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Research paper

The possible impact of employee absenteeism risk on a construction project

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Abstract: Worker absenteeism is identified as the greatest threat to not meeting the completion date of a construction project. The purpose of this paper is to quantify the impact of employee absenteeism risk on the probabilistic lead time of a construction project. Calculations of employee absenteeism risk values were performed using data from the Central Statistical Office (Big Data). Probabilistic schedules with probability density functions (Normal, Exponential, Reyleigh, Triangle, Gamma, Cauchy) with and without calculated employee absenteeism risk were prepared. Student's t-test and MAPE analysis of mean absolute percentage errors were performed to determine differences between groups. It was found that with respect to the probability of completing the task in the range of 75 to 95% for all functions, an unacceptable MAPE error of 32.82% to 69.23% arises. Therefore, the authors postulate that the risk of worker absenteeism should be considered in every construction process when performing probabilistic scheduling, i.e., in the Building Information Modeling BIM methodology.

Keywords: absenteeism, BIM, construction process, risk, time

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1. Introduction

The construction industry is burdened with a very high risk related to the employment of qualified workers, and consequently their absence from work. 2020 is the year of the emergence of the infectious disease COVID-19 in the world, which was recognized by the World Health Organization as a pandemic on March 11, 2020. According to the 2020 Sickness Absence Report of the Department of Statistics and Actuarial Forecasts of March 2020, the disease caused an increase in the number of sickness absence days of employees by 4.4% compared to 2019 [20, 21, 24]. Sickness absenteeism can be caused by: employee's own illness, caring for a child, caring for other family members, quarantine related to COVID-19. Frequent absenteeism caused by illness not only results in additional costs for employers, but also forces constant changes in the organization of work. Problems in the transport and communication sector are also significant for the construction industry. The lack of deliveries on time and the reduced mobility of transport companies prevent the implementation of a number of construction projects, where the necessary materials and equipment to carry out subsequent works on a given site are missing. According to the Polish Association of Construction Employers and the Polish Chamber of Commerce for Road Construction, it significantly reduces the construction production capacity and will affect the timeliness of contractors who will not be able to meet the previously agreed commissioning periods. However, regardless of the external and internal situation, it is necessary to prepare work schedules, taking into account a very important factor of the risk of absenteeism. The article quantifies the risk of absenteeism of construction workers in order not only to introduce this value to the schedules in a probabilistic approach but also to determine the impact on the duration of construction processes under the assumptions of various distributions of the probability density function.

2. Quantification of employee absenteeism

The quantification of employee absenteeism was performed on the basis of the data (BIG DATA) of the Central Statistical Office in Poland (CSO) for the construction industry. The data of the Central Statistical Office include only construction companies employing more than 8 employees. The number of people employed in construction in thousands is 363.3 (2015), 376.6 (2016), 390.5 (2017), 398.7 (2018), 393.3 (2019)). In fact, the number of construction workers is estimated at around 1.3 million. Due to the lack of data on absenteeism of employees in enterprises with fewer than 8 employees, CSO data was used for the calculations.

According to the 2020 Department of Statistics and Actuarial Forecasting (DSAF) Report, the disease caused an increase in the number of days of sickness absence by 4.4% compared to 2019. Due to the lack of data from the Central Statistical Office for 2020, an increase in absenteeism in the construction industry was assumed in accordance with the DSAF data. Therefore, it should be assumed that absenteeism in the construction industry in 2020 is 26.06% + 4.40% = 30.46%.

Table 1. Summary of data and calculations of employee absenteeism in the construction industry

Year	The average length of sickness absence in a year patient's own disease	Average length of holiday absenteeism per year	The sum of the number of days of absence in a year	Number of working days in a year	Absence from work %
	[days]	[days]	[days]	[days]	[%]
2015	41.00	26	67.00	252	26.59
2016	41.22	26	67.22	258	26.05
2017	39.98	26	65.98	250	26.39
2018	38.40	26	64.40	250	25.76
2019	37.97	26	63.97	251	25.49
Average	39.714	26	65.714	252.2	26.06

3. Reasons for absenteeism in the construction industry

Working in the construction industry is one of the hardest types of work. Employees must meet the following requirements: physical (fatigue, noise, temperature), mental (high precision, monotony, a multitude of duties), emotional (negative emotions, quarrels, misunderstandings). Employees are exposed to difficult working conditions, negative emotions and negative assessment of the manager. Actions can be taken to reduce the absenteeism of employees [3,4,6,15,17–19] by ensuring good working conditions, motivating employees, clearly defining professional duties and understanding the meaning of work, generating positive emotions by receiving accurate feedback, allowing certain autonomy in decision-making, and others. The basic factors causing the increase and decrease in employee absenteeism in the construction industry are shown in Figure 1.

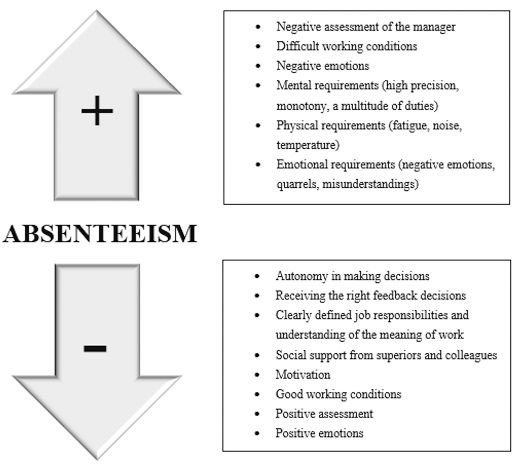


Fig. 1. Basic factors causing the increase and decrease in employee absenteeism in the construction industry

4. Probabilistic scheduling

The construction project consisting of 6 processes P1, P2, P3, P4, P5 and P6, arranged as in Fig. 3, was analyzed. The minimum, average and maximum times, as well as the project implementation time, are presented in Fig. 2. The Risky Project Professional program was used for the calculations.

	Task Name	Low Dur	Base Dur	High Dur	Risks	Start	Finish	Resource	Predecessors
1	**Building**		**38 days**		**0**	**04/21/21 08:00**	**06/11/21 17:00**		
2	P1	13 days	13 days	16 days	0	04/21/21 08:00	05/07/21 17:00	B1	
3	P2	9 days	10 days	14 days	0	05/10/21 08:00	05/21/21 17:00	B2	2
4	P3	10 days	15 days	22 days	0	05/24/21 08:00	06/11/21 17:00	B3	3
5	P4	6 days	10 days	16 days	0	05/14/21 08:00	05/27/21 17:00	B4	2+4 days
6	P5	8 days	12 days	18 days	0	05/20/21 08:00	06/04/21 17:00	B5	2+8 days
7	P6	3 days	5 days	7 days	0	05/11/21 08:00	05/17/21 17:00	B6	2+1 day
8	STOP	0 days	0 days	0 days	0	06/11/21 17:00	06/11/21 17:00		3;4;5;6;7

Fig. 2. List of minimum, average and maximum times as well as the duration of the project

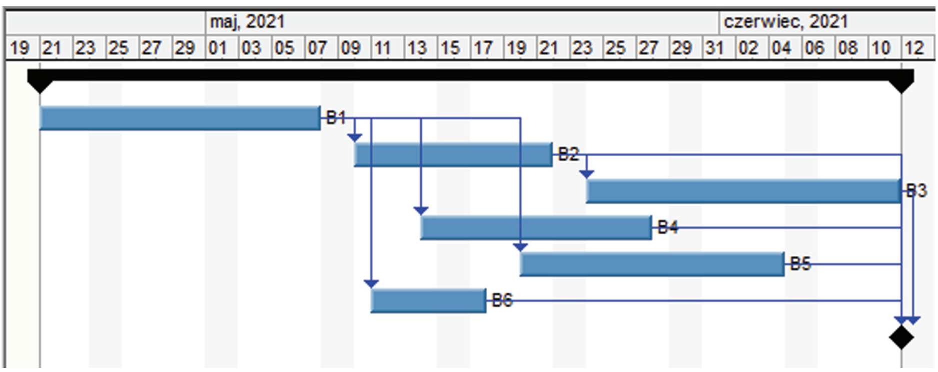


Fig. 3. Schedule the project construction implementation consisting of 6 processes P1, P2, P3, P4, P5 and P6 in terms of discrete distribution

In the first stage of calculations, only probability density distributions will be assigned to individual processes and according to [14] the following distributions were selected: gamma, Cauchy, exponential, Rayleigh, triangular and normal. In the second stage, each process was given the risk of employee absenteeism with the value calculated in the second point of the article equal to 30.46%. The results of the calculations will be used to analyze the impact of the risk of absenteeism on the probabilistic completion time of the construction project.

The course of calculations is presented on the example of the normal distribution of the probability density function. Analogous calculations were made for the remaining functions being tested.

In turn, each of the processes was given a normal distribution (Fig. 4). After performing the Monte Carlo calculations, a probabilistic Gantt chart was obtained (Fig. 4), together with the results of the calculations (Fig. 5). Next, the probabilities of completing the construction project were calculated (normal distributions of individual processes). The probabilities were counted from 5% to 95% at intervals – every 5%. The results are shown in Fig. 6.

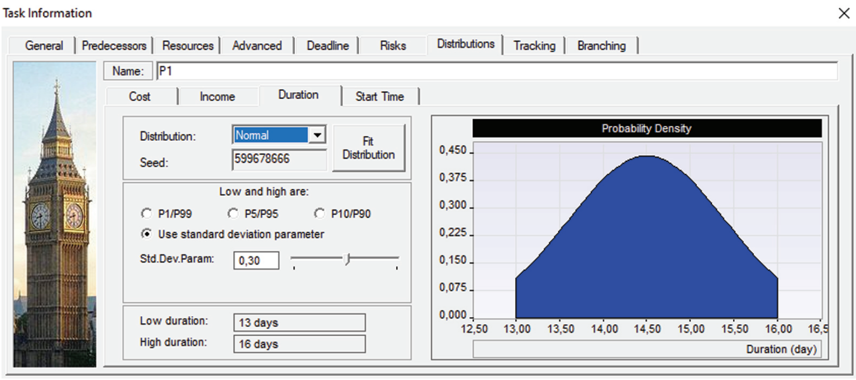


Fig. 4. Information about the P1 process – giving a normal probability distribution

	Task Name	Low Dur	Base Dur	High Dur	Low Dur	Mean Dur	High Dur	Distrib.,Dur
1	**Building**		**38 days**		**37,96 days**	**43 days**	**46,33 days**	**Undefined**
2	P1	13 days	13 days	16 days	13,58 days	4,51 day	15,45 days	Normal
3	P2	9 days	10 days	14 days	10,7 days	1,49 day	12,4 days	Normal
4	P3	10 days	15 days	22 days	13,41 days	6,83 day	18,48 days	Normal
5	P4	6 days	10 days	16 days	8,64 days	11 days	13,66 days	Normal
6	P5	8 days	12 days	18 days	10,85 days	13 days	15,78 days	Normal
7	P6	3 days	5 days	7 days	4,36 days	4,96 days	5,48 days	Normal
8	STOP	0 days	0 days	0 days	0 days	0 days	0 days	Undefined

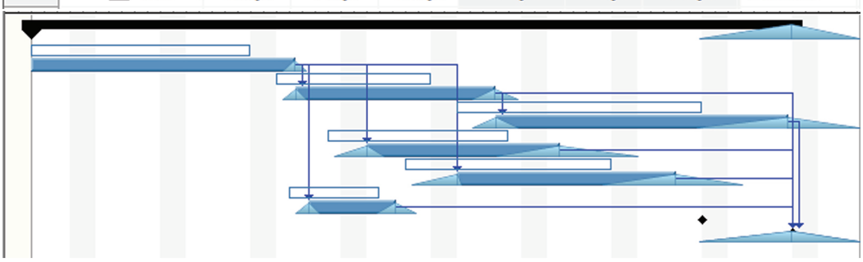
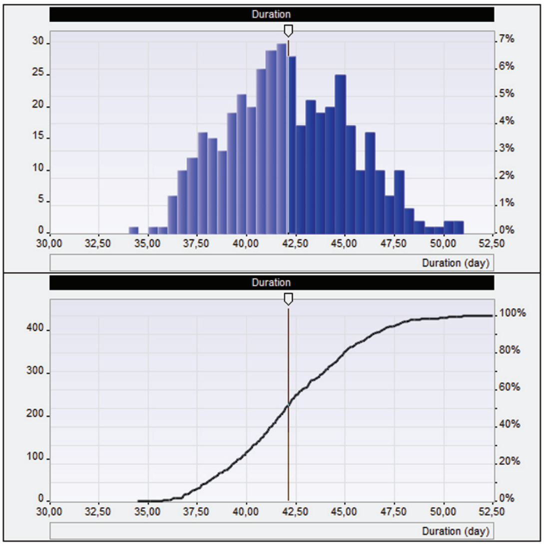


Fig. 5. A probabilistic schedule in the form of a Gantt chart for a normal distribution with no risk of absenteeism

Then, the absenteeism risk of 30.46% was introduced to each process. The probabilistic schedule for the normal distribution of risk-assigned processes is shown in Fig. 7.



5th Percentile	37,11 days
10th Percentile	37,96 days
15th Percentile	38,57 days
20th Percentile	39,25 days
25th Percentile	39,85 days
30th Percentile	40,27 days
35th Percentile	40,82 days
40th Percentile	41,15 days
45th Percentile	41,58 days
50th Percentile	41,96 days
55th Percentile	42,27 days
60th Percentile	42,77 days
65th Percentile	43,24 days
70th Percentile	43,9 days
75th Percentile	44,46 days
80th Percentile	44,91 days
85th Percentile	45,5 days
90th Percentile	46,33 days
95th Percentile	47,5 days

Fig. 6. Compilation of construction project completion time probabilities for normal distributions of the probability density functions of P1–P6 processes

	Task Name	Low Dur	Base Dur	High Dur	Low Dur	Mean Dur	High Dur
1	Building		38 days		38,47 days	48 days	68,03 days
2	P1	13 days	13 days	16 days	13,71 days	17 days	23,28 days
3	P2	9 days	10 days	14 days	10,66 days	12 days	18,28 days
4	P3	10 days	15 days	22 days	13,92 days	19 days	26,47 days
5	P4	6 days	10 days	16 days	8,95 days	12 days	18,53 days
6	P5	8 days	12 days	18 days	11,03 days	15 days	21,23 days
7	P6	3 days	5 days	7 days	4,55 days	5 days	8,39 days
8	STOP	0 days	0 days	0 days	0 days	0 days	0 days

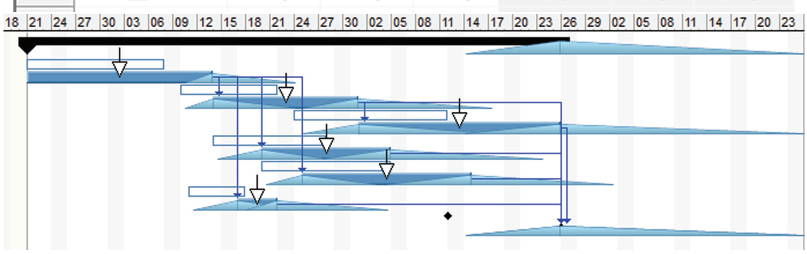


Fig. 7. Probabilistic schedule in the form of a Gantt chart for normal distribution with the assigned risk of absenteeism

The probabilities of completing the construction project were calculated (normal distributions of individual processes, risk of absenteeism 30.46%). The probabilities were counted from 5% to 95% at intervals – every 5% [23]. The results are shown in Figure 8.

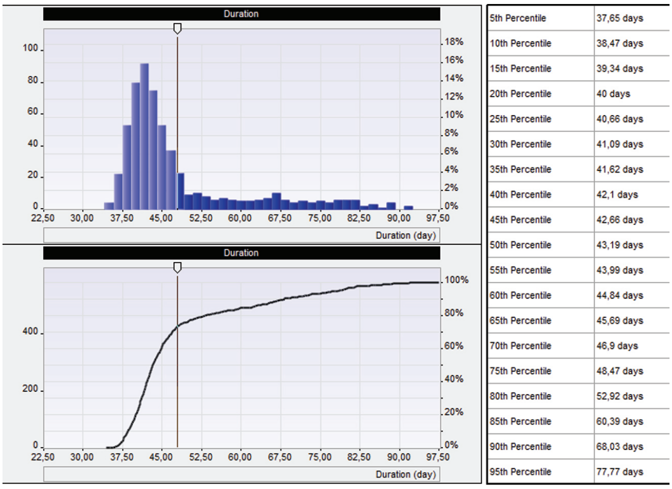


Fig. 8. Summary of the probabilities of the completion time of a construction project for the normal distributions of the probability density functions of the P1–P6 processes with the assigned risk of 30.46% absenteeism

Analogous calculations were performed [22] for the remaining five selected probability density distributions (gamma, Cauchy, exponential, Rayleigh, triangular). The calculation results are presented in Table 2.

Table 2. Summary of construction project completion times with reference to probability density distribution and the risk of absenteeism

Probability of task completion [%]	Normal		Gamma		Cauchy	
	Without risk	With risk	Without risk	With risk	Without risk	With risk
5	37.11	37.65	32.01	37.46	32.76	37.50
10	37.96	38.47	32.01	38.34	33.00	38.41
15	38.57	39.34	32.01	39.22	33.24	39.04
20	39.25	40.00	32.02	39.82	33.45	39.72
25	39.85	40.66	32.03	40.36	33.64	40.45
30	40.27	41.09	32.05	41.07	33.81	41.08
35	40.82	41.62	32.09	41.68	34.09	41.49
40	41.15	42.10	32.12	42.14	34.31	41.98
45	41.58	42.66	32.20	42.83	34.55	42.68
50	41.96	43.19	32.29	43.79	34.83	43.06

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Table 2 [cont.]

Probability of task completion [%]	Normal		Gamma		Cauchy	
	Without risk	With risk	Without risk	With risk	Without risk	With risk
55	42.27	43.99	32.43	44.34	35.03	43.88
60	42.77	44.84	32.57	44.95	35.20	44.63
65	43.24	45.69	32.85	45.80	35.65	45.75
70	43.90	46.90	33.18	46.75	36.11	46.51
75	44.46	48.47	33.59	48.44	36.47	47.40
80	44.91	52.92	33.83	51.85	36.85	51.48
85	45.50	60.39	34.67	59.67	37.35	60.94
90	46.33	68.03	38.22	69.35	38.22	67.71
95	47.50	77.77	40.27	78.58	40.27	75.61
Probability of task completion [%]	Exponential		Rayleigh		Triangular	
	Without risk	With risk	Without risk	With risk	Without risk	With risk
5	36.92	37.50	36.92	37.50	37.11	37.65
10	37.89	38.41	37.89	38.41	37.96	38.47
15	38.50	39.04	38.50	39.04	38.57	39.34
20	39.05	39.72	39.05	39.72	39.25	40
25	39.55	40.45	39.55	40.45	39.85	40.66
30	40.02	41.08	40.02	41.08	40.27	41.09
35	40.64	41.49	40.64	41.49	40.82	41.62
40	41.09	41.98	41.09	41.98	41.15	42.10
45	41.47	42.68	41.47	42.68	41.58	42.66
50	41.91	43.06	41.91	43.06	41.96	43.19
55	42.30	43.88	42.30	43.88	42.27	43.99
60	42.83	44.63	42.83	44.63	42.77	44.84
65	43.19	45.75	43.19	45.75	43.24	45.69
70	43.67	46.51	43.67	46.51	43.90	46.90
75	44.06	47.40	44.06	47.40	44.46	48.47
80	44.80	51.48	44.80	51.48	44.91	52.92
85	45.55	60.94	45.55	60.94	45.50	60.39
90	46.14	67.71	46.14	67.71	46.33	68.03
95	46.94	75.61	46.94	75.61	47.50	77.77

5. Results analysis and conclusions

In order to determine the statistical significance of the differences between the groups, a t-test was performed, assuming a 5% probability of making an error in evaluation (p = 0.05) and the number of freedom equal to 15. The number of degrees of freedom is the number of independent observation results minus the number of relations linking these results with each other. In the analyzed case, the number of relations connecting the results is 4 and they are: the minimum, average and maximum time from the deterministic schedule and the value of the assigned risk of employee absenteeism – 30.46%. The number of independent results equals 19 – the number of analyzed probabilities of completing the construction project. The t-test critical value for probabilities of 0.05 and 15 degrees of freedom is 2.131. If the absolute value of the t-test is above 2.131, it will mean that the hypothesis of equality of variables cannot be accepted – the variables will differ [1, 16]. Table 3 shows the results of the t-test significance test. The obtained results of the t-test show that the groups with Gamma and Cauchy distributions differ statistically significantly from each other and from other distributions. On the basis of the test, it was found that the groups with the assigned risk did not differ from each other. This indicates the dominant nature of the factor risk of absenteeism in relation to the variable process time probability density function. Fig. 9 shows the calculations of completion times of the construction project in terms of the probability density distribution and the risk of absenteeism.

Table 3. Values of the t coefficient of t-test for the process completion times

t	Gama	Cauchy	Exponential	Normal	Rayleigh	Triangular	Gama + Risk	Cauchy + Risk	Exponential + Risk	Normal + Risk	Rayleigh + Risk	Triangular + Risk
Gama	0.00	**2.79**	**10.32**	**10.43**	**10.32**	**10.43**	**5.44**	**5.56**	**5.56**	**5.54**	**5.56**	**5.53**
Cauchy	**2.79**	0.00	**8.43**	**8.55**	**8.43**	**8.55**	**4.72**	**4.80**	**4.80**	**4.79**	**4.80**	**4.79**
Exponential	**10.32**	**8.43**	0.00	0.16	0.00	0.16	2.03	1.98	1.98	2.06	1.98	2.06
Normal	**10.43**	**8.55**	0.16	0.00	0.16	0.00	1.97	1.92	1.92	1.99	1.92	1.99
Rayleigh	**10.32**	**8.40**	0.00	0.16	0.00	0.16	2.03	1.98	1.98	2.06	1.98	2.06
Triangular	**10.43**	**8.55**	0.16	0.00	0.16	0.00	1.97	1.92	1.92	1.99	1.92	1.99
Gama + Risk	**5.44**	**4.72**	2.03	1.97	2.03	1.97	0.00	0.10	0.10	0.00	0.10	0.00
Cauchy + Risk	**5.56**	**4.80**	1.98	1.92	1.98	1.92	0.10	0.00	0.00	0.09	0.00	0.10
Exponential + Risk	**5.56**	**4.80**	1.98	1.92	1.98	1.92	0.10	0.00	0.00	0.09	0.00	0.01
Normal + Risk	**5.54**	**4.79**	2.06	1.99	2.06	1.99	0.00	0.09	0.09	0.00	0.09	0.00
Rayleigh + Risk	**5.56**	**4.80**	1.98	1.92	1.98	1.92	0.10	0.00	0.00	0.09	0.00	0.01
Triangular + Risk	**5.53**	**4.80**	2.06	1.99	2.06	1.99	0.00	0.10	0.10	0.00	0.01	0.00

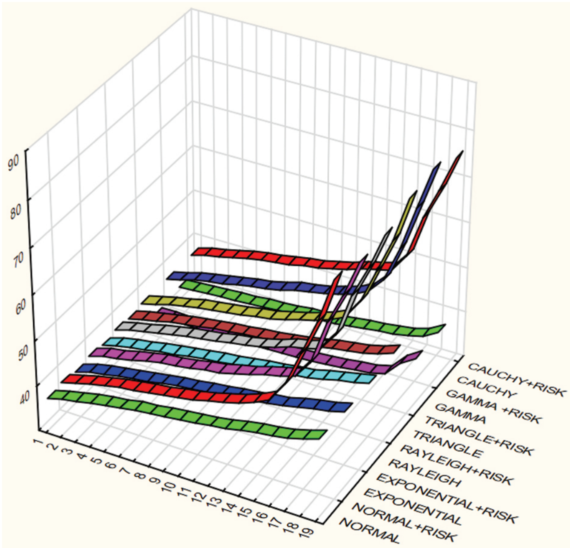

Fig. 9. 3D graph of the completion times of a construction project in terms of the probability density distribution and the risk of absenteeism

Figure 9 clearly shows the non-uniformity of the impact of the risk factor on the time of task completion, depending on the value of the probability of the completion time. At around 70% probability of completing the task, the task realization time increases sharply. Figure 10 shows the probability graphs of the completion time of a construction project for individual functions of the probability density distributions with and without the assigned risk of absenteeism.

In order to determine the value of differences between the groups, an analysis of the mean absolute percentage errors – MAPE (Eq. (5.1)) was performed [2, 5, 7–12]. The calculation results are presented in Table 4.

$$\text{MAPE} = \frac{1}{T}\sum_{i=1}^{T}\frac{|Y_i - Y_{ip}|}{Y_i} \tag{5.1}$$

where: MAPE – mean absolute percentage error, T – sum of the number of calculation periods, Y_i – value of the variable in period i (without risk), Y_{ip} – value of the variable in period i (with risk).

The calculated values of the MAPE errors are shown in Fig. 11.

According to the classification proposed by [13] Table 5, the unacceptable MAPE error is estimated from the value of 15%.

It follows from the adopted assessment that neglecting the impact of employee absenteeism as the risk of the construction project implementation time generates a MAPE error of 32.82% to 69.23% depending on the preset probability density function in relation to the probability range of the task completion from 75 to 95%. This is a very big error – thus –

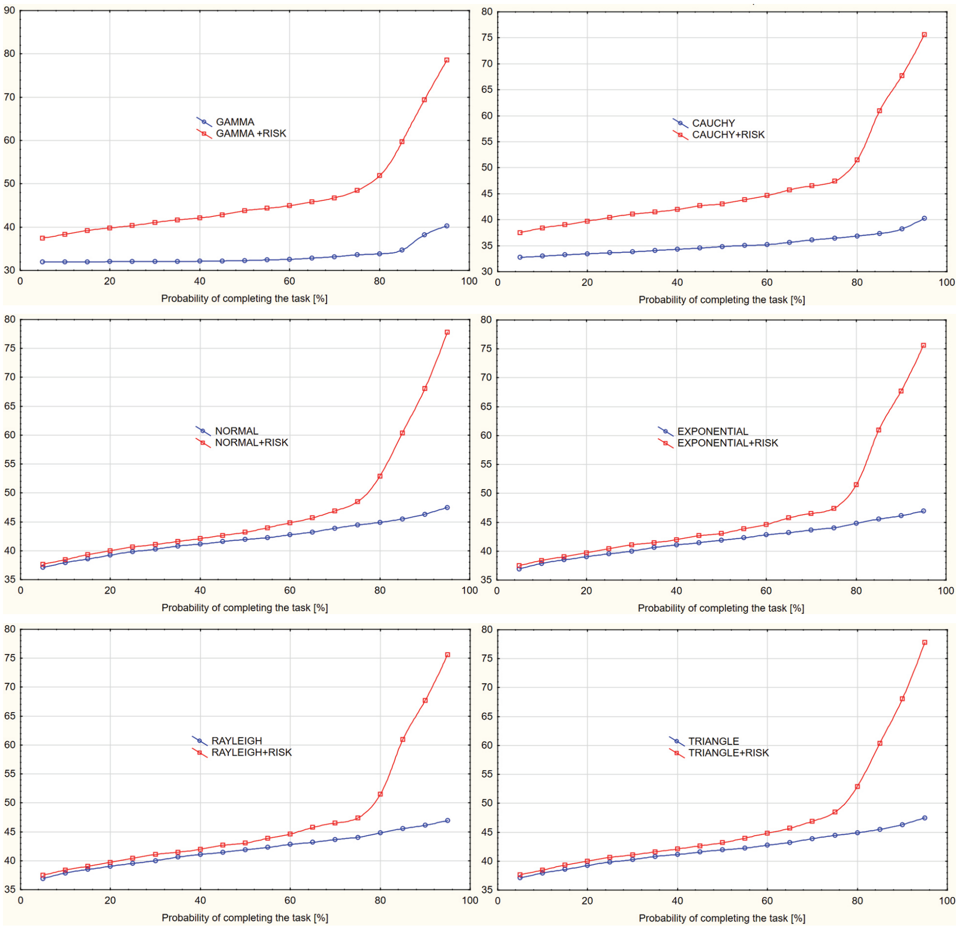

Fig. 10. Probability graphs of the completion time of a construction project for individual functions of probability density distributions with the assigned risk of absenteeism and without risk

unacceptable. Very high MAPE errors were recorded in relation to the Gamma and Cauchy functions in each probability range for completing the task. Failure to take into account the risk of absenteeism in the calculations used to prepare the schedule generate in these cases an unacceptable error. With regard to the probability of completing the task in the range from 5 to 70% for the Normal, Exponential, Reyleigh, Triangle functions, the MAPE error is small and amounts to about 3%, but for values from 75–95% it is already unacceptable (32.8 by 34%). The mean value for the 5% to 95% probability of the MAPE error is 11% – therefore it is an acceptable error. Due to the standard requirements of ISO 15686-5 Buildings and constructed assets – Service life planning, there is a recommendation to quantify the time with the probabilities of an event consisting in exceeding the time of a construction project with a value of at least 10, 50 and 90%.

Table 4. Values of the mean absolute MAPE percentages for probabilities of completing the task in time from 5 to 70%, 75 to 95% and in total from 5 to 95%

Name of the function of the probability density	Probability of task completion 5–70%	Probability of task completion 75–95%	Probability of task completion 5–95%
	MAPE [%]		
Normal	2.998616	34.028901	11.164480
Gamma	**30.185585**	**69.233345**	**40.461311**
Cauchy	**22.086461**	**59.549365**	**31.945120**
Exponential	2.948124	**32.821066**	10.809424
Reyleigh	2.948124	**32.821066**	10.809424
Triangle	2.998616	**34.028901**	11.164480

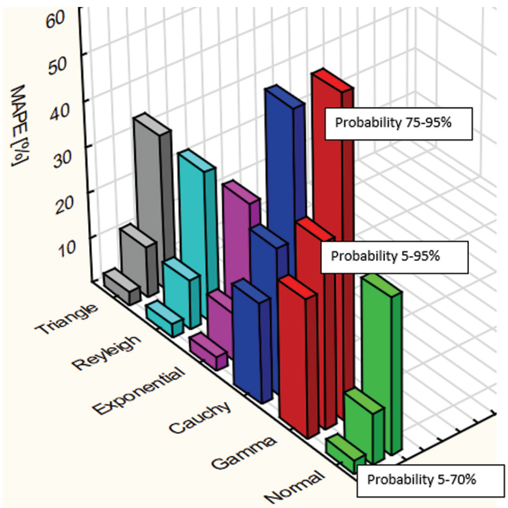

Fig. 11. Bar graphs of the MAPE error values for the probabilities of completing the task in time from 5 to 70%, 75 to 95% and in total from 5 to 95% between the values with no risk of absenteeism and with this risk

Table 5. Percentage and linguistic evaluation of MAPE errors [13]

No.	The value of MAPE error	Linguistic evaluation of the MAPE error
1	0–1%	Very small
2	1–3%	Small
3	3–5%	Medium
4	5–10%	Large
5	10–15%	Acceptable
6	More than 15%	Very large – unacceptable

Therefore, the authors postulate that the risk of absenteeism should be taken into account in each construction process when performing probabilistic schedules, i.e. in the Building Information Modeling BIM methodology.

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Probabilistyczne harmonogramowanie przedsięwzięć budowlanych w aspekcie ryzyka absencji pracowniczej

Słowa kluczowe: absencja pracownicza, ryzyko, czas, BIM, proces budowlany

Streszczenie:

W artykule przeprowadzono kwantyfikację ryzyka absencji pracowników budowlanych celem wprowadzenia tej wartości do harmonogramów w ujęciu probabilistycznym oraz określenie wpływu na czas realizacji procesów budowlanych przy założeniach różnych rozkładów funkcji gęstości prawdopodobieństwa. Pominiecie wpływu absencji pracowniczej jako ryzyka czasu realizacji przedsięwzięcia budowlanego generuje błąd MAPE o wartości 32,82% do 69,23% w zależności od zadanej funkcji gęstości prawdopodobieństwa w odniesieniu do przedziału prawdopodobieństw ukończenia zadania od 75–95%. Jest to bardzo duży błąd – niedopuszczalny. Bardzo wysokie błędy MAPE zanotowano w odniesieniu do funkcji Gamma i Cauchy w każdym przedziale prawdopodobieństw ukończenia zadania. Nieuwzględnienie ryzyka absencji pracowniczej w obliczeniach służących do sporządzenia harmonogramu generują w tych przypadkach niedopuszczalny błąd. W odniesieniu do prawdopodobieństwa ukończenia zadania w przedziale od 5 do 70% dla funkcji Normal, Exponential, Reyleigh, Triangle błąd MAPE jest mały i wynosi około 3%, ale dla wartości od 75–95% jest już niedopuszczalny (32,8 o 34%). Wartość średnia dla prawdopodobieństwa od 5 do 95% błędu MAPE wynosi 11% – zatem jest to błąd dopuszczalny. Ze względu na wymagania normowe ISO 15686-5 Buildings and constructed assets- Service life planning, istnieje zalecenie kwantyfikcji czasu z prawdopodobieństwami wystąpienia zdarzenia polegającego na przekroczeniu czasu realizacji przedsięwzięcia budowlanego o wartościach co najmniej 10, 50 i 90%.

W związku z powyższym autorzy postulują uwzględnianie ryzyka absencji pracowniczej w każdym procesie budowlanym podczas wykonywania harmonogramów probabilistycznych, czyli w metodologii Building Information Modeling BIM.

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