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Reasons of delays in construction projects

Причины отставаний строительных проектов

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Key words: civil engineering; construction management; project scheduling; critical path method

Ключевые слова: управление инвестиционно-строительными проектами; расписание проекта; метод критического пути

Abstract. Usually, the actual duration of construction projects significantly exceeds the scheduled duration. Reasons for this phenomenon are presented. Firstly, numerous stochastic factors impact on the works. The second reason is insufficiently reliability of traditional scheduling methods. Finally, the third reason is quasi-activities that were not included in the schedule. This paper discloses the essence quasi-activities, their impact on the completion times. The approach is identified additional dummy arcs, causing implicit activities. The general applicability of the method is demonstrated. A comparison was drawn between the proposed method and traditional techniques. The mean duration of the simple chain of activities is underestimated by 15-20%.It is confirmed that the traditional method of calculating the time to complete a project is almost always shorter. Implementation of this method will allow for the determination of a more precise duration for the performance of complex works at the planning stage. The suggested methodology can be recommended for use by construction project managers.

Аннотация. Как правило, фактическая продолжительность строительства значительно превышает запланированные сроки. Представлены причины этого явления. Во-первых - это влияние на работы множества случайных факторов. Второй причиной является недостаточная достоверность и надежность традиционных методов планирования. Наконец, третья причина-это квази-работы, которые не были включены в календарный график. В статье раскрыта сущность квази-работ, их влияние на сроки строительства. Подход выявил неявные дополнительные ресурсно-объектные связи, вызванные квази-работами, находящимися вне поля графика. Изложенный подход проиллюстрирован расчетами. Проведено сравнение между предложенным и традиционным методами. Установлено, что средняя продолжительность ряда последовательных работ, рассчитанная традиционным методом, занижена в среднем на 15-20%. Реализация метода позволит определять более точные сроки завершения строительного проекта на стадии планирования. Предложенная методология может быть рекомендована для использования руководителями строительных проектов.

Introduction

The analysis of the current state of the theory and practice of scheduling illustrates the lack of realistic scheduling.

Therefore, the actual duration of various construction projects significantly exceeds the planned ones [1-8].

The reason for the significant difference between planned and actual construction durations is, primarily, the impact of the works due to numerous stochastic factors [9, 10]. So, for average and strong levels of impact of destabilizing factors on technological processes, their mean productivity is reduced in 1.5-2.5 times from the norm [10]. It is established that process productivity is subject to the normal law of distribution. The duration of the activities is described by a Beta distribution or inverse to normal law [11]. In these circumstances, duration of activities can be evaluated using probabilistic estimation [12-16].

The second reason is insufficiently reliable traditional PERT (Program Evaluation and Review Technique) method. The PERT method is generally intended for the calculation of schedules that have

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certain structures set by unambiguous technological processes. The activity time spans are assumed to follow a general Beta distribution [17-21].

The traditional PERT method uses only the activity time means to calculate the critical path, reducing the stochastic model to a deterministic model. In PERT, three-time estimates are required for each activity. The time estimates represent a pessimistic time, an optimistic time, and a most likely time for the duration of the activity.

The method assumes that the sum of the mean completion times of activities on the critical path is normally distributed. This allows the calculation of the probability of completing the project within a given time period. A single critical path is thus calculated and relied upon, where in reality, there may be numerous possible critical paths that exist. For a large network plan, the probability that any given path could be the critical path may be very small. PERT method yields results which are biased high. The construction project manager is thus grossly misled into thinking his chances are very good when in reality they are very poor. If the network has multiple parallel paths with relatively equal means, PERT calculations will be considerably biased [22]). As a result, the time to complete a project calculated by the traditional PERT method is almost always too short [23]).

A universal method developed for the calculation of networks schedule with multiple critical paths. This method was used for the calculation of a more realistic time span for the construction of a road [24]. A comparison was drawn between the proposed method and traditional techniques. The mean duration of the technological process calculated by a universal method is 30 % more than for a known critical path method. It is confirmed that the traditional method of calculating the time to complete a project is almost always shorter.

Similar results have also been observed when using the technique of crashing PERT [25]). Completion times with the PERT method are much shorter than completion times calculated with the Monte Carlo method [19, 26, 27].

The third reason for delays in construction projects is quasi-activities that were not included in the schedule [28].

The aim of the present paper is to reveal the essence quasi-activities, their impact on the completion times.

Objectives of the study are:

1. Show essence of the resource-object relations, that constitute the inner nature of schedules;
2. Reveal impact of quasi-activities on the completion times;
3. Calculate the completion times of the chain of activities.

Methods

Assume, that sequential works of crews F, G, H on the 5-th object (chain of activities) is presented in Figure 1.

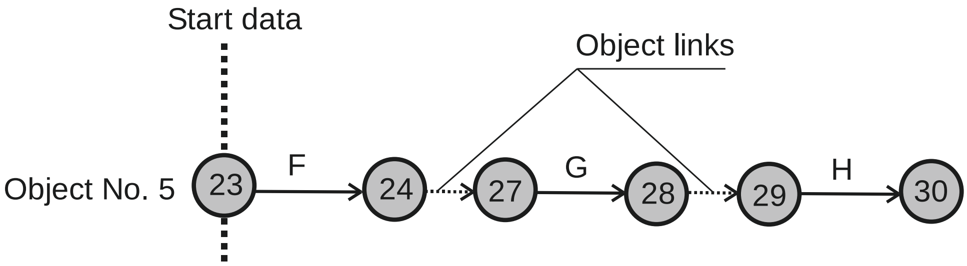

Figure 1. Fragment of chain activities

It is obvious that for deterministic values the length of the chain (23-24-27-28-29-30) is the sum of the durations of individual activities.

For stochastic estimates, the parameters of the event 30 are determined by the composition of the laws of duration of work of each crew. So, for the normal distributions, the mathematical expectation of the length of the chain (23-24-27-28-29-30) will be the sum of the activity time means.

However, the actual time the events of 30 always exceed the planned.

The sequential chain (Fig. 1) does not reflect fully the essence of the resource-object relations that constitute the inner nature of schedules.

So, the crews G and H to the planned date of the beginning of their work usually always busy at the previous objects (work areas), which causes additional resource links.

This allows us to convert the initial model (Fig 2).

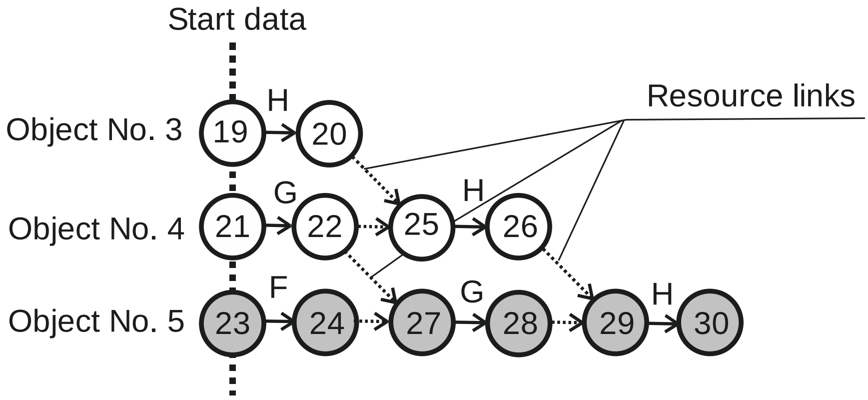

Figure 2. Model of the chain of activities, taking into account implicit resource links

This scheme is lawful to use only in the case where the scheduling date coincides with the start date. Otherwise, the model chain of activities of is converted into the following (Fig. 3).

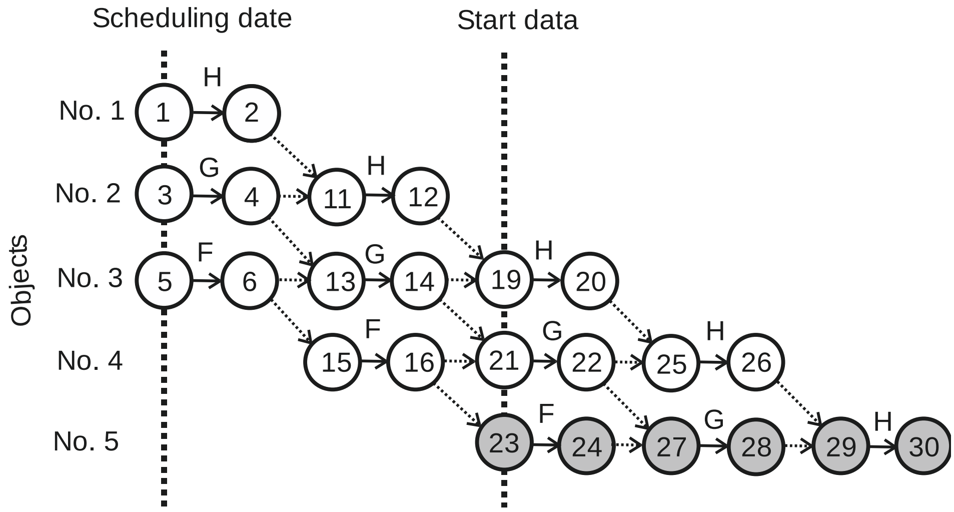

Figure 3. Model of the chain of activities, taking into account to the scheduling date and an implicit of the resource links

It is obvious that increase in an interval between start date and date of planning, leads to increase in resource and object links for works G and H.

In addition, in this case there are additional (implicit) object links caused by the necessity of preparing the fifth object for the crew F.

This, in turn, causes the need to consider possible links with the previous crews (E and D) on objects 4 and 5 (Fig. 4).

This scheme is the model of the initial chain (F, G, H) (model quasi-activities).

Quasi-activities are works of crews outside of the schedule and causing an implicit resource and object links to the events of the schedule.

The presented model of quasi-activities on the structure is equivalent to model of a flow of works with multiple critical paths and can be calculated in a similar way.

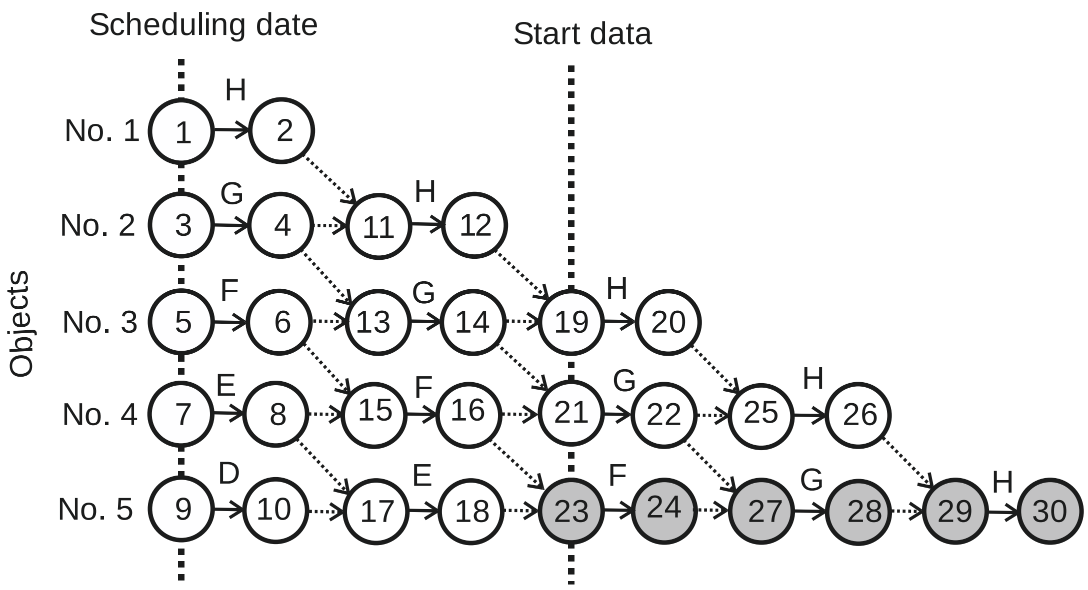

Figure 4. The converted model of initial chain (model of quasi-activities)

Results and Discussion

Model of the chain of activities (Fig. 4) was realized by means of the universal method and Monte-Carlo method under the following data.

The duration of work of each crew follows a general Beta distribution with the parameters: $\alpha = 1, \beta = 2, A = 5, B = 15$. The mean duration is 8.33.

The flow of works with equal durations is presented in Figure 5.

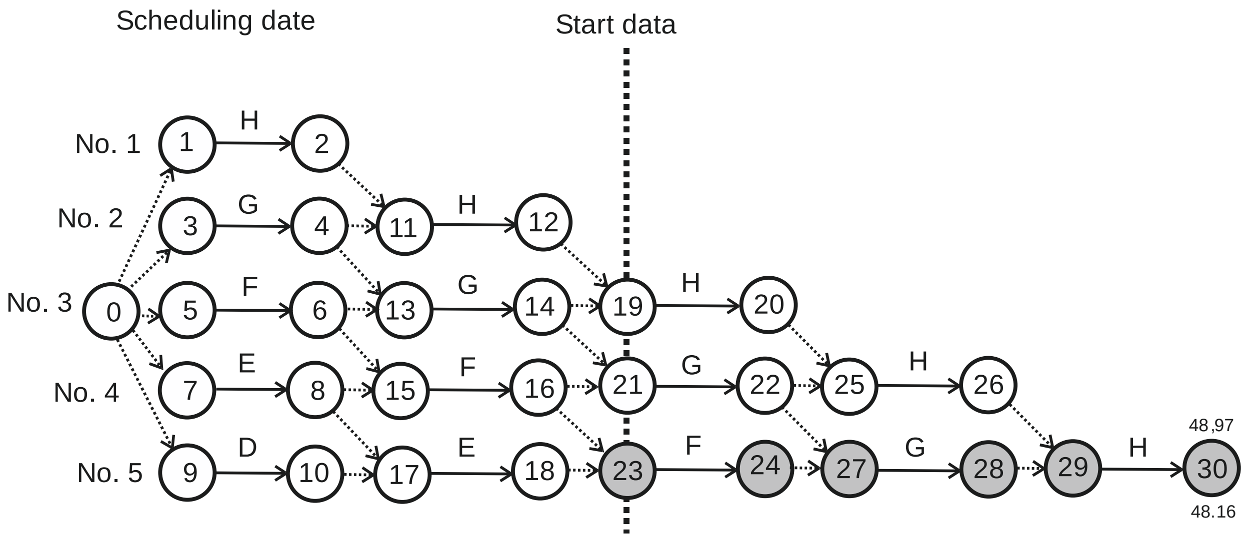

Figure 5. Network of a flow of works

The stochastic parameters of the events network of a flow of works were calculated by the universal method (Table 1).

Table 1. Stochastic parameters of events

# an of event	20 equiprobable values time, shift																				P(t)=0.25	P(t)=0.5	P(t)=0.75
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5.13	5.38	5.65	5.92	6.20	6.49	6.78	7.09	7.42	7.75	8.11	8.48	8.88	9.30	9.76	10.26	10.82	11.46	12.26	13.42	6.34	8.33	10.01
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	5.13	5.38	5.65	5.92	6.20	6.49	6.78	7.09	7.42	7.75	8.11	8.48	8.88	9.30	9.76	10.26	10.82	11.46	12.26	13.42	6.34	8.33	10.01
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	5.13	5.38	5.65	5.92	6.20	6.49	6.78	7.09	7.42	7.75	8.11	8.48	8.88	9.30	9.76	10.26	10.82	11.46	12.26	13.42	6.34	8.33	10.01
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	5.13	5.38	5.65	5.92	6.20	6.49	6.78	7.09	7.42	7.75	8.11	8.48	8.88	9.30	9.76	10.26	10.82	11.46	12.26	13.42	6.34	8.33	10.01
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	5.13	5.38	5.65	5.92	6.20	6.49	6.78	7.09	7.42	7.75	8.11	8.48	8.88	9.30	9.76	10.26	10.82	11.46	12.26	13.42	6.34	8.33	10.01
11	5.79	6.47	6.95	7.35	7.74	8.11	8.46	8.80	9.11	9.39	9.76	10.13	10.37	10.82	11.17	11.46	12.10	12.26	13.36	13.42	7.92	9.65	11.32
12	12.18	13.43	14.20	14.82	15.37	15.86	16.34	16.76	17.22	17.63	18.06	18.50	18.93	19.38	19.87	20.44	21.07	21.85	22.88	24.77	15.61	17.98	20.15
13	5.79	6.47	6.95	7.35	7.74	8.11	8.46	8.80	9.11	9.39	9.76	10.13	10.37	10.82	11.17	11.46	12.10	12.26	13.36	13.42	7.92	9.65	11.32
14	12.18	13.43	14.20	14.82	15.37	15.86	16.34	16.76	17.22	17.63	18.06	18.50	18.93	19.38	19.87	20.44	21.07	21.85	22.88	24.77	15.61	17.98	20.15
15	5.79	6.47	6.95	7.35	7.74	8.11	8.46	8.80	9.11	9.39	9.76	10.13	10.37	10.82	11.17	11.46	12.10	12.26	13.36	13.42	7.92	9.65	11.32
16	12.18	13.43	14.20	14.82	15.37	15.86	16.34	16.76	17.22	17.63	18.06	18.50	18.93	19.38	19.87	20.44	21.07	21.85	22.88	24.77	15.61	17.98	20.15

# an of event	20 equiprobable values time, shift																				P(t)=0.25	P(t)=0.5	P(t)=0.75
17	5.79	6.47	6.95	7.35	7.74	8.11	8.46	8.80	9.11	9.39	9.76	10.13	10.37	10.82	11.17	11.46	12.10	12.26	13.36	13.42	7.92	9.65	11.32
18	12.18	13.43	14.20	14.82	15.37	15.86	16.34	16.76	17.22	17.63	18.06	18.50	18.93	19.38	19.87	20.44	21.07	21.85	22.88	24.77	15.61	17.98	20.15
19	14.43	15.83	16.57	17.12	17.61	18.06	18.48	18.85	19.18	19.48	19.87	20.29	20.56	21.07	21.50	21.85	22.67	22.88	24.67	24.77	17.84	19.79	21.68
20	21.30	23.00	23.94	24.64	25.25	25.79	26.31	26.79	27.26	27.77	28.19	28.69	29.21	29.78	30.30	30.89	31.57	32.41	33.52	35.70	25.52	28.12	30.59
21	14.43	15.83	16.57	17.12	17.61	18.06	18.48	18.85	19.18	19.48	19.87	20.29	20.56	21.07	21.50	21.85	22.67	22.88	24.67	24.77	17.84	19.79	21.68
22	21.30	23.00	23.94	24.64	25.25	25.79	26.31	26.79	27.26	27.77	28.19	28.69	29.21	29.78	30.30	30.89	31.57	32.41	33.52	35.70	25.52	28.12	30.59
23	14.43	15.83	16.57	17.12	17.61	18.06	18.48	18.85	19.18	19.48	19.87	20.29	20.56	21.07	21.50	21.85	22.67	22.88	24.67	24.77	17.84	19.79	21.68
24	21.30	23.00	23.94	24.64	25.25	25.79	26.31	26.79	27.26	27.77	28.19	28.69	29.21	29.78	30.30	30.89	31.57	32.41	33.52	35.70	25.52	28.12	30.59
25	24.17	25.76	26.58	27.17	27.74	28.19	28.66	29.11	29.52	29.88	30.30	30.74	31.03	31.57	32.03	32.41	33.30	33.52	35.60	35.70	27.97	30.15	32.22
26	31.15	32.99	34.00	34.78	35.44	36.03	36.57	37.11	37.59	38.10	38.61	39.09	39.63	40.23	40.84	41.47	42.16	43.03	44.21	46.50	35.74	38.48	41.15
27	24.17	25.76	26.58	27.17	27.74	28.19	28.66	29.11	29.52	29.88	30.30	30.74	31.03	31.57	32.03	32.41	33.30	33.52	35.60	35.70	27.97	30.15	32.22
28	31.15	32.99	34.00	34.78	35.44	36.03	36.57	37.11	37.59	38.10	38.61	39.09	39.63	40.23	40.84	41.47	42.16	43.03	44.21	46.50	35.74	38.48	41.15
29	34.27	35.99	36.86	37.50	38.07	38.61	39.06	39.52	39.96	40.35	40.84	41.31	41.60	42.16	42.64	43.03	43.98	44.21	46.39	46.50	38.34	40.64	42.83
30	41.32	43.26	44.32	45.13	45.82	46.45	47.01	47.56	48.08	48.58	49.13	49.62	50.17	50.78	51.44	52.09	52.79	53.69	54.90	57.25	46.14	48.97	51.76

When modeling Monte Carlo's method has carried out 10000 realizations. The mean duration of completion times for the 30th event was equal to 48.16 shifts.

The distributions of completion times for the 30th event are presented in Figure 6.

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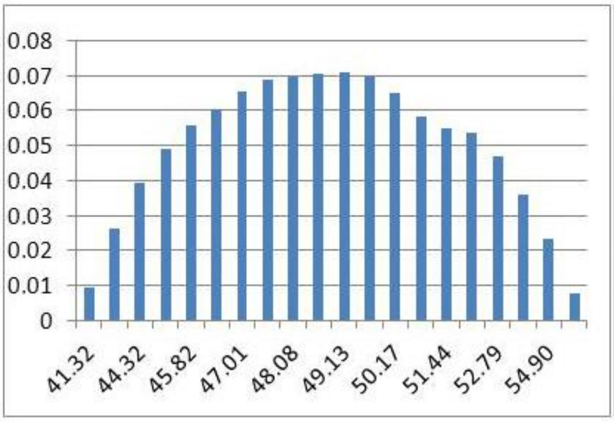

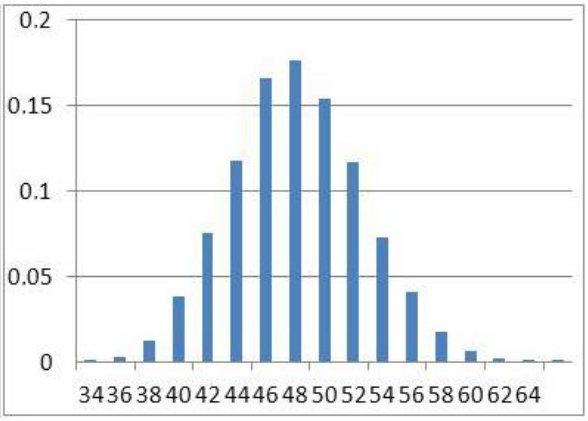

a) Universal method **b) Monte Carlo's method**

Figure 6. Distributions of completion times (for the 30th event)

Comparison of the two distributions shows their proximity.

Somewhat compressed laterally, the histogram of the density distribution for a universal method is due to rounding of extreme values at each calculation step. In addition, the interval values on the axis X are different.

The length of the chain (9-10-17-18-23-24-27-28-29-30) is the sum of the mean durations. It is 41.65 shifts.

The length of the chain 23-24-27-28-29 (Fig. 1) is 16.66 shifts. The mean duration of completion times was equal to 19.79 shifts (Table 1).

Thus the mean duration of completion times of the chain of activities is underestimated by 15-20%.

Similar results have also been observed when using the other techniques. Completion times with the traditional method are perceptibly shorter than completion times calculated with the Monte Carlo method and universal method [19, 23, 24, 28].

Conclusions

1. The actual duration of various construction projects significantly exceeds the scheduled durations. Firstly, numerous stochastic factors impact on the works. The second reason is insufficiently reliability of traditional scheduling methods. Finally, the third reason is quasi-activities that were not included in the schedule. As a result, the traditional method of calculating the time to complete a project is almost always too short.

2. The essence of the impact of quasi-activities on the completion times presented.

The crews to the planned date of the beginning of their work usually always busy at the previous objects (work areas), which causes additional resource links. In addition, in this case, there are additional (implicit) object links caused by the necessity of preparing the objects for the crews. Quasi-activities are works of crews outside of the schedule and causing an implicit resource and object links to the events of the schedule.

The presented model of the chain of activities is equivalent to the model of a flow of works with multiple critical paths and was calculated in a similar way.

3. The model of a flow of works with the Beta distribution of duration was calculated by the universal method and Monte Carlo's method (10000 realizations). Comparison of the two distributions of completion times shows their proximity.

The calculation showed that the mean duration of completion times of the chain of activities is underestimated by 15-20 %. With a probability of 0.75, the completion times will exceed the scheduled durations on 24 %.

4. These results show the efficacy of the offered method to calculate more realistic of completion times. Implementation of this method will allow for the determination of a more precise duration for the performance of complex works at the planning stage. The suggested method can be recommended for

use by construction project managers in order to prevent a potential failure of project completion deadlines.

References

1. Afanasyev V., Afanasyev A. *Potochnaya organizatsiya rabot v stroitelstve* [Flowing organization works in construction]. Saint-Petersburg: SPbGASU. 2000.169 p. (rus)
2. Bolotin S., Birjukov A. Time Management in Drafting Probability Schedules for Construction Work. *World Applied Sciences Journal.* 2013. Vol. 23. No.13. Pp. 1-4.
3. Bovteev S.V., Kanyukova S.V. Development of methodology for time management of construction projects *Magazine of Civil Engineering*. 2016. No. 2. Pp. 102-112.
4. Sadi A., Sadiq A. Causes of delay in large construction projects. *Journal Project Management.* 2006. No. 24(4). Pp. 349-357.
5. Simankina T., Sergeenkova O. Resource optimization of construction on a basis of the frontal and rhythmical stream. *Applied Mechanics and Materials.* 2015. Vols. 725-726. Pp. 984-989.
6. Simankina T.S. *Sovershenstvovaniye kalendarnogo planirovaniya resursosberegayushchikh potokov s uchetom additivnosti intensivnosti truda ispolniteley: diss. na soisk. uchen. step. k. t. n.: Spets. 05.23.08.* [Improvement of scheduling of resource-saving streams taking into account additivity of intensity of work of performers. Cand. Tech. sci. diss.] Saint-Petersburg: 2007. 156 p. (rus)
7. Kurochka P.I. *Razrabotka modeley i mekhanizmov organizatsionno-tekhnologicheskogo proyektirovaniya stroitelnogo proizvodstva: diss. na soisk. uchen. step. d. t. n.: Spets. 05.23.08.* [Development of models and mechanisms of organizational and technological design of construction production. Doc. Tech. sci. diss.] Voronezh: 2004. 324 p. (rus)
8. Trauner T., Manginelli W., Lowe J., Nagata M., Furniss B. Construction delays: understanding them clearly and delay analysis in construction analyzing them correctly. London, UK: Elsevier Inc. 2009. 288 p.
9. Romanovich M.A. *Povysheniye organizatsionno-tekhnologicheskoy nadezhnosti monolitnogo domostroyeniya na osnove modelirovaniya parametrov kalendarnogo plana: diss. na soisk. uchen. step. k. t. n.: Spets. 05.23.08.* [Increase in organizational and technological reliability of monolithic housing construction on the basis of modeling of parameters of the planned schedule. Cand. Tech. sci. diss] Saint-Petersburg: 2015. 194 p. (rus)
10. Kalugin Ju.B. Modelirovanie vozdeistviya destabiliziruyushchikh faktorov na tekhnologicheskii kompleks [Modeling of destabilizing factors of the technological complex]. *News of Higher Educational Institutions. Construction.* 2013. No. 7. Pp. 93–102. (rus)
11. Kalugin Ju.B. Osobennosti i sushchnost rascheta veroyatnostnykh vremennykh parametrov otdelnoy raboty (tekhnologicheskogo protsessa) [Features and essence of calculation of probabilistic temporary for work (technological process]. *News of Higher Educational Institutions. Construction.* 2013. No. 8. Pp. 104–109. (rus)
12. Golenko-Ginzburg D.I. *Stokhasticheskie setevye modeli planirovaniya i upravleniya razrabotkami* [Stochastic models of network planning and management development]. Voronezh: Science Book. 2010. 284 p. (rus)
13. Golenko-Ginzburg D. On the Distribution of Activity Time in PERT. *Journal of the Operational Research Society.* 1988. Vol. 39. No. 8. Pp. 767-771.
14. Maltsev Y. *Ekonomiko-matematicheskie metody proektirovaniya transportnykh sooruzhenii* [Economic-mathematical methods of design of transport objects]. Moscow: Academia. 2010. 320 p. (rus)
15. Miller R. *Schedule, Cost and Profit Control with PERT*.

Литература

1. Афанасьев В.А., Афанасьев А.В. Поточная организация работ в строительстве. СПб:СПбГАСУ. 169 с.
2. Bolotin S., Birjukov A. Time management in drafting probability schedules for construction work // World Applied Sciences Journal. 2013. Vol. 23. № 13. Pp. 1-4.
3. Бовтеев С.В., Канюкова С.В. Развитие методики контроля сроков инвестиционно-строительного проекта // Инженерно-строительный журнал. 2016. № 2(62). С. 102-112.
4. Sadi A., Sadiq A. Causes of delay in large construction projects // Journal Project Management. 2006. № 24(4). Pp. 349-357.
5. Simankina T., Sergeenkova O. Resource optimization of construction on a basis of the frontal and rhythmical stream // Applied Mechanics and Materials. 2015. Vols. 725-726. Pp. 984-989.
6. Симанкина Т.С. Совершенствование календарного планирования ресурсосберегающих потоков с учетом аддитивности интенсивности труда исполнителей: дисс. на соиск. учен. степ. к. т. н.: Спец. 05.23.08. СПб: 2007. 156 с.
7. Курочка П.И. Разработка моделей и механизмов организационно-технологического проектирования строительного производства: дисс. на соиск. учен. степ. д. т. н.: Спец. 05.23.08. Воронеж: 2004. 324 с.
8. Trauner T., Manginelli W., Lowe J., Nagata M., Furniss B. Construction Delays: Understanding them Clearly and Delay Analysis in Construction Analyzing them Correctly. London, UK: Elsevier Inc. 2009. 288 p.
9. Романович М.А. Повышение организационно-технологической надежности монолитного домостроения на основе моделирования параметров календарного плана: дисс. на соиск. учен. степ. к. т. н.: Спец. 05.23.08. СПб: 2015. 194 с.
10. Калугин Ю.Б. Моделирование воздействия дестабилизирующих факторов на технологический комплекс // Известия вузов. Строительство. 2013. № 7. С. 93-102.
11. Калугин Ю.Б. Особенности и сущность расчета вероятностных временных параметров отдельной работы (технологического процесса) // Известия вузов. Строительство. 2013. № 8. С. 104-109.
12. Голенко-Гинзбург Д.И. Стохастические сетевые модели планирования и управления разработками. Воронеж: Научная книга. 2010. 284 с.
13. Golenko-Ginzburg D. On the Distribution of Activity Time in PERT // Journal of the Operational Research Society. 1988. Vol. 39. № 8. Pp. 767-771.
14. Мальцев Ю.А. Экономико-математические методы проектирования транспортных сооружений. М.: Академия. 2010. 320 с.
15. Miller R. Schedule, Cost and Profit Control with PERT. McGraw-Hill. 1963. 58 p.
16. Руководство по разработке и применению вероятностных сетевых моделей в строительстве. М.: ЦНИПИАСС. 1979. 56 с.
17. A Guide to the Project Management Body of Knowledge. Project Management Institute. 2008. 506 p.
18. Birrell G. Construction planning beyond the critical path // J. Constr. Div. ASCE. 1980. Vol. 106(3). Pp. 389–407.
19. Голенко Д.И. Статистические методы сетевого планирования и управления. М.: Наука. 1968. 400 с.
20. Mubarak S. Construction Project Scheduling and Control. Second Edition. New Jersey. Hoboken: John Wiley & Sons, Inc. 2010. 479 p.

McGraw-Hill. 1963. 58 p.

16. *Rukovodstvo po razrabotke i primeneniyu veroyatnostnykh setevykh modelei v stroitel'stve* [Guidelines for the development and application of probabilistic network models in construction]. Moscow: TsNIPIASS. 1979. 56 p. (rus)
17. *A Guide to the Project Management Body of Knowledge.* Project Management Institute. 2008. 506 p.
18. Birrell G. Construction planning beyond the critical path. *J. Constr. Div. ASCE.* 1980. No. 106(3). Pp. 389–407.
19. Golenko D.I. *Statisticheskie metody setevogo planirovaniya i upravleniya* [Statistical methods of network planning and management]. Moscow: Science. 1968. 400 p. (rus)
20. Mubarak S. *Construction Project Scheduling and Control.* Second Edition. New Jersey. Hoboken: John Wiley & Sons, Inc. 2010. 479 p.
21. Oleinikova S.A. Kriticheskii analiz metoda PERT resheniya zadachi upravleniya proektami so sluchainoi dlitel'nost'yu vypolneniya rabot [Critical analysis of the PERT method for solving the problem of project management with random duration of the work]. *Control Systems and Information Technology.* 2013. Vol. 51. No 1. Pp. 20-24. (rus)
22. Klingel A. Bias in PERT completion times calculations for a real network. *Management Science.* 1966. Vol. 13(4). Pp. 476-489.
23. Schonberger R. Why projects are always late: a rationale based on manual simulation of a PERT/CPM network. *Interfaces.* 1981. Vol. 11(5). Pp. 66-70.
24. Kalugin Ju.B. Universal method for calculation of reliable completion times. *Magazine of Civil Engineering*. 2016. No. 7, Pp. 70-80.
25. Haga W., O'Keefe T. Crashing PERT Networks: A Simulation Approach. *Proc. of the 4th International conference of the Academy of Business and Administrative Sciences Conference.* Quebec City, Canada. 2001.
26. Burt J., Garman M. Conditional Monte Carlo: A simulation technique for stochastic network analysis. *Management Science*. 1971. No. 18(3). Pp. 207-217.
27. Van Slyke R. Monte Carlo methods and the PERT problem. *Operations Research.* 1963. Vol. 13. Pp. 141-143.
28. Kalugin Ju.B. Prognozirovanie srokov realizatsii proekta s pomoshchyu modeli kvaziparallelnykh rabot [Predicting the timing of the project with the help of a model quasi-parallel processes]. *News of Higher Educational Institutions. Construction.* 2011. No. 3. Pp. 45–51. (rus)

21. Олейникова С.А. Критический анализ метода PERT решения задачи управления проектами со случайной длительностью выполнения работ// Системы управления и информационные технологии. 2013. Т. 51. № 1. С. 20-24.
22. Klingel A. Bias in PERT completion times calculations for a real network // Management Science. 1966. Vol. 13(4). Pp. 476-489.
23. Schonberger R. Why projects are always late: a rationale based on manual simulation of a PERT/CPM network // Interfaces. 1981. Vol. 11(5). Pp. 66-70.
24. Калугин Ю.Б. Универсальный метод вычисления достоверных сроков реализации проекта. // Инженерно-строительный журнал. 2016. № 7. С. 70-80.
25. Haga W., O'Keefe T. Crashing PERT Networks: A Simulation Approach // Proc. of the 4th International conference of the Academy of Business and Administrative Sciences Conference. Quebec City, Canada, 2001.
26. Burt, J., Garman M. Conditional Monte Carlo: A simulation technique for stochastic network analysis // Management Science. 1971. № 18(3). Pp. 207-217.
27. Van Slyke R. Monte Carlo methods and the PERT problem // Operations Research. 1963. Vol. 13. Pp. 141-143.
28. Калугин Ю.Б. Прогнозирование сроков реализации проекта с помощью модели квазипараллельных работ// Известия вузов. Строительство. 2011. № 3. С. 45-51.

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Калугин Ю.Б. Причины отставаний строительных проектов // Инженерно-строительный журнал. 2017. № 6(74). С. 61–69.