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IMPACT OF BASELINE TERMS ON THE COURSE OF CRITICAL PATHS AND TIME BUFFERS IN THE MODIFIED GOLDRATT'S METHOD

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The introduction of a baseline term to the dependency network most often results in a change, break and/or generation of a new sequence of critical path, depending on the type of such a baseline term and the exact date selected. Each of those situations has an impact on the location or need to include new time buffers in the modified Goldratt's method. The purpose of this article was to identify possible effects brought by declaration of each type of baseline term and to point out actions to be taken in each case. It must be noted that guidelines provided should in each individual case be adapted to the specific character of schedule changes caused by implementation of the relevant baseline term.
The example presented herein exemplifies one of such solutions to be implemented as a result of break of the critical path and need to introduce new time buffers.

Key words: project buffer, baseline term, critical path, Goldratt's method

Introduction

In engineering practice, various types of constraints (so-called baseline terms) are often used. Sometimes they need to be used for technological and organizational reasons, while in other cases – because it is necessary to meet a contractual deadline for completion of a stage or the whole construction task. Proper implementation of appropriate constraints during scheduling of civil works can contribute to efficient management of construction project execution [3,7].

The categories of different types of constraints which can be used in schedules are borrowed from C. Chatfield and T. Johnson [1] and from S. Wilczewski [8], who split those constraints into three groups: flexible, inflexible and moderate (semi-flexible). Such classification also applies to baseline terms which can be used in MS Project, applied herein for the purpose of schedule analysis. Similar constraints can also be found in other project management software tools (Primavera, PertMaster).To select and implement a specific type of the aforementioned constraints, it is necessary to define an appropriate type of constraint and to determine its date. Types of constraints which can be used in MS Project are described below in order of appearance in the system.

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The first group includes flexible constraints which, whenever used, enable the system to determine the start and finish date of a given task. Every task which is subject to this constraint shall be planned in such a way as to be completed as late (constraint type „As Late As Possible") or as soon (constraint type „As Soon As Possible") as it can be completed. In this type of constraint no date needs to be provided.

The second group contains inflexible constraints. Any task under such a constraint, or, to be more specific, its start or finish, according to the selected option, shall occur on a strictly determined date. The system shall calculate the time frame for task execution in such a way as to make it start (constraint type „Must Start On") or finish (constraint type „Must Finish On") exactly on the selected date.

The third group is constituted by moderate (semi-flexible) constraints. They are a kind of barrier for free planning because they reduce the number of possible changes in start and finish dates selected for specific tasks. Nevertheless, such a limitation guarantees that a given task will not start after a determined date (constraint type "Start No Later Than") or before a determined date (constraint type „Start No Earlier Than") or that a given task will not be finished after a determined date (constraint type „Finish No Later Than") or before it (constraint type „Finish No Earlier Than").

The system's default type of constraint for any task scheduled is "As Soon As Possible".

To meet a deadline likely to be jeopardized during execution of a construction project, either „Must Start On" (inflexible) or „Start No Later Than" constraint (moderate) is most often used, depending to the specific needs of each case [3]. It depends, however, on the needs defined by the scheduler each time a schedule is developed. Emphasis must be placed on the responsibility incumbent on the engineer who develops a given schedule. They ought to consider and take into account necessary technological and organizational assumptions underlying the construction task under preparation, yet, first and foremost, they should be aware that if they use baseline terms in a wrong way, they can lose control over the schedule because such baseline terms can contradict one another.

Therefore, it is recommended to start scheduling by building a dependency network and analyzing the earliest deadlines (organizational reasons). Then, technological needs must be taken into consideration, because their impact often makes it necessary to use a specific type of constraints. As a result, subsequent time analyses along with tracking down and evaluation of impact of successively introduced baseline terms on the final deadline and course of the critical path creates desired effects. Hence, baseline terms must be used in a very skillful and thought-out way.

While applying constraints to a schedule, especially inflexible ones, one should bear in mind that their use can, apart from the aforementioned aspects, lead to a change and/or break of the critical path. It is, however, closely related to the date determined for the constraint and the selected type of constraints. The latest baseline terms (inflexible and moderate ones) can also result in occurrence of a negative total slack which, in turn, can lead to selecting unrealistic lead times for tasks. Nevertheless, it is also important to assign the earliest deadlines to those tasks which can extend the duration of the whole project.

Method

To use baseline terms, you must be aware of the consequences they are likely to bring for the schedule. Types of effects to the slack and course of the critical path depend on the selected types of constraints and adopted baseline dates, which, in turn, often decide whether it is necessary to modify the location of time buffers used in the Goldratt's method [2,4,5]. Figure 1 shows a diagram which identifies possible consequences of implementation of a task's baseline term in the dependency network .

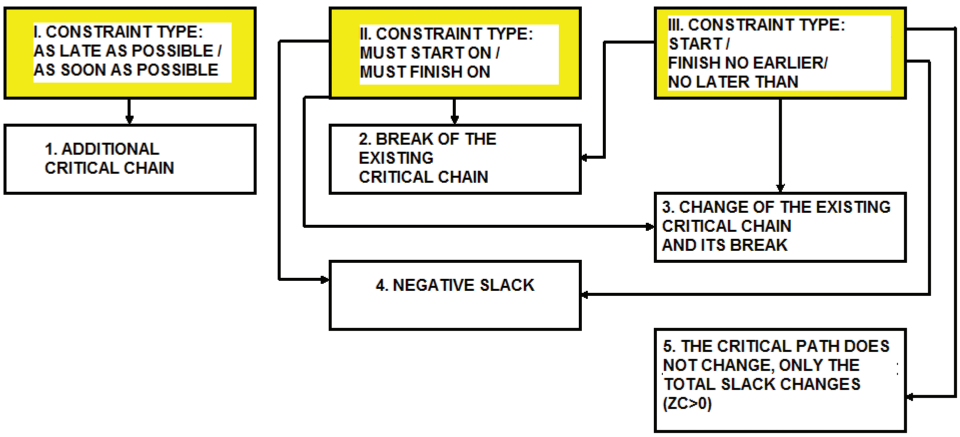

Fig. 1. Diagram of types of constraints with possible consequences of their implementation

I. Constraint type: "*As Late As Possible / As Soon As Possible"*
   1. Additional critical chain

II. Constraint type : "*Must Start On / Must Finish On*"
   2. Break of the existing critical chain
   3. Change of the existing critical chain and its break
   4. Negative slack

III. Constraint type: "*Start / Finish No Earlier / No Later Than*
   5. The critical path does not change, only the total slack changes.

Whenever any of possible consequences occurs, it is necessary to take the appropriate action in the modified Goldratt's method (as shown in Figure 1):

1. to implement new buffers, as for the existing critical sequences,

2. to use a feeding buffer at the end of the non-critical sequence which has arisen (just before the task with a baseline term), and if needed, to add buffers wherever new non-critical sequences part their ways,
3. to implement appropriate time buffers once again in the new location,
4. to change dates and/or types of baseline term so as to avoid negative slack,
5. to leave designed time buffers as they are,

Calculation example

This example is based on the schedule of earth works developed for construction of the „A19" metro station in Warsaw (Figure 2). These data were adopted as an output model for further stages of the experiment the purpose of which is to depict an exemplary impact of a baseline term on the course of a critical path (critical chain) in the event time buffers are implemented.

The initial deadline scheduled for the whole project is 09 August 2005, with the duration being 83 days.

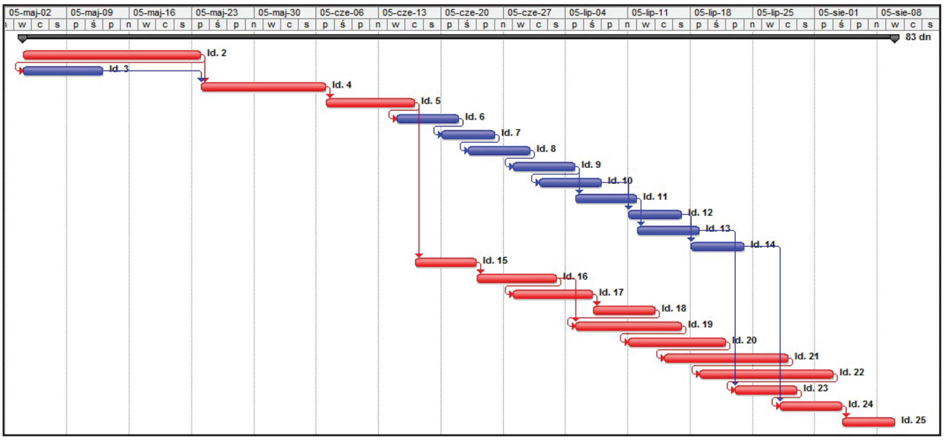

Fig. 2. Schedule of earth works developed for construction of the „A19" metro station with no baseline date being fixed (tasks belonging to the critical path are marked in red)

The baseline term – inflexible „Must Start On" constraint was assigned to the task no. 18, lying on the critical path. The initial start date for this task is 07 July 2005, but the selected constraint puts the start off until 18 July 2005. Once the constraint has been implemented, the finish date for the whole project becomes 20 August 2005, while the project execution takes 92 days.

As a result of the adopted baseline term, the critical path was broken (case no. 2, figure 1). As the course of the critical path changed, it was necessary to add a new feeding buffer - BZ1 and BRN1[4] where non-critical sequences part their ways (see figure 3 and 4) .

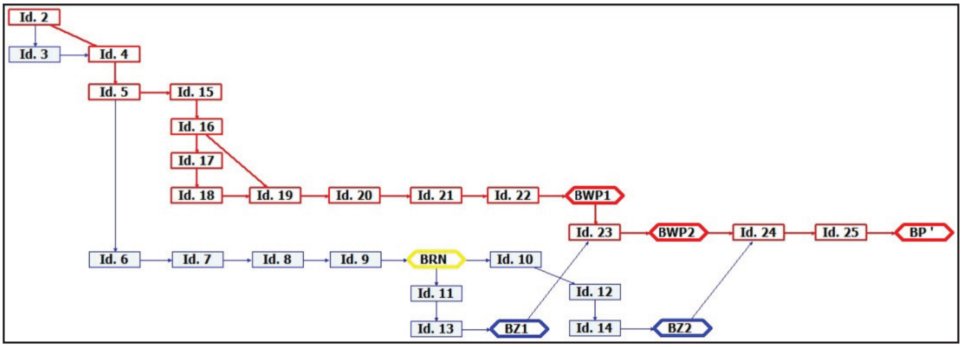

Fig. 3. Dependency network with time buffers without implementation of the baseline term

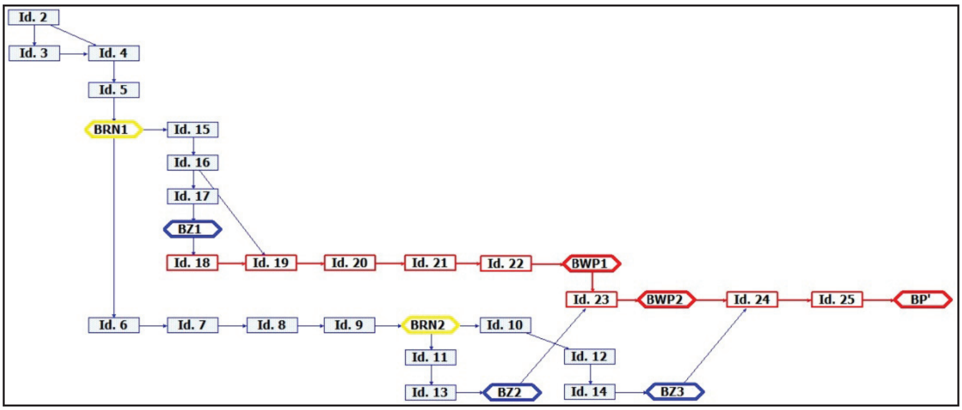

Fig. 4. Dependency network with inserted time buffers BZ1 and BRN1 after implementation of baseline term

The schedule obtained after the implementation of the baseline term can be seen in Figure 5.

To calculate the buffer size, the duration of all the tasks included in the dependency network was reduced. To make the calculations easier to comprehend, the duration of the tasks was reduced in % and appropriate relations were shown in the schedule model. It resulted in the following sizes of applied time buffers [4,5] (table 1).

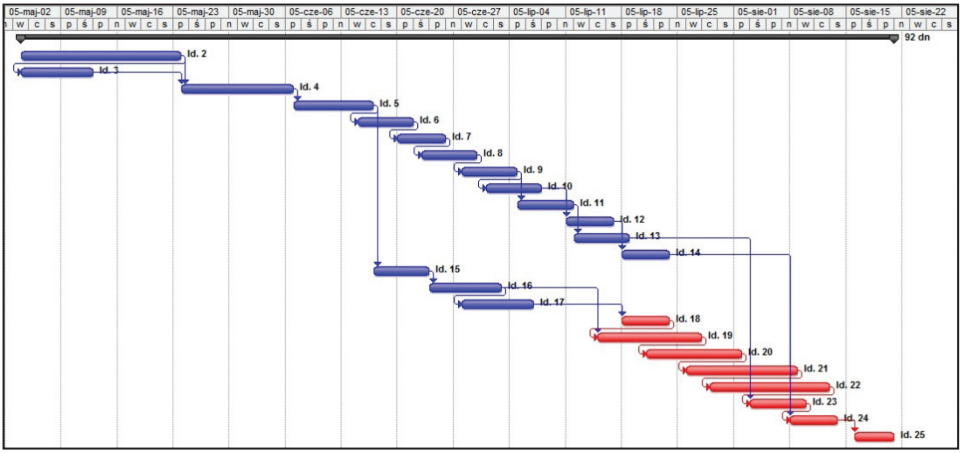

Fig. 5. Gantt chart with the „Must Start On 18 July 2005" baseline date assigned to the task no. 18 (tasks lying on the critical path are marked in red)

By inserting the calculated time buffers to the dependency network, the schedule was obtained as shown in Figure 6 and Table 2.

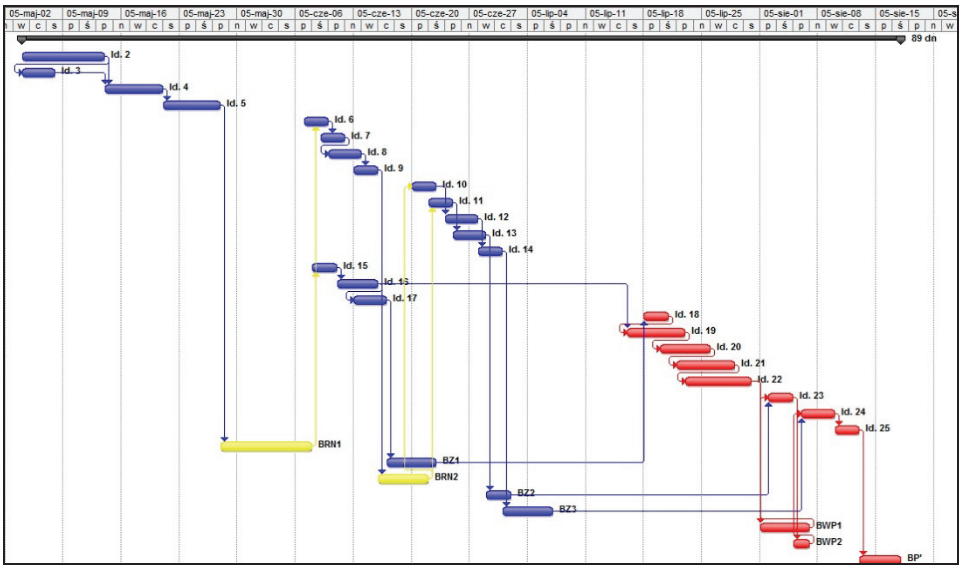

Fig. 6. Gantt chart with the baseline term after insertion of time buffers (shown with their sizes) (tasks lying on the critical path are marked in red).

Table 1

Table showing sizes of adopted time buffers

Lp.	Nazwa bufora czasu wraz z chronionym przez niego ciągiem czynności	Id. ciągu czynności		Termin trwania ciągu czynności								Obliczony czas trwania bufora
				Przed skróceniem				Po skróceniu				
				Rozpoczęcie Tpp_i		Zakończenie Tpk_j		Rozpoczęcie Tsp_i		Zakończenie Tsk_j		
		i	j	Data	Wartość numeryczna	Data	Wartość numeryczna	Data	Wartość numeryczna	Data	Wartość numeryczna	$WB_{i\text{-}j}$ [dzień]
1	BRN1 ciąg Id. 2-3-4-5	2	5	04.05.2005	1	16.06.2005	37	04.05.2005	1	27.05.2005	20	9
2	BZ 1 ciąg Id. 15-16-17	15	17	17.06.2005	38	06.07.2005	54	28.05.2005	21	06.06.2005	28	5
3	BRN2 ciąg Id. 6-7-8-9	6	9	15.06.2005	36	04.07.2005	52	27.05.2005	20	04.06.2005	27	5
4	BZ2 ciąg Id. 11-13	11	13	05.07.2005	53	18.07.2005	64	06.06.2005	28	11.06.2005	33	3
5	BZ3 ciąg Id. 10-12-14	10	14	01.07.2005	50	23.07.2005	69	03.06.2005	26	14.06.2005	35	5
6	BWP1 ciąg Id. 18-19-20-21-22	18	22	18.07.2005	64	12.08.2005	86	18.07.2005	64	30.07.2005	75	6
7	BWP2 ciąg Id. 23	23	23	03.08.2005	78	09.08.2005	83	26.07.2005	71	28.07.2005	73	2
8	BP' ciąg Id. 24-25	24	25	08.08.2005	82	20.08.2005	92	28.07.2005	73	03.08.2005	78	3

Table 2

Schedule data adjusted according to the baseline term after implementation of time buffers

Id.	Nazwa zadania	Cz. trw.	Rozpoczęcie	Zakończenie	Następniki	Całkowity zapas
1	**Budowa stacji metra A19 Marymont w Warszawie - roboty ziemne /fragment harmonogramu/**	**67 dn**	**śro, 05-05-04**	**czw, 05-07-21**		**0 dn**
2	MOBILIZACJA I PRZYGOTOWANIE SPRZĘTU	9 dn	śro, 05-05-04	pią, 05-05-13	3ZR-9 dn;4	0 dn
3	PRZYGOTOWANIE FRONTU ROBÓT	4 dn	wto, 05-05-10	pią, 05-05-13	4	0 dn
4	WYKONANIE ŚCIAN SZCZELINOWYCH - SEKCJE 11-18 i 37-44	6 dn	sob, 05-05-14	pią, 05-05-20	5	0 dn
5	WYKONANIE ŚCIAN SZCZELINOWYCH- SEKCJE 19-26 i 31-36	5 dn	sob, 05-05-21	pią, 05-05-27	26	0 dn
6	WYKONANIE PALI ŚCIANKI BERLIŃSKIEJ	3 dn	sob, 05-06-11	wto, 05-06-14	7ZR-1 dzień	0 dn
7	WYKONANIE WYKOPU WSTĘPNEGO SEKCJE 5A i 5B	3 dn	wto, 05-06-14	czw, 05-06-16	8ZR-2 dn	0 dn
8	SKUCIE ŚCIAN SZCZELINOWYCH ORAZ USZCZELNIENIE POLACVZENIA ZE STROPEM ZEWNETRZNYM- SEKCJE 18-25 i 32-37	3 dn	śro, 05-06-15	pią, 05-06-17	9ZR-1 dzień	0 dn
9	SZALOWANIE SEKCJI 5A	3 dn	pią, 05-06-17	pon, 05-06-20	27	0 dn
10	ZBROJENIE I BETONOWANIE SEKCJI 5A	3 dn	pią, 05-06-24	pon, 05-06-27	12ZR+1 dzień	0 dn
11	SZALOWANIE SEKCJI 5B	3 dn	pon, 05-06-27	śro, 05-06-29	13	0 dn
12	ZBROJENIE I BETONOWANIE SEKCJI 5B	3 dn	śro, 05-06-29	pią, 05-07-01	14	0 dn
13	SZALOWANIE PRZEWYŻSZENIA SEKCJI 5A	3 dn	czw, 05-06-30	sob, 05-07-02	28	0 dn
14	ZBROJENIE I BETOWNOWANIE PRZEWYŻSZENIA SEKCJI 5A	3 dn	sob, 05-07-02	wto, 05-07-05	29	0 dn
15	WYKONANIE ŚCIAN SZCZELINOWYCH- SEKCJE 27-30 i 58-59	3 dn	śro, 05-06-08	pią, 05-06-10	16	0 dn
16	WYKONANIE ŚCIAN SZCZELINOWYCH- SEKCJE 8-10 i 45-47	4 dn	sob, 05-06-11	śro, 05-06-15	19;17ZR-3 dn	0 dn
17	WYKONANIE PALI ŚCIANKI BERLIŃSKIEJ	4 dn	pon, 05-06-13	czw, 05-06-16	18	0 dn
18	TYMCZASOWE PRZEŁOŻENIE KABLI ENERGETYCZNYCH I TRAKCYJNYCH - WIĄZKA 2	3 dn	pią, 05-06-17	pon, 05-06-20	19ZR-4 dn	0 dn
19	WYKONANIE ŚCIAN SZCZELINOWYCH- SEKCJE 1-7 i 48-57	6 dn	czw, 05-06-16	śro, 05-06-22	20ZR-3 dn	0 dn
20	WYKONANIE PALI ŚCIANKI BERLIŃSKIEJ	5 dn	pon, 05-06-20	pią, 05-06-24	21ZR-3 dn	0 dn
21	WYKONANIE WYKOPU WSTĘPNEGO SEKCJE 1, 2A, 2B	6 dn	śro, 05-06-22	wto, 05-06-28	22ZR-5 dn	0 dn
22	SKUCIE ŚCIAN SZCZELINOWYCH ORAZ USZCZELNIENIE POLACZENIA ZE STROPEM ZEWNETRZNYM- SEKCJE 1-8 i 47-57	7 dn	czw, 05-06-23	czw, 05-06-30	30	0 dn
23	SZALOWANIE SEKCJI 1	3 dn	czw, 05-07-07	sob, 05-07-09	31	0 dn
24	ZBROJENIE I BETONOWANIE SEKCJI 1	3 dn	wto, 05-07-12	czw, 05-07-14	25	0 dn
25	ZBROJENIE I BETONOWANIE SEKCJI 2B	3 dn	pią, 05-07-15	pon, 05-07-18	32	0 dn
26	BRK1	9 dn	sob, 05-05-28	wto, 05-06-07	15;6ZR-1 dzień	0 dn
27	BRK2	5 dn	wto, 05-06-21	sob, 05-06-25	10ZR-2 dn;11	0 dn
28	BZ1	3 dn	pon, 05-07-04	śro, 05-07-06	23	0 dn
29	BZ2	5 dn	śro, 05-07-06	pon, 05-07-11	24	0 dn
30	BWP1	10 dn	pią, 05-07-01	wto, 05-07-12	23ZR-5 dn	0 dn
31	BWP2	2 dn	pon, 05-07-11	wto, 05-07-12	24ZR-1 dzień	0 dn
32	BP'	3 dn	wto, 05-07-19	czw, 05-07-21		0 dn

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