MODELING OF CONSTRUCTION PROCESSES FOR A SPECIFIC OBJECT BASED ON ENVIRONMENTAL PARAMETERS

S.G. Abramyan, O.V. Burlachenko, O.V. Oganesyan

Institute of Architecture and Civil Engineering of Volgograd State Technical University (IACE VSTU), 1 Akademicheskaya str., Volgograd, 400074, Russian Federation,

ABSTRACT. This paper suggests that building information modeling is predominantly aimed at deriving certain economic benefits. The construction schedule is prepared without considering the proper balance in the environment. Due to their complex and diverse nature, construction operations cannot be ideally modeled in terms of environmental sustainability. Still, a reduction of some hazardous impacts is manageable. This paper primarily focuses on the methodology that can be used to calculate the volume of polluting substances emitted during machinery operation. It highlights that during construction of large residential and environmental complexes, when several objects and linear facilities of tens or hundreds kilometers are being built simultaneously, it is especially dangerous to use a fleet of machines and mechanisms. The originality of this paper is underpinned by the conceptually new approach to the environmental basis of the construction processes during building construction. Hazardous emissions are suggested to be calculated using the generally known methodology for determining the maximum amount of technical resources required per shift. Given a known machinery brand, engine capacity and the number of operating shifts of a machine or mechanism, the maximum emission volume can be derived. By comparing the calculation results with the maximum allowable concentrations, the final conclusion can be made regarding the conformity of the construction schedule with the applicable environmental standards.

KEY WORDS: modeling, construction, machinery, hazardous emissions, environmental planning

FOR CITATION: Abramyan S.G., Burlachenko O.V., Oganesyan O.V. Modeling of Construction Processes for a Specific Object Based on Environmental Parameters. Vestnik MGSU [Proceedings of Moscow State University of Civil Engineering]. 2017, vol. 12, issue 7 (106), pp. 797–803. DOI: 10.22227/1997-0935.2017.7.797-803
Any model capturing construction operations is developed to ensure management of such operations. But any management task is essentially linked to a multitude of solutions. Because construction operations form a multifaceted and complex system they are hard to model in all the relevant respects, the more so to properly govern, due to their dynamics and the likelihood of occurrence of specific events. It should be remembered that the concept of environmental planning in urban development appeared more than 30 years ago, but the body of research so far remains mostly in the theoretical domain.

Nevertheless, the intensive development of the construction industry, which is indispensable in the development of any civilization, is comparably intensive in disturbing the environmental balance through negative impacts on all the geospheric shells of the Earth and the biosphere. A human being as an object of biodiversity becomes unable to adapt to ongoing environmental changes within the human ecosystem, and succumbs to increasingly numerous diseases, both individually and population-wise.

The topicality of this research is associated with the applied significance of environmental planning, which normally is ignored when developing method statements and roadmaps, or at best remains on paper only. In order to expand on the scientific significance of the topic of interest, including the complexity and importance of building modeling, and in particular, schedule planning, we will provide an overview of some research papers. Thus, the paper [1] argues that, according to the 2011 poll, only 37% projects were completed in line with the original plan even though all related risks were taken into account. The importance of construction modeling is discussed in the works [2–8]. In particular, the work [2] speculates that the invention of information technologies and modeling techniques is being slow in the construction engineering projects in Malaysia. While the work [8], conversely, considers information modeling the basis for setting up a uniform classifier of civil buildings due to its omnipresence. In addition to the above reference literature, a number of other sources were considered where construction modeling is discussed by the Russian scientists [9–15].

The work [16] underlines that the use of building information modeling (BIM) should be instrumental at all stages of real property lifecycle as it sets a relevant contemporary trend in solving the construction efficiency challenges. Efficiency thereby is mostly understood as the improvement of construction product quality, reduction of construction time and cost. This means the economic component is predominant in setting the construction goals. When implementing a construction project, a model is an abstract reflection of the most significant characteristics, processes and interrelations of real-life systems that allows exploring a nominal object of construction and, as such, managing the same.

Therefore, schedule planning is considered the basis of management in many industries and is being increasingly on the move along with the growing complexity of projects and the need for their efficient implementation [17–18]. The author’s approach to the organization of construction, subject to its environmental components, is also based on the schedule-related modeling.

The scientific importance of environmental planning therefore heavily relies on the sustained environmental balance when implementing the construction processes. Considering this, the dominating idea should be the preservation of the biodiversity currently existing on the Earth, rather than the delivery of economic benefits.

The topic being explored stems from the view that environmental planning should become an integral part of construction method statements. The preliminary environmental plan should be approved before the beginning of the construction and installation phase and should be adjusted along with the performance of works, considering that it is virtually impossible to develop and further control an ideal environmental plan. Also, the construction processes remain basically underexplored in terms of their environmental safety aspect [19], although the assurance of safety at the construction site [20] and elimination of environmental hazards, including hazards for the people’s health [21–23], should be given a priority as against the derivation of economic value.

In order to select the optimal construction modeling option, a number of schedule-based models were considered (Gantt bar charts for buildings and Budnikov’s charts for linear facilities), setting aside the considerable benefits delivered by time-phased network diagrams [24–26] in terms of the management of an organization.

That said, whatever management principles are used to arrange the construction processes to ensure their timely completion, all the same, materials, machines and mechanisms involved in the process of manufacturing of the final product will affect, one way or another, the coexistence of the three ecological systems: the humans — the nature — the construction. In this context, each construction process is found to influence the environment in its own specific way: everything depends on the quantity and characteristics of materials, machines and mechanisms used therein. Theoretically, it is relatively easy to determine the degree of environmental influence of each construction process. Whereas the environmental plan is developed to mitigate hazardous effects on the atmosphere, such as during operation of machines and mechanisms, then, at the stage of structuring the process flows, special attention should be given to the work scopes involving the maximum number of machines and mechanisms – for example, transportation and earthworks, as well as pipe-laying during construction and reconstruction of
trunk pipelines, road surface dressing etc. This means, standardized environmental plans practically cannot be considered an option for buildings and structures with uniform dimensional patterns, identical process and performance indicators. Environmental planning, unlike schedule-based planning, is individual by its nature, although when putting up an environment-centered plan certain scheduling elements can be used: description and scope of works, as well as demand for machines and mechanisms, indicating their brands and the number of operating shifts.

Having a model of the environmental plan on hand allows determining the combined peak emissions of hazardous substances — in this case during operation of machines and mechanisms, and getting an opportunity to reduce emissions exceeding the maximum allowable concentrations (MAC) through adjusting the available model: by re-scheduling the commencement or completion of individual construction processes in the schedule-based model without disturbing the succession of the works and the process cycle as a whole. Tracing downward fluctuations of peak emissions of hazardous substances allows making key decisions in terms of adjusting the organizational model of the construction process at a particular site, because a schedule-based model depends on the environment-based model.

It is therefore demonstrated that the organizational modeling for construction of a specific object based on environmental premises is developed in a few stages (Fig. 1).

![Algorithm for modeling environmental plan](image-url)

**Fig. 1.** Algorithm for modeling environmental plan
Stage 1. Modeling and developing the construction schedule based on the generally recognized methodologies.

Stage 2. Modeling and developing the chart of inventory flows with reference to the construction schedule.

Stage 3. Identifying the works that involve the greatest number of machines and mechanisms.

Stage 4. Calculating the amount of hazardous emissions in the performance of works involving the greatest number of machines and mechanisms. Identifying peak emissions of hazardous substances including the dates thereof according to the construction schedule. Comparing the peak emission values with the MAC limits. If the peak emissions are higher than the MAC, the schedule-based model developed at the first stage is required to be adjusted. For this, the commencement of those works which produce the maximum emissions should be re-scheduled, and the processes included in stages two to four should be repeated. If the peak emissions are lower than the MAC, it is safe to proceed with the following stage.

Stage 5. Modeling and developing the chart of workforce flows.

Stage 6. Developing the construction master plan. Here, some specifications regarding the fourth modeling stage could be useful. The amount of atmospheric emissions of hazardous substances emerging during operation of machines and mechanisms, namely nitrogen oxides in form of NOx and carbon, carbon and sulfur dioxides, methane, ammonia, nitrous oxides, non-methane hydrocarbons and various solids, depend not only on the number of machinery operating shifts and the engine capacity, but also on the «aging» of the machines’ engines. As such, replacement of the machines and mechanisms assumed as per the construction schedule with their environmentally friendly analogues can also be an optimal scenario for reducing atmospheric emissions.

There are a number of contemporary methodologies for environmental assessment during building construction. These however, do not link the calculations to any specific time or place pegs. The suggested methodology, developed on the basis of the data, takes into account both the time and location parameters of the construction processes. It is known that in spring, summer (summer school camps) and early autumn, recreational activities for children are mostly arranged. Concerts, meetings of clubs and educational circles, health and culture events are held in residential quarters, large public buildings to be rented outdoors, where there are multiple construction sites of different kinds. Moreover, the number of various types of machines and mechanisms assumed as per the construction schedule, with more focus on the identification of hazardous emissions during transportation, earth works, concrete works and road paving in the above streets. It was calculated that the combined emissions of certain substances (CO2, SO2, N2O) exceeded the MAC limits. The combined emissions were analyzed for the following substances: CO, VOC as CH1,85, NOx as NO2, PM, SO2, CO2, CH4, NMVOC, NH3, N2O, during operation of tracked excavators, bulldozers and cranes, agitating trucks, truck-mounted concrete pumps, dump trucks for removal of earth, delivery of bulk materials, asphalt pavers, self-propelled road rollers etc.

According to the [28] data, during this period the Voroshilovsky District of Volgograd was the leader in terms of infant morbidity. The most frequent infant diseases were headache, asthma and pneumonia. Child Health Center No. 6 in the Voroshilovsky District, which is close to the development site, also ranked first by the number of visits and complaints of varying nature.

The facts discussed here are not a coincidence as they truly support the calculations performed during environmental planning as part of construction of the above objects. The research shows that in the case hazardous emissions exceed the MAC limits, it is possible to reduce the level of adverse impact on the atmosphere by re-scheduling the commencement and completion of...
construction stages (or certain construction works within the same construction site), replacement of machines and mechanisms with environmentally-safe analogues. In a word, it is possible to optimize the performance of each construction process and, on the whole, each building construction project with an adequate justification of the environmental solutions adopted.

This paper is original in that it offers a fundamentally new approach to arranging the construction processes during building construction. For the first time, the generally adopted methodology for calculating the maximum number of workers required for correct organization of a construction site will be used to determine the maximum amount of hazardous emissions during operation of construction machinery. The methodology developed by the authors allows to calculate the amount of atmospheric emissions of hazardous substances during building construction takes into account the time and spatial parameters of the construction processes, which eventually enhances environmental safety and the quality of people’s life.

REFERENCES

1. Oak K., Laghate K. Analysis of Project Management Issues in Information Technology Industry: an Overview of Literature. International Journal of System Assurance Engineering and Management. 2016, vol. 7, issue 4, SI, pp. 418–426.

2. Latiffi A.A., Mohd S., Rakiman U.S. Potential Improvement of Building Information Modeling (BIM) Implementation in Malaysian Construction Projects. IFIP Advancements in Information and Communication Technology. 2016, vol. 467, pp. 149–158.

3. Ahn Y.H., Kwak Y.H., Suk S.J. Contractors’ Transformation Strategies for Adopting Building Information Modeling. Journal of Management in Engineering. 2016, vol. 32, issue 1, article number 05015005.

4. Martin J.L.N. Classification of Construction Costs — An International Overview from a UK Perspective. American Society for Testing and Materials Special Technical Publications. 2014, vol. 1586, pp. 52–79.

5. Succar B., Kassem M. Macro-BIM Adoption: Conceptual Structures. Automation in construction. 2015, vol. 57, pp. 64–79.

6. Morlhon R., Pellerin R., Bourgault M. Defining Building Information Modeling Implementation Activities Based on Capability Maturity Evaluation: A Theoretical Model. International Journal of Information Systems and Project Management. 2015, vol. 3, issue 1, pp. 51–65.

7. Eadie R., Browne M., Odeyinka H. et al. A Survey of Current Status of and Perceived Changes Required for BIM Adoption in the UK. Built Environment Project and Asset Management. 2015, vol. 5, issue 1, pp. 4–21.

8. Pobegaylov O.A., Shemchuk A.V. Modelirovanie technologicheskikh protsessov pri organizatsii stroitel’nogo proizvodstva [Simulation of Technological Processes in the Construction Industry]. Internet-journal “Naukovedenie” [Internet-journal “Naukovedenie”]. 2012, no. 4 (13). Available at: http://naukovedenie.ru/sbornik-4.pdf. (In Russian)

9. Volkov A.A., Rakhmonov E.K. Infograficheskoe modelirovanie sistemy chelovek — tekhnika — sreda (ChTS) [Infographic Modeling of the Man-Machinery-Environment System Exemplified by an Intelligent Building within the Framework of Innovative Conflicts]. Vestnik MGSKU [Proceedings of Moscow State University of Civil Engineering]. 2012, no. 11, pp. 259–263. (In Russian)

10. Siverikova A.I., Velichkin V.Z. Parallel’no-potokovy metod organizatsii stroitel’stva [Parallel and Stream Methods of Construction Organization]. Stroitel’stvo unikal’nykh zdaniy i sooruzheniy [Construction of Unique Buildings and Structures]. 2015, no. 4 (31), pp. 135–162. (In Russian)

11. Bolotin S.A., Dadar A.Kh., Pushina I.S. Simulation of Calendar Planning in Building Information Modelling Programms and Regression Detailing of Construction Period Rules. Magazine of Civil Engineering. 2011, no. 7 (25), pp. 82–86.

12. Zelentsov L.B., Zelentsov A.I., Ostrovskiy K.N. Web-prilozheniya — osnova sovremennykh informatsionnykh tekhnologiy v stroitel’stve [Web Applications — Basis of the Modern Informational Technologies In Construction]. Vestnik Volgogradskogo gosudarstvennogo arkhitekturno-stroitel’nogo universiteta. Seriya: Stroitel’stvo i arkhitektura [Bulletin of Volgograd State University of Architecture and Civil Engineering. Series: Civil Engineering and Architecture]. 2012, vol. 48, issue 29, pp. 224–230. (In Russian)

13. Volkov A.A., Rakhmonov E.K. Infograficheskoe modelirovanie sistemy chelovek — tekhnika — sreda (ChTS) na primere intellektual’nogo zdaniya v usloviyakh innovatsionnykh konflikтов [Infographic Modeling of the Man-Machinery-Environment System Exemplified by an Intelligent Building within the Framework of Innovative Conflicts]. Vestnik MGSKU [Proceedings of Moscow State University of Civil Engineering]. 2012, no. 11, pp. 259–263. (In Russian)

14. Siverikova A.I., Velichkin V.Z. Parallel’no-potokovy metod organizatsii stroitel’stva [Parallel and Stream Methods of Construction Organization]. Stroitel’stvo unikal’nykh zdaniy i sooruzheniy [Construction of Unique Buildings and Structures]. 2015, no. 4 (31), pp. 135–162. (In Russian)

15. Demenev A.Y., Artamonov A.S. Informatsionnoe modelirovanie pri eksploatatsii zdaniy i sooruzheniy [Information Modeling on Operation of Buildings and Structures]. Internet-zhurnal «Naukovedenie» [Internet-journal “Naukovedenie”]. 2015, vol. 7, no. 3. Available at: http://naukovedenie.ru/sbornik-7/3/pdf. (In Russian)

16. Chelnokova V.M. Osobennosti kalendarnogo planirovaniya kompleksnogo osvoeniya territorii developmentskoy organizatsiy [Features of Calendar Scheduling of Complex Development of Territory by the Development Organization]. Vestnik grazhdanskikh inzhenerov [Bulletin of Civil Engineers]. 2016, no 3 (56), pp. 136–141. (In Russian)

17. Sergeenkova O.A. Kalendarnoe planirovanie stroitel’stva kompleksa ob’ektov s uchetom osobennostey programmnnykh sredstv [Planning of Construction of a Complex of Objects Taking into Account the Software Features]. Stroitel’stvo unikal’nykh zdaniy i sooruzheniy [Construction of Unique Buildings and Structures]. 2014, no. 7 (22), pp. 176–193. (In Russian)
18. Abramyan S.G. Environmental Compliance during Construction. Procedia Engineering. 2016, vol. 150, pp. 2146–2149.

19. Choudhry R.M., Fang D., Ahmed S.M. Safety Management in Construction: Best Practices in Hong Kong. Journal of Professional Issues in Engineering Education and Practice. 2008, vol. 134, issue 1, pp. 20–32.

20. Loosemore M. Managing Public Perceptions of Risk on Construction and Engineering Projects: How to Involve Stakeholders in Business Decisions. International Journal of Construction Management. 2007, vol. 9, no. 2, pp. 65–74.

21. Izirzar J., Simonsen K.L., Abraham D.M. Effect of Safety and Environmental Variables on Task Durations in Steel Erection. Journal of Construction Engineering and Management-Asce. 2005, vol. 131, issue 12, pp. 1310–1319.

22. Zou P.X.W., Zhang G.M. Comparative Study on the Perception of Construction Safety Risks in China and Australia. Journal of Construction Engineering and Management. 2009, vol. 135, issue 7, pp. 620–627.

23. Usov A.V., Maksimov S.S. Primenenie modeli kalendarnogo planirovaniya dlya proektovogo upravleniya v stroitel’stve [Application of Scheduling Model for Project Management in Construction]. Vostochno-Evropeyskiy zhurnal peredovikh tehnologiy [East-European Journal of Enterprise Technologies]. 2014, vol. 1, no. 4 (67), pp. 39–42. (In Russian)

24. Katargin N. V. Optimizatsiya setevogo grafika vypolneniya kompleksa rabot [Optimization of the Network Schedule of a Complex of Operations]. Upravlencheskie nauki [Management Sciences]. 2012, no. 1 (2), pp. 87–93. (In Russian)

25. Soshinov A.G., Guseva N.V., Shevchenko N.Yu., Lebedeva Yu.V. Imitatsionnoe modelirovanie v obravozatel’nom processe [Imitation Modeling in Education]. Sovremennye problemy nauki i obrazovanija [Modern Problems of Science and Education]. 2013, no. 5. Available at: http://www.science-education.ru/ru/article/view?id=10048. (In Russian)

26. Abramyan S.G., Potapov A.D. Obosnovanie ekologicheskoi bezopasnosti tekhnologii rekonstruktii magistral’nykh truboprovodov [Substantiation of Ecologically Safe Reconstruction Technology for Trunk Pipelines]. Vestnik MGSU [Proceedings of Moscow State University of Civil Engineering]. 2014, no. 8, pp. 91–97. (In Russian)

27. Abramyan S.G., Oganesyan O.V. Ustoychivoe razvitie i ekologicheskaya bezopasnost’ stroitel’stva zdanii i sooruzhenii: tekhnogennyye faktory, vozdeystvuyushchie na atmosferu. Chast’ 1 [Sustainable Development and Ecological Safety of Construction of Buildings and Facilities: Technogenic Factors Influencing the Atmosphere. Part I]. Vestnik Volgogradskogo gosudarstvennogo arkhitekturno-stroitel’nogo universiteta. Seriya: Stroitel’stvo i arkhitektura [Bulletin of Volgograd State University of Architecture and Civil Engineering. Series: Civil Engineering and Architecture]. 2015, issue 42 (61), pp. 202–210. (In Russian)

28. Doklad «O sostoyanii okruzhayushchei sredy Volgogradskoy oblasti v 2012 godu» [Report “On the State of the Volgograd Region Environment in 2012”]. Volgograd, SMOTRI Publ., 2013, 300 p. (In Russian)

Received in March 2017.
Adopted in revised form in May 2017.
Approved for publication in May 2017.

About the authors: Abramyan Susanna Grantovna — Candidate of Technical Sciences, Associate Professor, Department of Construction Technology, Institute of Architecture and Civil Engineering of Volgograd State Technical University (IACE VSTU), 1 Akademicheskaya str., Volgograd, 400074, Russian Federation; susanagrant@mail.ru;
Burlachenko Oleg Vasi1ievich — Doctor of Technical Sciences, Professor, Head of the Department of Construction Production Technology, Deputy Director for Science, Institute of Architecture and Civil Engineering of Volgograd State Technical University (IACE VSTU), 1 Akademicheskaya str., Volgograd, 400074, Russian Federation; oburlachenko@yandex.ru;
Oganesyan Oganes Valer’evich — student, Faculty of Construction and Housing and Communal Services, Institute of Architecture and Civil Engineering of Volgograd State Technical University (IACE VSTU), 1 Akademicheskaya str., Volgograd, 400074, Russian Federation; ogoganesyan@mail.ru.

С.Г. Абрамян, О.В. Бурлаченко, О.В. Оганесян
S.G. Abramyan, O.V. Burlachenko, O.V. Oganesyan

ЛИТЕРАТУРА
Моделирование организации строительства конкретного объекта по экологическим параметрам
Modeling of construction processes for a specific object based on environmental parameters

С. 797–803

ногого производства // Интернет-журнал «Науковедение». 2012. № 4 (13). Режим доступа: http://naukovedenie.ru/PDF/46trgsu412.pdf.

9. Волков А.А., Аникин Д.В. Функциональное моделирование жизненного цикла корпоративной информационной пространства строительных организаций // Вестник МГСУ. 2013. № 11. С. 226–233.

10. Романова А.И., Добросердова Е.А. Моделирование качественной составляющей строительных работ и услуг хозяйствующих субъектов // Вестник экономики, права и социологии. 2015. № 1. С. 38–44.

11. Boloitin S.A., Dadar A.Kh., Fushina I.S. Simulation of calendar planning in Building information modelling programs and regression detailing of construction period rules // Magazine of Civil Engineering. 2011. No. 7 (25). Pp. 82–86.

12. Зеленцов Л.Б., Зеленцов А.Л., Островский К.И. Web-приложения — основа современных информационных технологий в строительстве // Вестник Волгоградского государственного архитектурно-строительного университета. Серия: Строительство и архитектура. 2012. Вып. 29 (48). С. 224–263.

13. Волков А.А., Рахмашов Э.К. Инфографическое моделирование системы человек — техника — среда (ЧТС) на примере интеллектуального здания в условиях инновационных конфликтов // Вестник МГСУ. 2012. № 11. С. 259–263.

14. Сивриков А.И., Величчук В.З. Параллельно-посточный метод организации строительства // Строительство уникальных зданий и сооружений. 2015. № 4 (31). С. 135–162.

15. Деменев А.В., Артамонов А.С. Информационное моделирование при эксплуатации зданий и сооружений // Интернет-журнал «Науковедение». 2015. Т. 7. № 3. Режим доступа: http://naukovedenie.ru/PDF/29TVN315.pdf.

16. Челунова В.М. Особенности календарного планирования комплексного освоения территорий девелопментской организации // Вестник гражданских инженеров. 2016. № 3 (56). С. 136–141.

17. Сергеенкова О.А. Календарное планирование строительства комплекса объектов с учетом особенностей программных средств // Строительство уникальных зданий и сооружений. 2014. № 7 (22). С. 176–193.

18. Abramyan S.G. Environmental compliance during ring construction // Procedia Engineering. 2016. Vol. 150. Pp. 2146–2149.

Поступила в редакцию в марте 2017 г.
Принята в доработанном виде в мае 2017 г.
Одобрена для публикации в мае 2017 г.

Об авторах: Абрамян Сусанна Грантовна — кандидат технических наук, доцент, профессор кафедры технологии строительного производства, Институт архитектуры и строительства, Волгоградский государственный технический университет (ИАнС ВолГТУ), 400074, г. Волгоград, ул. Академическая, д. 1, susanagrant@mail.ru;
Бурлаченко Олег Васильевич — доктор технических наук, профессор, заведующий кафедрой технологии строительного производства, заместитель директора по науке, Институт архитектуры и строительства, Волгоградский государственный технический университет (ИАнС ВолГТУ), 400074, г. Волгоград, ул. Академическая, д. 1, oburlachenko@yandex.ru;
Оганесян Оганес Валерьевич — студент факультета строительства и жилищно-коммунального хозяйства, Институт архитектуры и строительства, Волгоградский государственный технический университет (ИАнС ВолГТУ), 400074, г. Волгоград, ул. Академическая, д. 1, ogoganesyan@mail.ru.