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Development of a forward chain approach for calculating self-delay of project activities

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Abstract

In the field of management, the delay within projects is a prominent and contentious issue. Due to the fact that delay leads to cost and time over-runs, it is often the subject of litigation claims and creation of managerial tensions. In a bid to bring such delays under control and also to diminish managerial tensions, it is necessary to recognize and understand the following four concepts:"types of delay", "extent of delay", its "causality" and "responsibility". Existing methods would just compare actual and target progresses with each other for project and its activities aimed at providing the extent of individual activity delay based on planned time schedule. This paper represents a forward chain approach to calculate self-delay while distinguishing the activities affecting project delay. Self-delay specifically deals with the activity itself and is irrelevant to the other activities. It consists of Stand By delay and progressive delay. Indeed, in the developed approach, quota of each activity in project delay is calculated. When analyzing a project status, a manager must calculate and analyze not only the delay in the entire project but also the delay in each activity and self-delay.

Keywords: Delay; Project delay; Self- delay; Progress; Quota; Forward chain

1. Introduction

Delay control is one of the major tools for project control and management. A delay can be either an approval delay, information delay or a piece of work to be done later than originally planned (Williams, T. et al, 2003). Considering the fact that delay would lead to cost and time over-runs, it is often the subject of managerial tensions. In order to control delay and reduce tension, it is imperative to recognize four concepts: ‘types of delay’, ‘extent’ and ‘causality of delay’ and its ‘responsibility’ (Al-Khalil, M. Al-Ghafly, M. 1999).

Efficient and optimized application of effects of such concepts would be feasible only if a manager is capable of calculating and evaluating the scale and range of each activity delay separately. Awareness of types and extent of project and each activity delay till current time are needed in order to better manage delay situations, to make up delays and to mitigate their consequences by resource leveling and activities float. Awareness of causalities of delay is intended to shed some light on the issue of real reasons of delay in order to avoid more delays or better manage delay situation. Moreover, management knowledge about delay responsibilities would lead to spotting the roots of delay. A managerial system and project control which include all aforementioned concepts could be effective in improving productivity of project resources. Benefit-

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ing highly from the aforesaid contents would come to practice if management could recognize each activity delay separately. This indicates that while analyzing a project situation in addition to measure the entire project and each activity's delay with respect to planned duration, the management should also calculate and analyze each activity's self-delay. (This delay is for the account of the activity itself and is irrelevant to other activities performance).

Some surveys have been conducted with respect to types of delays, reasons of delays and various ways of calculating the delays among projects 'e.g. (Harie, N. 2001). Calculated delays in the studies are limited merely to the entire project as well as the individual activity delay, compared to the target plan (Williams, et al., 1995). The manifestation of the calculated delay in such approaches is not genuinely what we refer to as delay. The available approaches such as CPM only deal with comparing actual progress with planned progress of the project and progress of each individual activity. Indeed such so-called delays are mistaken as actual delay.

This paper represents a forward algorithm to calculate the actual delay of individual activity in a project through the impact of external and internal elements on delays in a project. In other words, what this disquisition is drawing attention to, is a forward mathematic approach for calculating self-delay which is imposed by each activity to the entire project. In the presented approach which is stressed on critical paths, the extent of self-delay for each activity is calculated through specific equations with respect to various prerequisite relationships (FF, FS, SS, and SF) of activities. The self-delay consists of two categories: The first one is caused by delay in advent of activity, referred to as Stand By (S.B), in spite of the fact that the entire prerequisite activities are completed. The second type of delay is due to lack of physical progress when the activity comes to operation and is referred to progressive delay (D). The total value of two kinds of the abovementioned delays is referred to as self-delay of individual activity (S.B. +D=S.D.).

Calculating S.B. delay is due to actual start dates and planned start dates. In order to calculate "D" delay, we benefit from actual start and actual finish dates and also planned start and finish dates as a forward chain from the first activity up to the last one. By using the presented formulas in this paper, the extent of self-delay for each individual activity will be calculated according to the type of delay and each activity (or one working station) portion in the entire project delay. Now, we elaborate on the following sections; namely, with an example illustrating calculation of self-delays and their impact on project completion date, describing the significance of issue and the consequences which the research is aiming at, representing the algorithm as well as calculating equations.

Prepare your final text following the instructions given here. This CIE 37 paper preparation format is adapted from ASME guidelines in MS-4. Start the text with a comprehensive introduction in order to clarify the topic and the environment of your work.

2. The issue and illustrative example

Let's think we are having a project including 8 activities with the following network (Figure 1). With respect to the plan this project should have the starting point on 23/08/2003 and meet the end on 14/11/2003. The activities as "A","B" and "D" go for Mechanics Department while the activities of "C","F" and "E" belong to the Electronics Department. Suppose it is December 28, 2003. The information on project activities and their starting and finishing dates is indicated in Table 1.

As seen, so far, this project is at least for 54 days behind the original schedule (early finish minus planned early finish). Hence, we face a 5% delay in completion (planned percent complete minus actual percent complete).

The main question remains: what percentage does each department contribute to such delays? Can we blame the remaining activity, H, for the whole delay of 5% of the project? What is the actual quota of Mechanics Department in this 54-day project delay? The activity of "A" has started with two day delay and has lasted 22 days rather than the planned 19 days.

"A" is the prerequisite of "B" and has finished on 10/09/2003; therefore, we could have started the activity of "B" on 11/09/2003 rather than 16/09/2003, this is the actual starting point of the so-called activity. The 24-day duration of "B" has been extended to 27 days.

Moreover, "D" has a 7-day delay in starting date and a 13-day of delay. What is the actual quota of Electronics Department in the whole project delay? What is the real portion of Montage Department in the 54-day of project delay? Great significant will be attached to the response to the aforesaid questions when we consider each department a factory or a sub-contractor and each activity a sub-project of a master project.

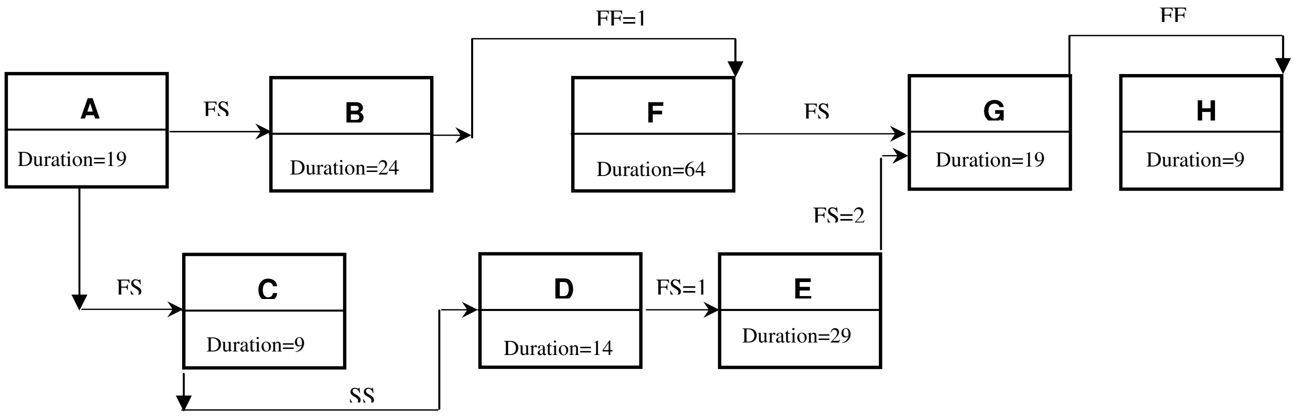

Figure 1. Network diagram of illustrative example.

Table 1. Planned time schedule and actual information relevant to example (1) on 28/12/2003.

Activity ID	Activity Description	Early Start	Early Finish	Actual Start	Actual Finish	Planned Early Start	Planned Early Finish
Total	**Project**	**23/08/03A**	**7/1/04**	**25/08/03**		**23/08/03**	**14/11/03**
1	A	25/08/03A	15/09/03A	25/08/03	15/09/03	23/08/03	10/09/03
2	B	16/09/03A	12/10/03A	16/09/03	12/10/03	11/09/03	04/10/03
3	C	17/09/03A	29/09/03A	17/09/03	29/09/03	11/09/03	19/09/03
4	D	23/09/03A	19/10/03A	23/09/03	19/10/03	11/09/03	24/09/03
5	E	21/10/03A	23/11/03A	21/10/03	23/11/03	26/09/03	24/10/03
6	F	23/08/03A	27/10/03A	23/08/03	27/10/03	23/08/03	25/10/03
7	G	01/12/03A	27/12/03A	1/12/03	27/12/03	27/10/03	14/11/03
8	H	30/12/03	7/1/04			06/11/03	14/11/03

Table 1 (continued). Planned time schedule and actual information relevant to example (1) on 28/12/2003.

Activity ID	Activity Description	Total Float	Actual % Complete	Planned % Complete	Remaining Duration	Actual Duration	Planned Original Duration
Total	**Project**	**0**	**95**	**100**	**9**	**129**	**84**
1	A	0	100	100	0	22	19
2	B	22	100	100	0	27	24
3	C	0	100	100	0	13	9
4	D	0	100	100	0	27	14
5	E	0	100	100	0	34	29
6	F	1	100	100	0	66	64
7	G	0	100	100	0	27	19
8	H	0	0	100	9	0	9

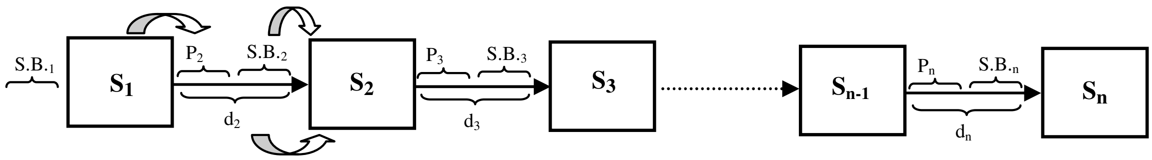

Figure 2. Parameters on an activity chain.

3. The notations and definitions

Below we will explain different parameters and entitlements. Various types of delays of a specific activity or a station of work are defined as follows:

S.B. (Stand By delay): The difference between the actual starting date and the last date of prerequisite activities completion.

D. (Progressive delay): The difference between the planned duration of an activity and its actual duration.

S.D. (Self-Delay): This kind of delay includes progressive and stand by delays. In fact self-delay is considered a result of each activity performance and is irrelevant to other activities' performance. The forward chain approach can be identified by determining the following parameters for each activity.

$[E.S.]_n$ (Earliest start time): The earliest time at which the activity can start that its precedent activities must be completed first.

$[E.F.]_n$ (Earliest finish time): Equal to the earliest start time for the activity plus time required to complete the activity.

$[P.S.]_n$ (Planned Start): Planned date of starting activity "n".

$[P.F.]_n$ (Planned Finish): Planned date of finishing activity "n".

$[A.S.]_n$ (Actual Start): Actual date of starting activity "n".

$[A.F.]_n$ (Actual Finish): Actual date of finishing activity "n".

d_n: External delay in starting activity "n" is the time difference between planned date and actual date of starting that activity.

$$d_n \begin{cases} [A.S.]_n - [P.S.]_n & \text{for started activities} \\ [E.S.]_n - [P.S.]_n & \text{for not started activities} \end{cases}$$

d'_n: External delay in finishing activity "n" is the time difference between planned date and actual date of finishing that activity.

$$d'_n = \begin{cases} [A.F.]_n - [P.F.]_n & \text{for completed activities} \\ [E.S.]_n - [P.S.]_n & \text{for uncompleted activities} \end{cases}$$

P_n (Previous Delay): Total delay of all previous activities or delay of stations before "n".

Effective Delay: The amount of the self-delay which has an impact on the project delay.

Actual Duration: A record of the amount of time spent on an activity to date.

Planned Duration: Original span of time planned to complete an activity.

4. The forward chain approach and algorithm

The prerequisite relationships among project activities are categorized by four types:

- SS (Start to Start)
- FS (Finish to Start)
- FF (Finish to Finish)
- SF (Start to Finish)

4.1. If the relationship type between two activities is 'FS'

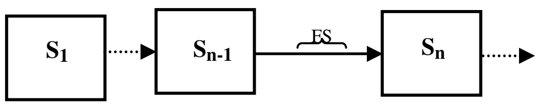

Figure 3. Finish to start prerequisite relationship.

First activity or station 1:

$$P_1 = [S.D.]_0 + P_0 = 0$$

$$[S.B.]_1 = [A:S]_1 - [P:S]_1 = d_1$$

$$D_1 = ([A:F]_1 - [A:S]_1) - ([P:F]_1 - [P:S]_1)$$

$$= d'_1 - d_1$$

$$[S.D.]_1 = [S.B.]_1 + D_1$$

Second activity or station 2:

$$P_2 = [S.D.]_1 + P_1$$

$$[S.B.]_2 = \begin{cases} d_2 - P_2 & \text{if} \quad d_2 > P_2 \\ 0 & \text{if} \quad \text{otherwise} \end{cases}$$

$$D_2 = ([A:F]_2 - [A:S]_2) - ([P:F]_2 - [P:S]_2)$$

$$= d'_2 - d_2$$

$$[S.D.]_2 = [S.B.]_2 + D_2$$

nth activity or station n:

$$P_n = [S.D.]_{n-1} + P_{n-1} = [S.D.]_{n-1} + [S.D.]_{n-1}$$

$$+ \ldots [S.D.]_1 + P_1 \quad \text{that} \quad P_1 = 0$$

$$[S.B.]_n = \begin{cases} d_n - P_n & \text{if} \quad d_n > P_n \\ 0 & \text{if} \quad \text{otherwise} \end{cases}$$

$$D_n = ([A:F]_n - [A:S]_n) - ([P:F]_n - [P:S]_n)$$

$$= d'_n - d_n$$

$$[S.D.]_n = [S.B.]_n + D_n$$

4.2. If the relationship type between two activities is 'SS'

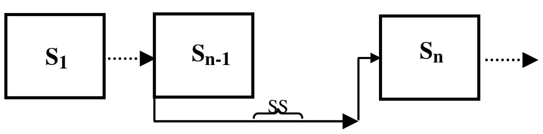

Figure 4. Start to start prerequisite relationship.

In this condition the whole delays of previous stations (p_n) equals to the total S.B. delay of station "n" plus the whole delays of previous stations. Indeed, the second type of delay of station "n-1" has no impact on station "n".

$$P_n = [S.B.]_{n-1} + P_{n-1} \quad \text{that} \quad P_1 = [S.B.]_0 = P_0 = 0$$

$$[S.B.]_n = d_n - d_{n-1}$$

$$D_n = ([A:F]_n - [A:S]_n) - ([P:F]_n - [P:S]_n)$$

$$= d'_n - d_n$$

$$[S.D.]_n = [S.B.]_n + D_n$$

4.3. If the relationship type between two activities is 'FF'

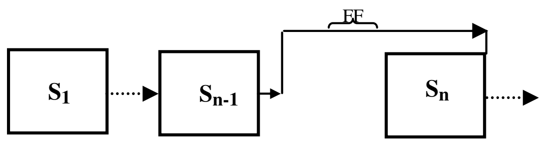

Figure 5. Finish to finish prerequisite relationship.

$$P_n = [S.D.]_{n-1} + P_{n-1} = [S.D.]_{n-1} + [S.D.]_{n-1}$$

$$+ \ldots [S.D.]_1 + P_1 \quad \text{that} \quad P_1 = 0$$

$$[S.B.]_n = d_n - d'_{n-1}$$

$$D_n = ([A:F]_n - [A:S]_n) - ([P:F]_n - [P:S]_n)$$

$$= d'_n - d_n$$

$$[S.D.]_n = [S.B.]_n + D_n$$

4.4. If the relationship type between two activities is 'SF'

$$P_n = [S.D.]_{n-1} + P_{n-1} = [S.D.]_{n-1} + [S.D.]_{n-1}$$

$$+ \ldots [S.D.]_1 + P_1 \quad \text{that} \quad P_1 = 0$$

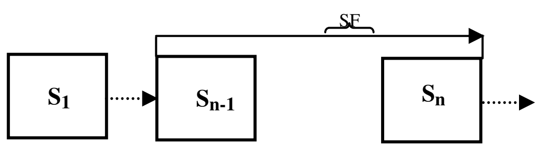

Figure 6. Start to finish prerequisite relationship.

$[S.B.]_n = d_n - d_{n-1}$

$D_n = ([A:F]_n - [A:S]_n) - ([P:F]_n - [P:S]_n)$

$= d'_n - d_n$

$[S.D.]_n = [S.B.]_n + D_n$

5. The usage of algorithm in problem solving and calculation

5.1. Example 1

According to the presented formulas in previous section, results of raised example calculations are figured out in Table 2. The effective delay of each activity must be calculated after calculating S.D. of each activity. By effective delay we mean the delay which has an impact on the project delay. The following items are true for all activities:

- Effective delay is zero if self activity has not been considered as critical activity or has not been located on critical path.
- Effective delay is S.D. if its effective requisition relationship which is located on critical path is FF or FS. Effective delay is S.B. if its effective requisition relationship which is located on critical path is SS.

Therefore the effective delay of activity "A" with requisition relationship of type FS would equal to 5 days. This means that 5/54 or 9.2 percent of the whole project delay would devote to the aforesaid activity. Activity "B" has 3 units of self-delay whereas its effective delay equals to zero because it is not situated on the critical path.

Effective delay of activity "C" would equal to one unit as its requisition relationship is SS and only its S.B. delay is categorized as influential delay for the whole project. Other activities delays are also available in Table 2. As it is shown, even though the only remained activity is "H", only 11 days of 54-day delay of the project is to blame for this activity.

In spite of the fact that the actual completion is compatible with planned completion for activity "D" and its volume, is 100, but 1.75 % of 5% of the whole project delay has been caused by the aforesaid activity.

5.2. Example 2

According to Figure 7, this project has been started since 03/01/2005. Project information for date 25/04/2005 is available in Table 3. So far we have 16 days of delay. Table 4 indicates the consequences of calculations as well as self and effective delays through presented algorithm.

Table 2. Consequences of calculations according the first example.

Activity ID	Activity Desc.	P	d	d´	S.B.	D	S.D. (S.B.+D)	Effective Delay
Total	**Project**							**54**
1	A	0	2	5	2	3	**5**	5
2	B	5	5	8	0	3	3	0
3	C	5	6	10	**1**	4	5	1
4	D	6	12	25	6	13	**19**	19
5	E	25	25	30	0	5	**5**	5
6	F	8	0	2	0	2	2	0
7	G	30	35	43	5	8	**13**	13
8	H	43	54	54	11	0	**11**	11

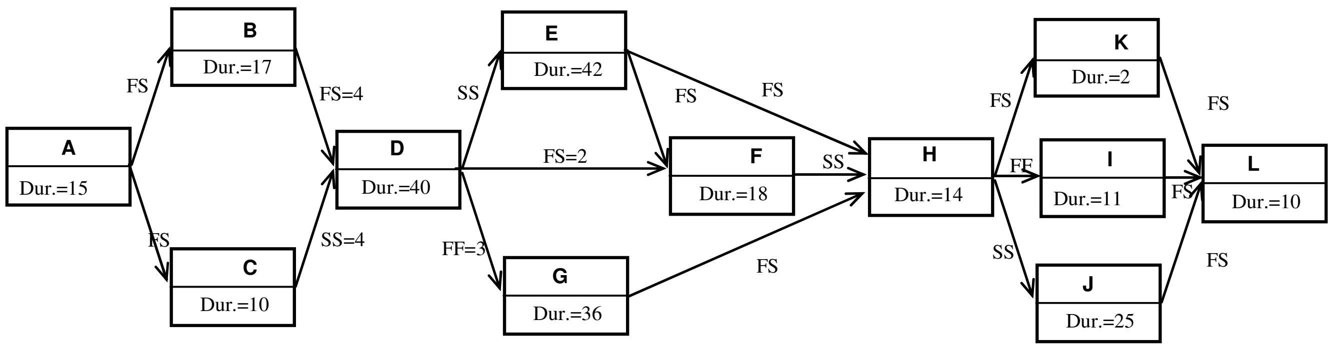

Figure 7. Network diagram of Example 2.

Table 3. Planned time schedule and actual information relevant to second example on 25/04/2005.

Activity ID	Activity Desc.	Early Start	Early Finish	Actual Start	Actual Finish	Planned Early Start	Planned Early Finish
Total	**Project**	**03/01/05A**	**29/05/05**	**03/01/05**		**03/01/05**	**13/05/05**
1	A	03/01/05A	20/01/05A	03/01/05	20/01/05	03/01/05	17/01/05
2	B	21/01/05A	05/02/05A	21/01/05	05/02/05	18/01/05	03/02/05
3	C	23/01/05A	02/02/05A	23/01/05	02/02/05	18/01/05	27/01/05
4	D	11/02/05A	29/03/05A	11/02/05	29/03/05	08/02/05	19/03/05
5	E	13/02/05A	29/03/05A	13/02/05	29/03/05	08/02/05	21/03/05
6	F	02/04/05A	20/04/05A	02/04/05	20/04/05	22/03/05	08/04/05
7	G	17/02/05A	04/04/05A	17/02/05	04/04/05	15/02/05	22/03/05
8	H	21/04/05A	03/05/05	21/04/05		09/04/05	22/04/05
9	I	25/04/05	05/05/05			12/04/05	22/04/05
10	J	25/04/05	19/05/05			09/04/05	03/05/05
11	K	04/05/05	05/05/05			23/04/05	24/04/05
12	L	20/05/05	29/05/05			04/05/05	13/05/05

Table 3(continued) . Planned time schedule and actual information relevant to second example on 28/12/2003.

Activity ID	Activity Desc.	Total Float	Actual % Complete	Planned % Complete	Remaining Duration	Actual Duration	Planned Original
Total	**Project**	**0**	**76**	**92**	**35**	**112**	**131**
1	A	0	100	100	0	18	15
2	B	0	100	100	0	16	17
3	C	17	100	100	0	11	10
4	D	0	100	100	0	47	40
5	E	0	100	100	0	45	42
6	F	0	100	100	0	19	18
7	G	17	100	100	0	47	36
8	H	0	35	100	9	4	14
9	I	11	0	100	11	0	11
10	J	0	0	64	25	0	25
11	K	0	0	100	2	0	2
12	L	0	0	0	10	0	10

Table 4. Consequences of calculations according to the second example.

Activity ID	Activity Desc.	P	d	d´	S.B.	D	S.D. (S.B.+D)	Effective Delay
Total	**Project**							**16**
1	A	0	0	3	0	3	**3**	3
2	B	3	3	2	0	-1	**-1**	-1
3	C	3	5	6	2	1	3	0
4	D	2	3	10	1	7	**8**	8
5	E	3	5	8	2	3	5	0
6	F	10	11	12	1	1	**2**	2
7	G	10	2	13	0	11	11	0
8	H	12	12	11	**0**	-1	-1	0
9	I	11	13	13	2	0	2	0
10	J	12	16	16	4	0	**4**	4
11	K	11	11	11	0	0	0	0
12	L	16	16	16	0	0	**0**	0

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