; - the ability to increase labor productivity by creating favorable working conditions; - building of a modern motivation system; - no necessity to expand the office while expanding the staff of the organization; - the ability to reduce wage costs by attracting the specialists from regions with lower living standards; - the ability to save valuable employees, if they do not have the opportunity to work in the office; - reducing the cost of maintaining parking spaces. | and telephone communications; - the probability of increasing complexity of the structure associated with the diversity of the participants; - the appearance of uncertainty of planning for virtual structures participants; - increasing the complexity of monitoring the implementation of tasks; - the necessity of further development of the data security system; - disability to control working conditions and implementation of safety regulations; - overhead connected with the acquisition of software license agreements.

- flexible timetable; - activities in several projects and teams, which allows to share the experience and have a broader view of problem solving; - the ability to choose the best employers; - the ability to full work for people with disabilities; - cost reduction by reducing transportation costs. - expanding the information base due to the ability to obtain specialized and specific information. | - risk of social exclusion; - lack of understanding of the processes taking place in the organization; - loss of involvement in work processes due to isolation from the work team; - the difficulty of creating working conditions at home; - certain limitation on career and professional growth; - risk of loss of professional and social competence; - lack of clear timelines for the working day.

To create a new structure based on the design organization, it is necessary to take a number of measures which will subsequently allow planning work activities. Such measures proposed: the introduction of new technology, improving the organization and design management (table 3).

**Table 3.** Preparing the design organization to create a new structure

| New technology introduction | Improvement of organization of design | Management system improvement |
|-----------------------------|--------------------------------------|-----------------------------|
| Availability of resources for the acquisition of new software products | Implementation of progressive norms and rates, including those based on a system of internal indicators | Improving the technology of preparing of management decisions |
| Facilitation of the process of transmission, reception, storage of documents | Determination of performance indicators for a specific employee, department or whole organization | Availability of training |
| The introduction of advanced technologies in design | Improving the reporting and control system | Implementation of execution control systems of instructions |
| The introduction and widely use of cloud technology | Development of progressive conditions for a virtual employee | Improving the wage system |

Design systems are complex multi-level hierarchical systems consisting of many interactive elements and subsystems. Study of the design process shows that it is hierarchical and iterative in nature. Iterative nature is determined by the lack of a clear algorithm, which can be the base of preparation of project estimates [32].

The structure is a specific characteristic of design system. Firstly, the structure is the significant and at the same time stable system properties (figure 3a). Identifying the objective patterns, existed is
structures, the head of the design organization solves issues related to the division of structural units for the formation of virtual structures by himself (figure 3b).

![Figure 3](image)

Figure 3

a) conditional image of the design system structure
b) variant of dividing into smaller structural units

There are two main types of virtual systems existence: temporary and permanent forms. Temporary forms have clear reference to a specific project, after the completion of the project they disintegrate. Permanent forms perform in particular field, and they are made for constant search and implementation of projects. Virtual structures of design organization are referred to the permanent structure, its life cycle can be represent as follows (figure 4), where the stage “n time of activity” doesn’t have exact time limit.

![Figure 4](image)

Figure 4. The Life cycle of the virtual structures of the design organization

Each structural element of organizational system should be considered as a system “enter – exit”. Each virtual structural element has particular production role, connected with the specific position of the virtual employee in the team. The fulfillment of the production and social role is always associated with the necessity of making decisions about the organization of the own, other people, or collectives actions.

Elements of the structure are individual employees, services and units of the control apparatus, performing particular functional duties within their authority. For successful operation of the virtual structures, good awareness about employees and correct distribution of workers are necessary. It needs clear understanding the roles within the design organization, where the participants are elements both within the structure itself and outside it.
Table 4. Participants of virtual structure of design organization

| Item no. | Role                                      | Characteristic                                                                                                                                                                                                 |
|---------|-------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.      | Participant of virtual structure          | An employee of the department with virtual structures, who has formalized labor relations with the design organization, possesses the necessary qualities and meets certain characteristics. His objective is to carry out tasks within the projects. |
| 2.      | Coordinating body                         | The coordinating body can be either a single person or a group of people with the authority to select staff, responsible for building relationships between team members and regulating and adjusting the activities of all team members. |
| 3.      | Head of the Department                    | Carries out the management of the department, the main objectives:  
- to provide prompt execution of project tasks by the department according to the work requirements;  
- to ensure the security of data, which constitutes a commercial secrecy of the organization, including personal data of employees;  
- to maintain discipline in the department;  
- to provide operational accounting of the key performance indicators of the department, prompt and complete presentation of statistical reporting on the performance indicators of virtual structures;  
- to monitor the progress of tasks, the compliance of the actual performance of the department with the planned ones and to take measures to address identified shortcomings;  
- to use the granted rights in relation to subordinates to promote them and to hold them accountable in accordance with the developed performance indicators;  
- to generate proposals based on the result of the analysis of the production activities of the department, aimed at improving it, etc. |
| 4.      | Office of the Chief Project Engineers     | The main objectives of the chief engineer of the project are to ensure the implementation of the project with the specified quality and on time. The objectives also include creating conditions for the growth of labor productivity and reducing the resources consumption. |
| 5.      | Project Planning and Control Department   | The main objectives of the quality control department:  
- to ensure the release of quality products by the organization;  
- to identify the causes of non-compliance of products with the requirements of standard technical documents, determine the abilities and necessary measures for correcting and eliminating the defects;  
- to execute documents, which certify the quality of design estimates;  
- prompt conduct the activities related to the introduction of new norms and standards, etc. |
| 6.      | Human Resources Department                | The Human Resources department takes on the following objectives:  
- provides the design organization with the necessary number of specialists;  
- assistance in the overcoming of the adaptation period for newly recruited employees;  
- provides support for the heads of departments for personnel management;  
- provides the preparation of necessary documents, develops and prepares orders, reports and other documents, etc. |

Synergistic effect in virtual structures is reached by the uniting implemented by the coordinating authority [28]. It fixes the pace and quality of performed tasks, accordance to the plan, and how the interactions among the virtual structures participants are performed.

5. Conclusions
Activity of virtual structure participants as part of the project is performed using the old software, which solves the issues of creating design estimates. Interactivity of all participants is provided by specially selected information systems and programs. They allows to create optimal conditions for communication between virtual designers, and make the analysis of activities and tasks in accordance with the established deadlines.

In such a way, the place of virtual structures in the design of construction is determined by the synergistic effect of combining the information resources of human capital.
References

[1] A.A. Volkov, A.B. Belyaev, A.E. Davydov and C.B. Yudin 2010 Nekotorye zadachi avtomatizatsii proektirovaniya v stroitel'stve [Some tasks of design automation in construction] Vestnik MGSU No 4 256-61 (rus).

[2] E.A. Gusakova, B.M. Krasnovskiy, V.M. Roytman. 2018 Problematika sistemnogo podkhoda k prognozirovaniyu, proektirovaniyu i ustoychivomu razvitiyu zhiznennogo tsikla ob"ektnov stroitel'xstva seychas krayne aktual'na i nakhoditsya v pole zreniya stroitel'noy nauki [Problems of a systematic approach to forecasting, designing and sustainable development of the life cycle of objects and being in the field of activity of the builder] Science and business: development ways No 9 (87) 6-10 (rus).

[3] A.V. Ginzburg, E.I. Nesterova 2011 Tekhnologiya nepryryvnoy informatsionnoy podrzhki zhiznennogo tsikla stroitel'nogo ob"ekta [Technology of continuous information support for the life cycle of a construction object] Vestnik MGSU No 5 317-320 (rus).

[4] V.P. Grakhov, S.A. Mokhnachev, P.E. Manokhin, A.Kh 2015 Ishtryakov. Sovershenstvovanie organizatsii proektynikh rabot putem vnedreniya tekhnologiy informatsionnogo modelirovaniya [Improving the organization of design work by introducing information modeling technologies] Modern problems of science and education No 1 615 (rus).

[5] A.A. Volkov, Yu.G. Losev, K.Yu. Losev 2012 Informatsionnaya podrzhka zhiznennogo tsikla ob"ektnov stroitel'stva [Information support for the life cycle of construction objects] Vestnik MGSU No 11: 253–258 (rus).

[6] V.A. Bazzhina, I.V. Tsygankova, O.Yu. Nikishina 2014 Razvitie nestandartnykh form zanyatosti v sovremennoy Rossi [The development of non-standard forms of employment in modern Russia] Russian Journal of Entrepreneurship Vol 5 No 24 71-86 (rus).

[7] The results of the first Russian research of the distance employment market. Retrieved from http://www.slideshare.net/bitrixcms1/02-setevoe-obshchestvo-kak-matritsa-sovremennoy-struktury-

[8] V.O. Sayapin 2016 Setevoe obschestvo kak matritsa sovremennoy struktury sotsial'noy virtual'nosti [Network society as a matrix of the modern structure of social virtuality] Manuscript No 1 (63) 141-147 (rus).

[9] L.P. Pidoymo and E.V. Buturlakina 2013 Upravlenie virtual'nymi organizatsiyami [Management of virtual organizations] Organizer of Production No 3 (58) 43-45 (rus).

[10] V.A. Serdyuk 2012 Ot virtual'noy real'nosti k virtual'nomu pravitel'stvu: mif ili real'nost' [From virtual reality to virtual government: myth or reality] Management in Russia and Abroad Journal No 2 25-37 (rus).

[11] X.A. Vyutrikh and A.F. Fillip 2009 Virtualizatsiya kak vozmozhnyy put' razvitiya upravleniya [Virtualization as a possible way of management development] International Journal of Management Theory and Practice No 5: 45-49 (rus).

[12] M.N. Lepeshkina. 2006 Razrabotka virtual'noy sistemy upravleniya realizatsiye investitsionno-stroitel'nogo proekta: dissertation of Ph.D. in Economics [Development of a virtual system for managing the implementation of an investment construction project: dissertation of Ph.D. in Economics] 08.00.05. 182 (rus).

[13] M.M. Chuchkevich. 2012 Chto takoe setevaya organizatsiya? [What is a network organization?] The Institute of Sociology of the Russian Academy of Sciences 207 (rus).

[14] S.N. Boleshakov and A.A. Volkov 2013 K voprosu proektirovaniya i postroeniyia virtual'nykh organizatsionnykh struktur v stroitel'stve V Vestnik MGSU No 11 218-225 (rus).

[15] S.N. Boleshakov 2013 Metodologicheskie osnovy formirovaniya virtual'nykh organizatsionnykh struktur predpriyatiy v ramkah stroitel'nogo kompleksa [Methodological foundations of the formation of virtual organizational structures of enterprises within the construction complex] Vestnik MGSU No 10 287-294 (rus).

[16] W. Saabeel. 2014 Model of Virtual Organization Structure & Process. Electronic Journal of Organizational Virtualness Vol.4. No 1.
[17] A.V. Kataev 2009 Virtual'nye biznes-organizatsii [Virtual business organizations] Izd-vo Politekhnicheskogo universiteta Pub 1 120 (rus).

[18] S.N. Bol'shakov 2013 Sistematikechnesko modelirovanie virtual'nykh organizatsionnykh struktur predpriyatiy stroitel'nogo kompleksa: dissertation of Ph.D. in Engineering [System engineering modeling of virtual organizational structures of building complex enterprises: dissertation of Ph.D. in Engineering] 05.13.12. Moscow State University of Civil Engineering.; 139 (rus).

[19] S.V. Bondarenko 2004 Sotsial'naya struktura virtual'nogo setevogo soobshchestva: dissertation of Doctor of Social Science [Social structure of a virtual network community: dissertation of Doctor of Social Science] 22.00.04. Rostov State University 396 (rus).

[20] K.V. Gerasin 2016 Predposylyki k sozdaniyu vertikal'no integrirovannoy korporatsii s setevoy sostavlyayushchey [Prerequisites for creating a vertically integrated corporation with a network component] Vestnik MGU No 9 119-29 (rus).

[21] P. Ziber 2010 Upravleniyu set'yu kak klyuchevaya kompetentsiya predpriyatiya [Network management as a core competency of an enterprise] International Journal of Management Theory and Practice No 3 92-6 (rus).

[22] N.B. Kuleshova 2009 Virtual'naya setevaya organizatsiya [Virtual network organization] The World of New Economy No 2 (4) 21-6 (rus).

[23] K.S. Lodzhenski. 2013 Predpriyat'sya novogo tipa [The causes and characteristics of the organization of a new type of enterprise] International Journal of Management Theory and Practice No 1 87-90 (rus).

[24] V. Meytus 2004 Virtualizatsiya proizvodstva [Virtualization of production]. International Journal of Management Theory and Practice No 1 91-5 (rus).

[25] A. A. Morozenko 2013 Refleksno-adaptivnyy tip organicheskih struktur stroitel'nikh predpriyatiy [Reflexive-adaptive type of building structures] Industrial and Civil Engineering No 8 72-74 (rus).

[26] N.V. Silaev 2010 Faktory konkurentosposobnosti virtual'nogo torgovogo predpriyatiya [Virtual competitiveness factors of trading enterprise] St. Petersburg State Polytechnical University Journal. Economics No 4 (102) 154-156 (rus).

[27] V. Tarasov 2008 Prichiny voznikhoveniya i osobennosti organizatsii predpriyatiya novogo tipa [The causes and characteristics of the organization of a new type of enterprise] International Journal of Management Theory and Practice No 1 87-90 (rus).

[28] M. Uorner and M. Vittsel 2005 Virtual'nye organizatsii [Virtual organizations] Dobraya kniga Publ 296 (rus).

[29] A.A. Morozenko. 2015 Matrisa proekta – osnova optimal'noy organizatsionnoy struktury investitsionno-stroitel'nogo proekta [The project matrix as the basis of the optimal organizational structure of the investment construction project] Industrial and Civil Engineering No 7 49-51 (rus).

[30] A.V. Kataev 2008 Issledovanie i razrabotka modelely dlya organizatsii i upravleniya virtual'nymi predpriyatiyami: dissertation of Ph.D. in Economics [Research and development of models for organizing and managing virtual enterprises: dissertation of Ph.D. in Economics] 05.13.10. St.Petersburg Polytechnic University 148 (rus).

[31] M.M. Merkulov 2005 Distantionnyy personal - mify i real'nost [Remote staff - myths and reality] Kadrovaya sluzhba i upravlenie personalom predpriyatiya No 7 11-26 (rus).

[32] V.P. Ignatov 2012 Modelirovanie stroiteľ'nogo proektirovaniya na osnove intellektual'nykh tekhnologii [Modelling of building design based on intelligent technologies] Knizhnyy mir Publ 152 (rus).